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FOREWORD

The International Scientific and Professional Conference POLITEHNIKA 2023 represents the seventh edition of the POLITEHNIKA scientific and professional events, occurring biannually since its inaugural event in 2011. POLITEHNIKA 2023 upholds a distinguished tradition and commitment to integrating higher education and practical application across a diverse spectrum of disciplines represented by defined thematic scopes.

Organized with the patronage of the Ministry of Education of the Republic of Serbia, the Ministry of Environmental Protection of the Republic of Serbia, the Ministry of European Integration of the Republic of Serbia, the Directorate for Occupational Safety and Health, the Office for Dual Education and National Qualifications Framework, the Conference of Academies of Applied Studies in Serbia, the Chamber of Commerce of Serbia, the Chamber of Commerce of Belgrade, the Institute for Standardization of Serbia, the Association of Belgrade Architects, the City of Požarevac and the Tourist Organization of the City of Požarevac, POLITEHNIKA 2023 stands as a collaborative platform at the intersection of academia, governmental institutions and industry.

This year heralds a notable progression with its international status and the incorporation of 10 conference scopes. Expanding beyond the thematic domains featured in previous events, the Conference now encompasses Environment and Sustainable Development, Occupational Safety and Health and Fire Safety, Smart Management Systems, Graphic Engineering, Design, Traffic Engineering, Biotechnology and Healthcare, Mechanical Engineering, Ecotourism and Rural development, and Mechatronics. By engaging experts, emerging professionals, and practitioners from these domains, the conference unifies fields of study programs of the Academy of Applied Technical Studies Belgrade. The thematic scopes, coupled with the structure of the compiled papers in this Proceedings, exhibit a rich diversity and multidisciplinary approach, fundamentally contributing to a holistic examination and resolution of societal and scientific challenges.

Comprising over 220 peer-reviewed contributions, the Proceedings represent a substantial intellectual asset, aligning with the conference's overarching objective of fostering the exchange of knowledge, research findings, and professional experiences among experts from industry, research institutions, and higher education establishments.

The Proceedings of the International Scientific and Professional Conference POLITEHNIKA 2023 serve as a comprehensive snapshot of the current landscape within the thematic realms of the conference, offering both insights and directives for ongoing scientific and professional development. Moreover, they proffer concrete solutions to practical challenges grounded in contemporary trends and pertinent insights.

The Academy of Applied Technical Studies Belgrade extends its sincere appreciation to all conference supporters whose financial contributions played a pivotal role in its successful realization. Special acknowledgment is reserved for the authors of the papers, whose diligence and eagerness to present their work to a wider audience, alongside the reviewers and members of the International Scientific Committee, Program Committee and Organizational Committee, have collectively contributed to the triumph of the International Scientific and Professional Conference POLITEHNIKA 2023.

Belgrade, December 2023
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ENVIRONMENT AND SUSTAINABLE DEVELOPMENT

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Srećko Stopić, PhD, Bernd Friedrich, PhD, Process Metallurgy and Metal Recycling, RWTH Aachen University, Germany
Advances in understanding of a role of unit metallurgical operations for recycling

Svetlana Grujić, PhD, Faculty of Technology and Metallurgy, University of Belgrade
Emerging pollutants in the environment: contamination of the Danube river basin in Serbia

Marija Nikolić, PhD, Faculty of Technology and Metallurgy, University of Belgrade
Biodegradable polyesters – from ecology to medicine

DESIGN

INVITED PAPER

Jelena Ristić Trajković, PhD, Faculty of Architecture, University of Belgrade
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ECOTURISAM AND RURAL DEVELOPMENT

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ENVIRONMENT AND SUSTAINABLE DEVELOPMENT

INTERNATIONAL SCIENTIFIC AND PROFESSIONAL CONFERENCE
POLITEHNIKA 2023
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ENVIRONMENT AND SUSTAINABLE DEVELOPMENT. MECHATRONICS. OCCUPATIONAL SAFETY AND HEALTH AND FIRE SAFETY. SMART MANAGEMENT SYSTEMS. GRAPHIC ENGINEERING. DESIGN. TRAFFIC ENGINEERING. BIOTECHNOLOGY AND HEALTHCARE. MECHANICAL ENGINEERING. ECOTOURISM AND RURAL DEVELOPMENT.

ADVANCES IN UNDERSTANDING OF A ROLE OF UNIT METALLURGICAL OPERATIONS FOR RECYCLING

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Abstract: *Unit operations in non-ferrous extractive metallurgy have high importance for recycling processes, an environmental protection and sustainable development. Three categories are included in unit operations in non-ferrous extractive metallurgy: (1) hydrometallurgy (leaching under atmospheric and high pressure conditions, mixing of solution with gas and mechanical parts, neutralization of solution, precipitation and cementation of metals from solution aiming purification, and compound productions during crystallization), (2) pyrometallurgy (roasting, smelting, refining), and (3) electrometallurgy (aqueous electrolysis and molten salt electrolysis). The high demand for critical metals in modern life, such as rare earth elements (REE), indium, scandium, and gallium has highly increased the need for an advance in understanding of an application of the unit operations in non-ferrous metallurgy regarding to an environmental impact. Exhaustion of ore reserves, accumulation of waste materials after their use leads to the use of unit operations in the development of new strategies for recycling secondary raw materials. Successful cases for use of the unit operations in recycling of wastewater solutions, bauxite residues and spent magnets will be presented in this paper.*
Keywords: recycling, hydrometallurgy, pyrometallurgy, metal, sustainable technologies

1. INTRODUCTION

The permanent goal of recycling is to increase the use of secondary raw materials (SRM) in different metallurgical engineering processes. General recycling strategy is shown at Figure 1.

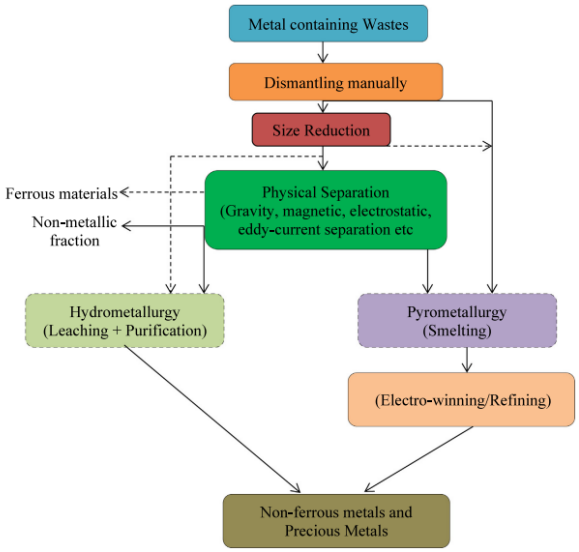

Figure 1. General recycling strategy containing Physical separation, hydro-and Pyro-treatment
Source: [1]

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The SRM contain mining and flotations tailings [2], flying ash [3], metallurgical slag [4], spent magnets [5], spent Li-Ion batteries [6], acid mine drainage water [7], and bauxite residues [8]. A proper combination of the unit operations was used to develop innovative solutions with added economic value for different applications of rare earth elements [9]. Most of the proposed activities have already been studied and tested at a research level (laboratory, demonstration plant and scale up conditions) [10, 11]. The aim is to present the recycling of different materials using a combination of pyrometallurgical and hydrometallurgical operations and explain their importance for environmental protection and recovery of metals.

2. METAL RECOVERY FROM WASTEWATER

2.1 Treatment of acid mine drainage water

Acid mine drainage (AMD) as wastewater solution formed by mining activities contain high concentration of dissolved heavy metals and sulfates, as shown in Table 1.

Table 1. Chemical composition of the AMD-Solution from South Africa

Species	Al	Fe	Mg	Ca	Mn	Si	Co	Cu	Zn	Ce	Nd	SO_4^{2-}
Conc, mg/L	396	4.290	474	592	93.9	47.5	1.42	0.78	14.3	5.35	1.23	12.100

As shown in Table 1 the content of valuable critical metals such as Co, Ce and Nd are very small (few milligrams per Liter). pH values can to be as low as 2.5. Therefore, AMD with these characteristics should not been discharged into public streams. In AMD systems, natural nanoparticles such as amorphous hydroxides, ferrihydrites, and goethite seemed to be formed, which could induce lethal and sublethal toxicity toward aquatic organisms.
Neutralization of an AMD Solution was performed using sodium hydroxide at different pH-values between 1 and 11 at room temperature, in order to study a precipitation of cerium and other elements. This strategy for removal of Fe, Al and Ca was previously studied in a cascade line reactor using a wastewater from an electrolytic plant [12]. The new step is precipitation of cerium.

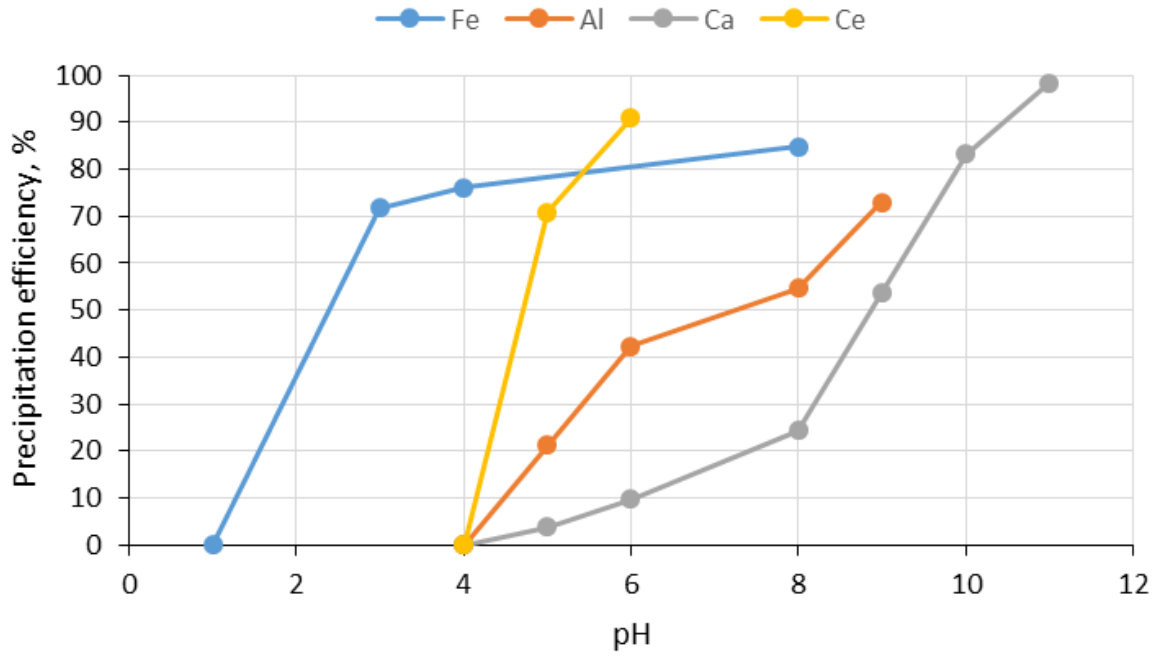

Figure 2. Precipitation efficiency during neutralization of AMD-solution with NaOH

As shown the best precipitation selectivity for iron was reached at pH-4 (at about 75 % removal degree). This is explained by the formation of $Fe(OH)_3$. A further increase of the pH-value to 6 leads to the precipitation efficiency of 85 %, more than 95 % can only be reached using an oxidation reagent such as H_2O_2 in order to oxidize $Fe^{2+}$to Fe^{3+}. The precipitation of cerium took place between pH-value of 4 and 6 in form of sodium cerium sulfate hydrate ($NaCe(SO_4)_2 \cdot H_2O$) reaching a precipitation efficiency of about 90 %, as shown with Eqs. (1) and (2):

$$H_2SO_4 + NaOH \rightarrow Na_2SO_4 + 2\ H_2O \quad (1)$$

$$Ce_2(SO_4)_3 + Na_2SO_4 + 2\ H_2O \rightarrow 2\ NaCe(SO_4)_2 \cdot H_2O \quad (2)$$

The obtained sodium cerium sulfate hydrate might be used for winning of this metal using solvent extraction for separation of cerium and an additional treatment of obtained cleaned solution using an ultrasonic spray pyrolysis method, what is innovative and used for the formation of rare earth oxide. With an increase of pH-value from 4 to 9, aluminium was removed in form of $Al(OH)_3$, as shown with Eq. 3.

$$Al_2(SO_4)_3 + 6\ H_2O \rightarrow 2\ Al(OH)_3 + 3\ H_2SO_4 \quad (3)$$

2.2 Treatment of wastewater from an electrolytic plant

Chemical precipitation of heavy metals is viable for selective removal of heavy metals from metal-bearing effluents in three reactor systems in a continuous process cascade line, as shown at Figure 3. The chemical composition of wastewater is shown in Table 2:

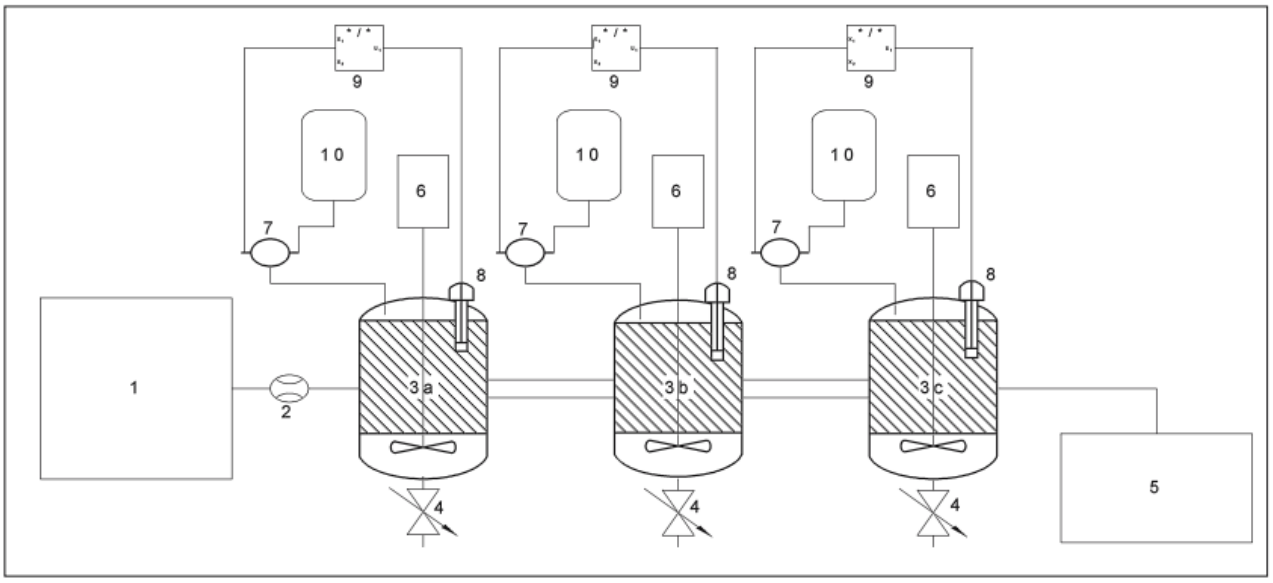

Figure 3. Cascade line reactor for continuous process of precipitation/chemical precipitation [12]. 1. tank with wastewater (200 dm^3); 2. flow meter; 10 dm^3 vessel for feed adjustment of solution; 3. three 10 dm^3 reactors; 4. valve for regulation of wastewater injection; 5. tank (200 dm^3) for purified solution; 6. mixers; 7. solenoid metering pumps; 8. protected electrodes; 9. pH transmitters; 10. tank with precipitation agent

Table 2. Chemical composition of the wastewater from an electrolytic plant

Species	Al	Fe	Cu	As	Mn	Si	Sb	Bi	Ni	Te	Se	SO_4^{2-}
Conc, g/L	0.04	0.09	8.33	0.66	0.001	0.02	0.08	0.03	0.66	0.07	0.26	117.0

The precipitation agent was 1M NaOH, which was injected into all three reactors using a solenoid diaphragm-dosing pump (BT4a 1005 ProMinent) with self-dosing head and a maximum capacity of 7.0 dm3/h (about 1 h was a retention time in a reactor).The obtained results for precipitation efficiency are shown in Table 3:

Table 3. Precipitation efficiency with NaOH at different pH-values

pH	Cu	Ni	As	Fe	Bi	Zn	Pb	Mn	Al	Si	Sb	Ca
4.0-4.5	48	27	67	**99**	**98**	86	**96**	74	52	57	84	-
6.5-7.0	**99**	45	**99**	-	-	79	-	27	**100**	79	84	14
9.0-9.5	-	**100**	-	-	-	**100**	-	68	-	83	100	25

Maximal precipitation efficiencies are for Fe, Bi, and Pb between 4.0-4.5, for As, Cu and Al at 6.5-7.0, and for Ni and Zn between 9.0 and 9.5 for Mn and Zn. The flow of metals from reactor to reactor and exothermic reaction could cause deviations from thermochemical prediction.

3. METAL RECOVERY FROM SOLID RESIDUE

3.1 Recovery of rare earth elements from spent magnets

Treatment of spent NdFeB-powder (%): 21.7 REE, 73.8 Fe, 0.66 B, is shown at Figure 4.

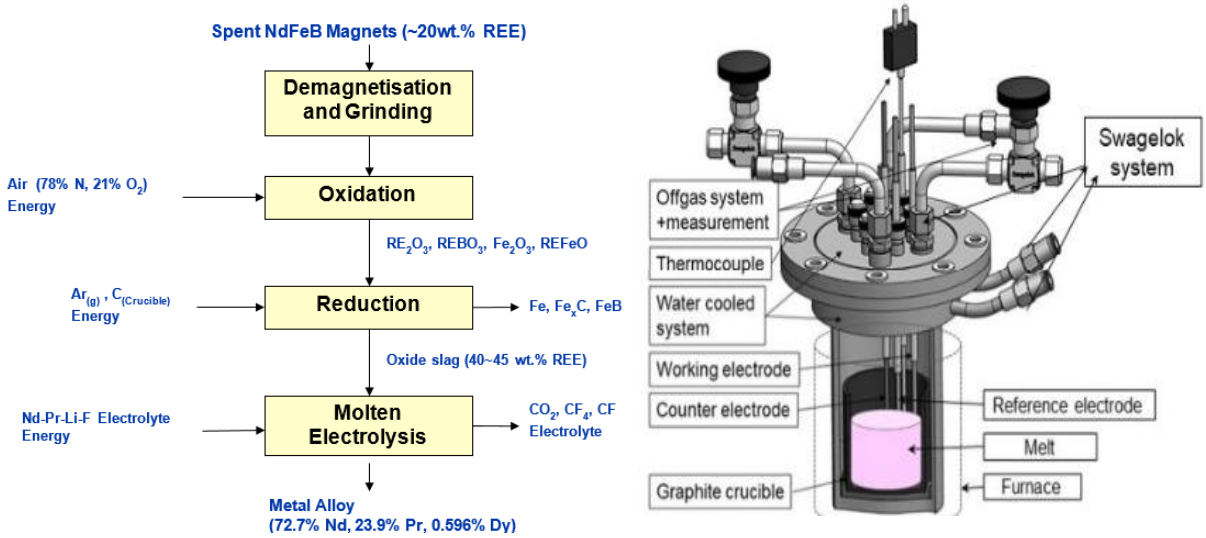

Figure 4. Pyrometallurgical strategy for recycling of spent NdFeB-magnets (left) with a reactor for molten salt electrolysis (right)

Source: [5]

This study includes the next operations: 1. demagnetisation and grinding of spent magnets, 2. oxidation of demagnetised and grinded solid residue, 3. Carbon reduction of oxidized material, 4. molten salt electrolysis as final step. The magnet recycling-derived oxide (MRDO) was produced from spent NdFeB magnets through oxidation in air and subsequently carbothermic reduction under an 80 mbar Ar gas atmosphere. This MRDO contained roughly 33 wt.% Nd and 10 wt.% Pr. The electrochemical reduction process of the MRDO on molybdenum electrodes in NdF_3 + LiF and NdF_3 + PrF_3 + LiF fused salts systems was investigated by cyclic voltammetry and chronoamperometry measurements. The resulting electrolytes and electrodes were examined after potentiostatic deposition by scanning electron microscopy (SEM), inductively coupled plasma optical emission

spectroscopy (ICP-OES), and X-ray diffraction (XRD) analysis. The electrodeposited metals appeared to accumulate on the cathode and X-ray diffraction analysis confirmed the formation of metallic Nd and Pr on the working substrate. The suitability of the obtained alloy intended for the remanufacturing of NdFeB magnets was then evaluated.

3.2 Recovery of titanium and valuable elements from bauxite residues

Bauxite is a clay-like sediment that is the principal host for alumina. Generally, bauxite is a naturally occurring mineral, soil, or rock formation comprising a conglomerate of multiple aluminum-bearing minerals with other valuable impurities. Iron oxides (Fe_2O_3 and FeO(OH)), clay minerals, silica, kaolinite, titanium minerals, rutile, and anatase are among the contaminants. Bauxite is mined for aluminum production because of high concentrations of the following aluminum-bearing minerals: Gibbsite: $Al(OH)_3$, Boehmite: AlO(OH), and Diaspore: AlO(OH). From an industrial perspective, bauxite is a material from which alumina is extracted using the Bayer Process. The process is based on contacting aluminium-bearing ores with a concentrated NaOH solution at temperatures between 150 – 250 ºC in an autoclave as shown with Eq. 4 and Eq. 5. It is a reddish-brown sludge containing iron, titanium, and silicon oxides, the majority of aluminum oxides that were not extracted during the clarification step, and other valuable metals. It is a large aspect of aluminum production, and it is a highly alkaline residue, as sodium hydroxide is added in the digestion step during the Bayer Process; each ton of processed alumina generates approximately 4-5 tons of red mud as a byproduct.

$$Al_2O_3 + 2\ NaOH \rightarrow 2\ NaAlO_2 + H_2O \quad (4)$$

$$2\ NaOH + SiO_2 \rightarrow Na_2SiO_3 + H_2O \quad (5)$$

EURO-TITAN concept will be studied in unlocking continuous Ti resources from metallurgical waste streams from alumina and Ti-dioxide production, creating the roadmap for producing 54 ktpy of Ti metal upon full industrialization, as shown at Figure 4. Titanium (Ti) is a grey metal and highly corrosion resistant with a high melting temperature and has a very low density but high strength, being a critical metal according to the 2023 CRM 5th list of EU. EURO-TITAN unlock domestic sources from Alumina, Zvornik, Bosnia and Herzegowina through its environmentally friendly, safe, and resource efficient extraction sustainable technologies.

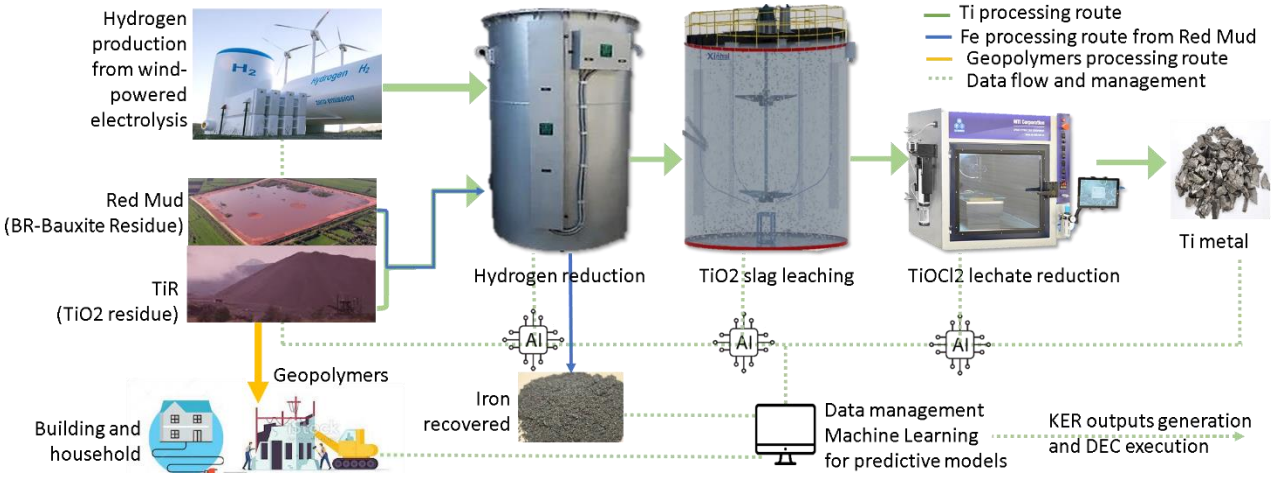

Figure 5. EURO-Concept (Decarbonized Titanium Recovery from Aluminium and Titanium Production Residues), Grant. No. 101135077 (Call: HORIZON-CL4-2023-RESILIENCE-01)

4. CONCLUSION

Advances in understanding of role of unit operation in recycling of waste materials helps to increase of recycling efficiency of metals from secondary materials, what is current problem in different industrial sectors in order to improve an environmental protection. General recycling strategy containing physical separation, hydrometallurgical and pyrometallurgical operations. Treatment of wastewater from electrolysis plant and acid mine drainage solution was mostly performed using neutralisation, filtration and precipitation method in order to remove some impurities from solution. Pyrometallurgical strategy was used for treatment of spent NdFeB-Magnets including demagnetisation and grinding, oxidation in air, reductive smelting in carbon crucible and final molten salt electrolysis. Decarbonized titanium recovery from bauxite Residues is new European sustainable concept based on pyrometallurgical and hydrometallurgical operations aiming a minimal of 20 % reduction of on-site energy and water consumption.

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EMERGING POLLUTANTS IN THE ENVIRONMENT: CONTAMINATION OF THE DANUBE RIVER BASIN IN SERBIA

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Abstract: *The quality of river water ecosystems is severely threatened by ever-increasing number of chemicals introduced through the wastewater treatment plants effluents, untreated sewage, agricultural runoff and industrial wastewater. Unregulated substances that may be candidates for future regulation depending on (eco)toxicity, potential health effects and monitoring data are considered to be emerging pollutants. For these substances, research indicates that they may pose a significant risk to or via the aquatic environment, but data are insufficient to reach a conclusion on the risk level. To support future prioritization, the Danube River and three main tributaries in Serbia (the Tisza, the Sava and the Morava) have been studied for the last 15 years. In Serbia, there is not a single treatment plant constructed along the entire course of the Danube, and only 8.1% of wastewater is treated. The results for about 100 pharmaceuticals, steroid hormones, sterols, pesticides and artificial sweeteners showed severe contamination of the investigated area, especially in the capital Belgrade. It was also determined that emerging pollutants detected in river sediments pose a significantly greater risk than those in surface water. The results indicate the much-needed treatment of municipal wastewater and inclusion in future monitoring of the most harmful substances.*
Keywords: Emerging Pollutants, the Danube, Environmental Risk Assessment, River Water, River Sediments

1. INTRODUCTION

Emerging pollutants (EPs), also known as contaminants of emerging concern (CECs), represent a global water quality challenge with potentially serious threat to human health and ecosystems. The rising concern is not only related to the widespread and growing use of diverse chemicals, but also to the improvement of analytical techniques that have enabled EP detection at trace levels in any environmental matrix. The primary route for their wide distribution in the environment is municipal and industrial wastewater, as well as agricultural run-off. As wastewater treatment plants (WWTPs) are not designed to completely remove most EPs, they are discharged into receiving waters. Due to their high water solubility and often poor degradability, many EPs pass through all natural filtrations and reach ground water, and ultimately drinking water. The major problem is the presence of antibiotics, because it can lead to the generation and spread of new strains of resistant bacteria. Nevertheless, most EPs are not regulated by national or international environmental legislation, as there is still limited knowledge about their environmental levels, fate and (eco)toxicological effects. Depending on research on their occurrence and impact in different environmental compartments, as well as toxicity and potential adverse health effects, many of them are candidates for future regulations [1].

For the purpose of supporting future prioritization of EPs relevant to the aquatic environment in the Republic of Serbia (RS), the Danube River Basin (DRB) has been studied for the past 15 years. The key source of water pollution in the RS is wastewater discharged into the recipient without any treatment, since only 8.1% of wastewater generated by agriculture, forestry and fishing, households and industry is treated [2]. Unlike neighbouring countries, there is not a single WWTP that has been

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constructed along the entire course of the Danube in the RS, so the environmental risk from exposure to EPs in the aquatic environment is expected to be high, especially in highly populated areas with high wastewater burden. The Danube River and its tributaries are an important resource for the drinking water production and agricultural irrigation for about 83 million people. It is a unique river ecosystem with the highest freshwater biodiversity in Europe. About 92% of the RS lies within the DRB, accounting for 10% of the total basin. Three major Danube tributaries on the territory of the RS are the Tisza, the Sava and the Morava. Considering the importance of the Danube River, the potential threat from unregulated discharge of untreated municipal wastewater along the entire course of the Danube in the RS was evaluated and the environmental risk for freshwater and benthic biota was assessed.

2. SAMPLING, SAMPLE ANALYSIS AND RISK ASSESSMENT

In many sampling campaigns performed over the last 15 years, about 150 samples of river water (RW), ~100 samples of ground water (GW) and ~50 sediments (SED) were collected to cover the entire course of the Danube in the RS (~500 km). Samples from the Danube's tributaries – the Tisza, the Sava and the Morava were collected a few km before the confluence with the Danube. At each sampling site, RW samples and several corresponding GW samples (from monitoring or Ranney wells) were taken. The corresponding SEDs were sampled less frequently.

The selection of EPs to be monitored was based on their very frequent use in the RS and suspected ecotoxicological potential, and was complemented with EPs that are most frequently detected in the European Union (EU). It included about 30 pharmaceuticals, 40 pesticides, 20 steroids and 10 artificial sweeteners, compounds with a wide range of physicochemical properties. Since the focus of EP research has changed over the years, from pharmaceuticals and pesticides to steroids and artificial sweeteners, not all selected EPs have been analyzed in all samples taken.

Several analytical methods have been developed and optimized for the identification and quantification of different classes of EPs in water and sediment matrices [3-6]. The most commonly used protocols for the determination of EP traces in complex environmental matrices consist of a water sample preparation by solid-phase extraction (SPE) or ultrasonic extraction (USE) of sediments, followed by extract analysis using liquid chromatography coupled to mass spectrometry (LC-MS). Due to the high selectivity and sensitivity, as well as confirmation possibilities, tandem mass spectrometric detection (MS/MS or MS^2) using an ion trap was chosen for EP determination. The list of EPs detected in RW, GW and SED samples of the DRB in the RS over the last 15 years is presented in Table 1.

Environmental risk assessment of EP levels detected in the samples was performed by calculating risk quotients (RQs). RQs were calculated by dividing the maximum environmental concentration of each EP with the corresponding predicted no-effect concentration for freshwater ($PNEC_{fw}$) or sediment ($PNEC_{sed}$). PNEC values were obtained from the Norman Ecotoxicology Database [7] as the lowest PNECs, preferably based on experimental ecotoxicity data for aquatic or benthic organisms. Environmental risk is classified into four categories: "negligible/no risk" ($RQ < 0.01$), "low risk" ($0.01 < RQ < 0.1$), "moderate/medium risk" ($0.1 < RQ < 1$) and "high risk" ($RQ \geq 1$).

Table 1. EPs detected in the Danube River Basin in Serbia over the past 15 years

	Frequency of detection (maximum concentration)			**$PNEC_{fw}/PNEC_{sed}$[7] (ng L^{-1}/ng g^{-1})**	**Env. risk RW(GW)/SED**
	RW (ng L^{-1})	**GW (ng L^{-1})**	**SED (ng g^{-1})**		
Pharmaceuticals					
Carbamazepine	53% (130)	18% (41)	22% (214)	2000/56.9	low(low)/high
Azithromycin	3% (55)	5% (68)	ND	19/40.8	high(high)/–
Sulfamethoxazole	1% (22)	ND	67% (30)	600/3.67	low(–)/high
Clopidogrel	25% (4)	ND	69% (14)	31000/2302	no(–)/no

Metoprolol	50% (92)	ND	ND	8600/557	low(–)/–
Bisoprolol	25% (7)	ND	ND	92000/17850	no(–)/–
Erythromycin	ND	ND	22% (36)	300/657	–(–)/low
Trimethoprim	16% (223)	1% (100)	ND	120000/872	no(no)/–
Pesticides					
Carbendazim	26% (269)	16% (88)	28% (3)	440/5.57	med.(med.)/med.
Carbofuran	2% (25)	6% (10)	72% (21)	16/0.07	high(med.)/high
Atrazine	3% (188)	8% (64)	89% (392)	600/6.11	med.(med.)/high
Propazine	8% (18)	ND	56% (72)	180/2.52	low(–)/high
Dimethoate	5% (23)	ND	17% (1222)	70/0.17	med.(–)/high
Malathion	ND	ND	28% (69)	6/0.078	–(–)/high
Imidacloprid	ND	ND	17% (4)	13/0.094	–(–)/high
Steroids					
Mestranol	ND	ND	74% (77)	1190/31857	–(–)/no
Coprostanol	69% (1907)	ND	100% (866)	NA	
Cholestanol	50% (1172)	ND	100% (1250)	NA	
Cholesterol	100% (1543)	ND	100% (1507)	85/394	high(–)/high
Cholestanone	25% (1440)	ND	95% (1182)	NA	
Desmosterol	47% (1126)	ND	42% (524)	110/413	high(–)/high
Stigmasterol	75% (655)	ND	100% (680)	47/227	high(–)/high
Campesterol	47% (1106)	ND	100% (733)	56/NA	high(–)
β-sitosterol	75% (1245)	ND	100% (1359)	49/142	high(–)/high
Sitostanol	41% (682)	ND	100% (936)	NA	
Epicoprostanol	50% (1066)	ND	32% (1230)	NA	
Epicholestanol	44% (296)	ND	ND	NA	
Artificial sweeteners					
Acesulfame	100% (83)	60% (20)	ND	72400/196	no(no)/–
Saccharin	55% (396)	ND	ND	35900/93.4	low(–)/–
Cyclamate	14% (129)	ND	ND	18500/NA	no(–)/–
Sucralose	100% (206)	40% (17)	ND	29700/88.5	no(no)/–
Aspartame	ND	ND	100% (568)	39300/385	–(–)/high
Neotame	ND	ND	80% (56)	1370/20.9	–(–)/high

ND – not detected
NA – not available
med. – medium risk

3. RESULTS AND DISCUSSION

3.1 Pharmaceuticals

In the collected samples, pharmaceuticals (~30) from different classes were analysed: antibiotics (penicillins, cephalosporines, sulfonamides, macrolides, tetracyclines), sedatives (benzodiazepines, antiepileptics), analgoantipyretics, antihypertensives (β-blockers, ACE inhibitors, calcium channel blockers), antihyperlipemics (statins), and anticoagulants. Eight pharmaceuticals have been consistently found over the years in samples from the DRB, however, only those most frequently found and showing high risk to aquatic or benthic organisms are discussed.

The antiepileptic carbamazepine was the most frequently detected pharmaceutical, due to its high resistance to biodegradation in the environment, as well as its very low removal rate in wastewater treatment. It passes through natural bank filtration and is found in GW, so it can ultimately reach drinking water as well. According to the $PNEC_{sed}$ value, the highest detected carbamazepine level poses a high risk to benthic organisms. The presence of azithromycin, the most commonly used antibiotic in the RS, in environmental samples is a major problem, especially in GW, as there is a potential for inducing bacterial resistance and reaching the drinking water. The $PNEC_{fw}$ value and calculated RQ (> 1) indicate a high risk to aquatic organisms at the detected levels in both RW and GW. Sulfametoxazole is one of the most frequently found antibiotics in the aquatic environment

worldwide. Although detected in just 1% of RW samples, at a level of low risk to aquatic organisms, the recorded concentrations in sediments are much higher than those expected to have adverse effects on sediment-dwelling organisms [3,8,9].

3.2 Pesticides

About 40 pesticides were investigated in water and sediment samples from the DRB: herbicides, insecticides and fungicides, such as organophosphates, neonicotinoids, carbamates, diacylhydrazines, benzimidazoles, triazines, phenylureas, etc. Over the last 15 years, seven pesticides were commonly found: fungicide carbendazim, insecticides carbofuran, dimethoate, malathion and imidacloprid, as well as herbicides atrazine and propazine. The frequency of their detection is explained by the extensive agricultural use in the RS, as agricultural land covers as much as 66% of the country's total land area. The highest pesticide concentrations were reported for samples from the Morava River, a tributary of the Danube, heavily impacted by agricultural practices.
Based on the very low values of $PNEC_{fw}$ and $PNEC_{sed}$, the levels of detected pesticides in the DRB in the RS, although low, pose a high or medium risk to aquatic and benthic organisms. At the time of sampling, most of these pesticides were approved for use in the RS. With the exception of malathion, all of them are now banned. Considering their high ecotoxicity at trace levels, the current ban is justified. Although atrazine and propazine were banned almost two decades ago, they are still being recorded at high levels in the samples of the DRB, due to their extreme persistence in the environment. Malathion, as a pesticide still approved for application, was found only in sediments, due to its extensive biodegradation and short half-life, as well as its almost complete immobilization in the organic-rich sediment matrix. Its detected concentrations are significantly higher than the levels known to have adverse effects on benthic organisms, so the results suggest that it should be included in the monitoring programs and restricted in use [4,9,10].

3.3 Steroid compounds

In the last ten years, EP research in the DRB has been extended to included 20 steroids: steroid hormones, such as natural estrogens and synthetic hormones, as well as human/animal and plant sterols. Of nine steroid hormones monitored, only mestranol was found in the sediments, at levels of low risk for benthic organisms. Since these compounds are usually present in the environment at very low concentrations, the inability to record them in water samples could be explained by the limited performance of applied analytical method. The investigated sterols were found at considerably higher levels than other detected EPs. Although some steroids occur naturally, they usually enter the environment in large quantities through discharges of raw sewage and treated urban wastewater, as well as via run-off from agricultural land treated with manure or sludge. Due to their highly hydrophobic properties, sterols show a strong preference to bind to solid organic-rich matrices and are found in all analysed SED samples. The human/animal sterol coprostanol was detected at the highest concentrations in RW samples, while cholesterol was the most abundant in the sediments. None of the GW samples tested contained sterol residues, indicating successful elimination by bank filtration. Coprostanol was recognized decades ago as one of the most important chemical markers for human-sourced sewage contamination. It has been proven to be a useful indicator in sterol ratios applied to confirm human faecal pollution and to distinguish between sewage-sourced and non-human biogenic inputs. Although cholesterol is the most abundant sterol in the human body, it is not a specific marker for sewage pollution of the environment, because it is also present in plant material. For many steroid compounds, there is a lack of ecotoxicity data, preventing the assessment of the potential risk to aquatic or sediment-dwelling organisms at detected levels. However, for those for which $PNEC_{fw}$ and $PNEC_{sed}$ are available, a high risk was found in both water and sediment samples. The detrimental impact of steroid compounds on the aquatic ecosystem have been recognized for more than two decades, as many ecotoxicity studies have shown abnormal reproductive function, impaired growth and endocrine disruption of aquatic and benthic organisms at trace amounts of

sterols and steroid hormones. The results have shown that the DRB in the RS is highly contaminated with raw, untreated sewage, leading to a high environmental risk to biota, which indicates the much-needed treatment of municipal wastewater [5,11-13].

3.4 Artificial sweeteners

The decades-long use of sweeteners in food products and medicines has resulted in their ubiquitous environmental occurrence. For this reason, five years ago, the focus of the EP investigation in the DRB in the RS was shifted to artificial sweeteners. The results have shown that acesulfame and sucralose were the most frequently detected, as they were found in all collected RW and GW samples. Their widespread presence in the aquatic environment can be explained by the fact that they are metabolically inert, highly soluble in water and very persistent. The lower detection frequency of saccharin and cyclamate in RW and GW is related to their limited stability and fast biodegradation. In recent years, acesulfame and sucralose are frequently used markers to indicate older sewage pollution, while saccharin and cyclamate are used as indicators of fresh sewage contamination. Aspartame and neotame were the only artificial sweeteners detected in the investigated SED samples. On the other hand, they were not detected in any water samples. The results can be explained by their rapid metabolism, high level of degradation in the environment and high sorption affinity for organic-rich sediment particles. The concentrations of detected artificial sweeteners indicate significant ecotoxicity of aspartame and neotame, leading to a high risk to benthic organisms [6,14].

4. CONCLUDING REMARKS

Levels of pharmaceuticals, pesticides and artificial sweeteners in the DRB in the RS were generally similar or lower than in other European countries with much larger populations and efficient wastewater treatments that significantly reduce concentrations of EPs to levels similar to those in the RS. The concentrations of detected sterols were much higher than those found in the EU, which is consistent with the high anthropogenic burden by untreated municipal wastewater. It is evident from the results that the sediments of the DRB are of greatest concern with regard to detected EPs, as a high or medium level risk to benthic organisms was determined. Given that sediments are considered as a major sink of organic pollutants, they can also act as a secondary source of pollution in case of resuspension. The results also revealed the highest ecotoxicological risk in the two largest cities – the capital Belgrade and Novi Sad, both heavily impacted by untreated sewage and high population density. It was determined that the Danube's tributary Sava in Belgrade is more polluted than the Danube, due to high dilution capacity of the Danube River. The obtained results indicate the improvement of the treatment and management of sewage wastewater and the necessity of including detected EPs with a high environmental risk in routine monitoring programs.

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BIODEGRADABLE POLYESTERS – FROM ECOLOGY TO MEDICINE

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***Abstract**: Polymeric materials, commonly known as plastics, are versatile group of macromolecular organic compounds which properties make them irreplaceable in many aspects of contemporary life. Due to their exceptional (e.g. lightweight, durability) and easily tailorable (e.g. from stiff to flexible, from superhydrophobic to water-soluble) properties they are important in many fields. The increased use of polymeric materials, especially in packaging sector, is associated with high amount of waste which became a serious environmental problem, since the most of this waste ends up in terrestrial and oceanic environment. One of the solutions of environmental impact of polymeric materials is replacement of non-biodegradable with synthetic biodegradable polymers. Aliphatic polyesters are the main class of synthetic biodegradable polymers and some of them can be produced from renewable sources (biomass), which further contribute to the issue of sustainability. Additionally, in the field of medicine, there is also a growing requirement for biodegradable polymers with temporary function and easy elimination from the body. Within the frame of this contribution the research on synthesis of biodegradable (co)polyesters mainly based on poly(butylene succinate) and polycaprolactone, their structure dependent properties, their nanocomposites with naturally occurring fillers like clays and sepiolites as well as their potential application will be presented.*

Keywords: biodegradable, synthetic polymers, polyesters

1. INTRODUCTION

Although the mass production and use of synthetic polymers started around the middle of last century, today's world is not imaginable without these materials. The reason for such high usage lies in their versatility in terms of physical and chemical properties. They are lightweight and durable and their properties span, for instance, from soft elastomers to hard thermosets, form watersoluble to superhydrophobic, just due to the chemical structure of monomeric unit form which they are comprised. Increased usage of conventional, durable polymeric materials, especially for short-term applications, lead to high amount of polymer waste which cannot be assimilated by living organisms in nature and their accumulation presents an environmental challenge. Therefore, the development of biodegradable polymers is of an utmost importance [1]. Biodegradable polymers are also of interest in biomedical filed where they are developed for controlled released systems or in tissue engendering. Among biodegradable polymers, aliphatic polyesters, due to the presence of hydrolysable ester group in their backbone, are the most promising candidates to replace conventional plastic materials like polyethylene, poly(ethylene terphatalate) or polystyrene [2,3]. They can be obtained from fossil based recourses as poly(butylene succinate), PBS, and poly(ε-caprolactone), PCL, or form renewable resources as poly(lactic acid), PLA (Figure1). However, in order to broaden the application window for biodegradable polyesters different approaches are used to render new materials with desired properties. The most versatile approach is copolymerization to yield random, block or star copolymers with new properties. Also, mechanical strength, barrier and thermal properties can be enhanced and tuned by application of nanocomposite approach. The development of nanocomposites with biodegradable polymer matrix is a very

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dynamic filed of current scientific and industrial interest. In this work research on some copolymers, nanocomposites and controlled release systems developed from PBS, PCL and PLA will be presented.

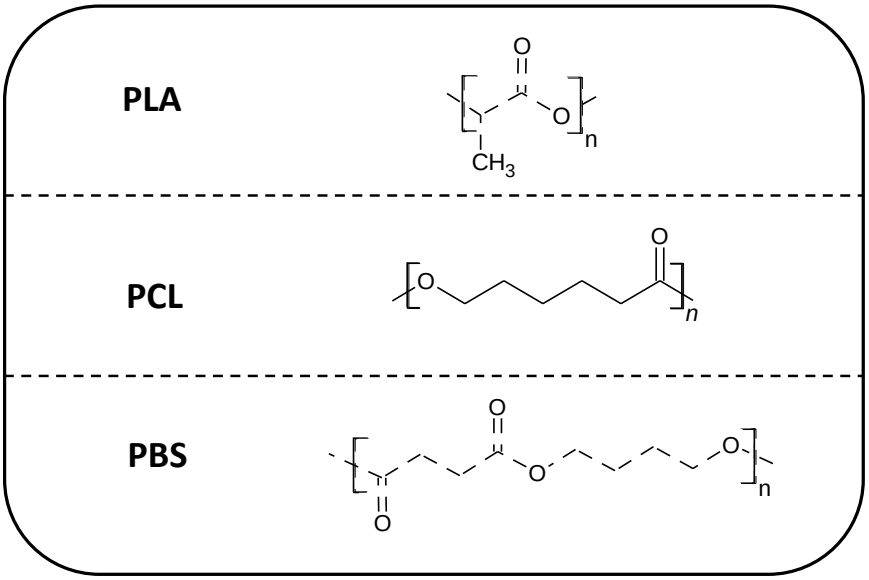

Figure 1. Overview of biodegradable polyesters considered in this work

2. COPOLYMERS OF DIFFERENT BIODEGRADABLE BUILDING BLOCKS.

2.1 Poly(buthylene succinate) based copolymers

Poly(butylene succinate) belongs to the large family of poly(alkylene dicarboxylate) polyesters which are obtained from diacids and diols . The favorable thermo-mechanical properties put apart PBS form other poly(alkylene dycarboxilate)s, since PBS is one of a few polyesters belonging to this family with melting temperature higher than 100 °C. PBS and its copolymers were commercialized in 1994. by Showa Denko (Japan) under trade name Bionolle. They were seen as resins for production of eco-friendly packaging, bottles and mulch films, i.e. as a suitable replacement for low density polyethylene. Fair mechanical properties together with good processability and thermal resistance are in favor of broader use of PBS, nevertheless its low gas-barrier properties are often criticized, especially for the food packaging applications. Hydrolytic degradation of PBS, which is the first step in biodegradation process, is slow, due to its hydrophobic nature and high crystallinity. The degree of crystallinity has a major influence on the degradation rate, since the degradation commences first in the amorphous parts of the polymer. Crystallinity can be tailored through copolymerization, the most effectively for random copolymers. By using transesterification reaction with highly effective titanium based catalyst random copolymers of PBS and poly(butylene adipate), PBA were successfully synthesized [4]. These high molecular weight copolymers were synthesized in order to combine different properties of the parent homopolyesters: high melting point of PBS and higher biodegradability of PBA. Enzymatic degradation test conducted by the use of *Candida cylindracea* lipase showed that all copolymers with high adipate content had an improved biodegradability compared to the homopolymers. By using similar procedure, copolymers of PBS with small amount of unsaturation, arising from fumarate units, were synthesized [5]. The introduction of double bonds into the main chain increased the melting and crystallization temperatures, but a decreasing trend in the crystallinity was observed. Since the biodegradation was not greatly correlated with crystallinity in this case, this study showed that stiffness of the molecular chains and the size of the spherulites are also factors which determined the biodegradation.

Changing the hydrophilicity/hydrophobicity of polymers can be done through copolymerization by the introduction of hydrophilic segments, such as polyethers, into the backbone of the polymer

chains. The introduction of polyether soft segments into polyesters not only change hydrophylicity, but leads to the formation of segmented polymers, the mechanical properties of which can be easily controlled by the type, the weight percent, and the length of these soft segments. Block-copolymers of PBS and two different polyethers of the same molecular weight: poly(tetramethylene oxide), PTMO and poly(ethylene oxide), PEO were synthesized. All prepared copolymers had improved biodegradability compared to PBS homopolymer. Also, copolymers with PEO in the soft segments were more susceptible to hydrolysis than those based on PTMO, which is to be expected from the lower hydrophilicity of PTMO compared to PEO. At the same time mechanical properties were modified and the presence of soft, polyether segments reduced storage modulus in rubbery state compared to PBS homopolymer by one to two decades, as reveled by dynamical mechanical analysis [6,7].

2.2 Poly(ε-caprolactone) based copolymers

Another prominent member of biodegradable aliphatic polyesters' family is poly(ε-caprolactone). PCL is hydrophobic, semicrystalline polymer with a melting point of about 60 °C, and low glass transition temperature of around – 60 °C. PCL is considered as a suitable, environmentally friendly replacement for some non-biodegradable commodity polymers for packaging or in agriculture. PCL exhibits good compatibility and miscibility with other polymers, it is biocompatible, and easily processable polymer. Due to its biocompatibility and slow hydrolytic degradation without the harsh change of pH in the surrounding medium, PCL has been investigated for some long-term medical applications, such as in some prolonged controlled release systems or for different scaffolds, where physical and mechanical properties should be maintained for at least 6 months.

In order to combine properties of PCL and PBS and to maintain high melting temperature of copolymers, multiblock copolymers of these two polymeric units were synthesized. Multiblock copolymers having PBS and PCL as building blocks were synthesized through diisocyanate coupling reaction, demonstrating that this approach yields copolymers with versatile properties [8]. Mechanical strength, deduced from storage modulus in glassy and rubbery state, was a firm function of composition, where softer materials were obtained with introduction of more flexible PCL block into the polymer chains. Biodegradability was investigated in alkaline medium and in soil burial test and it was strongly compositional dependent. The copolymers with higher density of ester linkages (higher content of PBS) were more prone to degradation in alkaline medium. PCL was more susceptible to degradation in soil as well as PCL-rich multiblock copolymers. Furthermore, triblock copolymers with PCL lateral blocks were synthesized, in order to broaden the application window of PCL and to establish correlation between macromolecular structure of block copolymers and their properties. As a central block two different condensation polyesters of a fixed molecular weight were used, poly(butylene succinate), PBS and poly(butylene adipate), PBA, while molecular weight of lateral PCL blocks was varying in the series of copolymers. Melting temperatures of all copolymers were slightly lower compared to PCL, as a consequence of imperfections of formed PCL crystallites, imposed by the presence of second crystallizable component. Conversely, degree of crystallinity of PCL fraction was considerably higher in all of the copolymers indicating a nucleation effect of the present PBS or PBA in the copolymers. Yet, in the hydrolytic degradation tests weight losses were lower in PBS series and higher in PBA series compared to PCL, indicating possibility of tailoring biodegradation kinetics by copolymer composition. The changes in molecular weights during the course of degradation revealed surface erosion mechanism for the both series of triblock copolymers.

Properties of copolymers can also be tailored by the change in the architecture of polymer chain. Through the synthesis and comparison of the properties of diblock and triblock copolymers of PCL and PEO, it was demonstrated that thermal, surface and degradation properties of these polymers depend not only on the chemical composition, but also on the chain architecture, i.e. diblock vs. triblock [9,10].

3. (NANO)COMPOSITES WITH BIODEGARDABLE POLYSTER AS A MATRIX.

3.1 Poly(ε-caprolactone) based (nano)composites

Mechanical, thermal or barrier properties of aliphatic polyesters can be significantly improved with the addition of small amount of nanofiller. A great number of nanofillers were employed in development of nanocomposites with biodegradable polymers, such as natural lamellar clays, carbon nanotubes, metallic nanoparticles, graphene, etc. [11-13]. From the economic viewpoint natural clays are a good choice since they are abundant and easy to exploit. Among natural clays, layered silicates are the most investigated, since they are of high mechanical strength, chemical resistance and well investigated intercalation chemistry which is important for surface modification. The most challenging task in nanocomposite preparation is to achieve good filler dispersion in polymer matrix. Only in the case of a good dispersion, the interface between a filler and matrix dramatically increases, allowing a full contribution of the filler to improve the matrix properties. Therefore, the surface of a filler is usually modified with suitable organic molecules (to yield organoclay) in such way to provide good interaction with polymer matrix. Solution casting was used to prepare PCL/organoclay nanocomposites with two different organically modified montmorillonites, Cloisite®30B and, more hydrophobic, Cloisite®15A. All nanocomposites had improved mechanical properties in terms of dynamic storage modulus. At the same time a trend of decrease in strain at break with increase in the clay loading is observed, similar to the usually found embrittlement effect of the clay [14]. Detailed rheological studies of these nannocomposites in melt and in solid state showed that mechanical properties are mainly influenced by the effective aspect ratio of the clay [15].
Sepiolite is fibrous natural clay, which emerges as a new inorganic nanofiller. Sepiolite fibres are organized in bundles and they can be easily functionalized through reaction with silanol groups at their surface. At the same time sepiolite possesses exchangeable cations, which makes the basis for modification through ion exchange reactions. Modification of sepiolite was performed with the goal to increase its compatibility with PCL hydrophobic matrix. Modification was performed with (3-mercaptopropyl) trimethoxysilane, by covalent attachment and with hexadecylamine by ion exchange reaction. Organomodification of sepiolites promoted the dispersion of nanofiller in PCL matrix and the mechanical performance of nanocomposites was improved. Due to the favorable interactions which could be established with PCL (whose repeating unit has long aliphatic part) the highest reinforcement was achieved for the sepiolites modified with hexadecylamine [16]. Also, barrier properties of nanocomposites' films were investigated on permeability to water vapor. It was found that the barrier properties were improved by addition of modified sepiolite into the PCL matrix.

3.2 Poly(lactide acid) based (nano)composites

The most researched and developed biodegradable aliphatic polyester is certainly poly(lactic acid), primarily because it is a polyester which can be produced from renewable resources. Due to the chiral monomeric unit, PLA can have a range of properties which depend strongly on its optical purity, i.e. content of L- and D-enantiomer. Optically pure PLLA (comprised of only L-enantiomer) is crystalline polyester with melting temperature around 170 °C and glass transition temperature of around 60 °C. PLA is seen as a polymer that can be broadly used for general packaging (compostable tableware and plastics bags), in agriculture (mulch films) and in fiber industry (disposable garments), since it can be easily processed using conventional equipment. However, in order to replace currently used commodity thermoplastics some of its shortcomings as poor barrier properties, brittleness and cost effective production has to be overcome. In the field of packaging application it would be of great importance to improve some functional properties of PLA, such as antibacterial activity. PLA composites with antibacterial activity were obtained by incorporation of silver-enriched zeolite (Ag-Z) in polymer matrix. Antibacterial activity of composites was proven

toward two bacterial strains, Gram-negative *Escherichia coli* DSM 498 and Gram-positive bacteria *Staphylococcus aureus* ATCC 25923 and was slightly pronounced toward *E.coli*. At the same time silver-enriched zeolite had a reinforcement effect on the polymer matrix.

4. BIODEGRADABLE POLYESTERS AS DRUG RELEASE SYSTEMS.

Microencapsulation of active substances is in the focus of current research efforts due to many advantages which these systems have, compared to conventional drug delivery systems. Besides the protection of a drug, microencapsulation offers possibility of controllable and targeted drug delivery. Natural choice for the matrix of microspheres in such systems is biocompatible and biodegradable polymeric material. Biodegradable and biocompatible PCL and its copolymers and blends are very often used as matrix-building material in drug release microspheres' systems, since PCL possesses good permeability for small molecules. The potential of PCL as drug carrier for hydrophobic carbamazepine as well as conditions for microencapsulation of this drug were evaluated. Microspheres in the size range from around 5 μm to around 100 μm could be successfully obtained, with high encapsulation efficiency. It was demonstrated that release of carbamazepine from smaller PCL microspheres was slower, as a consequence of better drug distribution in comparison to the bigger microspheres [17]. By changing the hydrophilicity of PCL microspheres through blending with PEO, release profiles of carbamazepine could also be efficiently modified [18]. Block copolymers of PCL with small amount of PEO block were likewise efficiently applied as drug carriers in microencapsulation of ibuprofene [19].

5. CONCLUSION

Biodegradable aliphatic polyesters are versatile materials which can be applied in different fields. In this work possibility to tailor material properties by copolymerization, nanocomposite preperation and blending approach, using PCL, PBS and PLA polyesters, is described. Also, the potential application of biodegradable polyesters as the matrix for drug release from polymer microspheres is presented. For other biodegradable synthetic polyesters further improvements through development of new building units, synthetic procedures and molecular architecture will certainly promote these materials' application. New achievements are expected particularly in the field of (nano)composites for an easy and efficient modification and tuning of properties. With this advances and growing ecological awareness, it is expected that the market of biodegradable aliphatic polyesters will see a steady growth in the future.

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THE *ESPeRT* PROJECT: A "POLYTECHNIC" STRATEGIC PLAN FOCUSED ON SUSTAINABILITY

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Abstract: *In this paper, a strategic research project, carried out by the Polytechnic Department of Engineering and Architecture of the University of Udine, and focused on sustainability, is presented. The project, named "ESPeRT", is focused on three interconnected research areas: sustainability of the production processes; energy and green economy; territorial resilience. The project is designed to be functional for the implementation of the UN 2030 Agenda on Sustainable Development, the Next-Generation EU and of the National Recovery and Resilience Plan. The research activities carried out in the framework of the ESPeRT project are complemented by a new teaching offer related to sustainability. Namely, a new Master course on "Industrial Engineering for Sustainable Manufacturing" has been designed and implemented, starting from the academic year 2023-24.*
Keywords: Sustainability, Ecological Transition, Digital Transition, Agenda 2030, UN SDGs

1. INTRODUCTION

In recent years, the issue of sustainable development has become increasingly central to global and local policies. At the same time, the climate changes underway are causing important transformations of the ecosystem and producing increasingly frequent extreme phenomena, with relevant socio-economic impacts. This fact highlighted the urgency of making a transition to a sustainable development, also aimed at reducing the risks of disasters and at mitigating threats, with a substantial reduction of climate-altering emissions and with a transition to clean energy. The sustainable development goals of the UN 2030 Agenda [1], the Paris Agreement [2] and the European Green Deal [3] aim at a progressive decarbonisation and at adopting circular economy solutions, based upon a science-based and risk-informed approach. It is therefore necessary to aim at a greater sustainability of the productive processes, by exploiting innovative technologies and management models capable of combining an efficient production with the needs of environmental protection and of the rational use of resources. The fragility of the territory and the plurality of risks to which it is subject also require improvement of the territorial resilience with a holistic and systemic vision, not only to face disasters and crises *ex-post* but also to anticipate them *ex-ante* and transform them into opportunities for regeneration and development in the recovery phases.
The effects caused by the COVID-19 pandemic are also added to this picture [4]. These effects have led to major changes and have placed new global challenges on the table, highlighting the close interconnection between health, technological and socio-economic aspects, and above all the difficulty of management and governance, due to the high level of complexity that characterizes the era of globalization. The recovery plans - such as the Next Generation EU [5] and the Italian National Recovery and Resilience Plan [6] - intend to promote a robust recovery of the economy under the banner of ecological transition, digitization, competitiveness, training and social, territorial and

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gender inclusion. The ecological transition, in particular, is focused on themes with a strong polytechnic connotation, such as:

- circular economy;
- energy efficiency and redevelopment of buildings;
- renewable energies, hydrogen, sustainable mobility;
- protection of the territory and of the water resources.

These plans follow the "build back better" principle introduced by the Sendai framework [7]: the goal is not a return to normality aimed at restoring pre-pandemic conditions, but rather a new normality characterized by more advanced standards of quality of life. In other words, the objective of these plans is to seize development and improvement opportunities by introducing among the recovery objectives also those defined by the above mentioned UN Agendas (and among these, primarily those of the UN 2030 Agenda on sustainable development), as well as the protocols on climate change and the Green Deal.
The ultimate goal is to shape the future with the new generations as a point of reference and to start a real process of change, transformation, renewal, regeneration and revitalization. It is a path of recovery and development in which research, first of all, is called to give its concrete contribution in terms of strategies and solutions. Research and technological innovation are among the main drivers of the economic development of a country, but in particularly complex historical moments, such as those of post-pandemic recovery, it is necessary to adopt an interdisciplinary and focused approach.
The Polytechnic Department of Engineering and Architecture, with the *ESPeRT* project, intends to systematize its expertise in a highly interdisciplinary general project, also open to contributions from other departments and institutions, with the aim of giving a concrete contribution of research and innovation in this direction.

2. GOALS AND STRUCTURE OF THE PROJECT

The *ESPeRT* project, coordinated by the Polytechnic Department of Engineering and Architecture of the University of Udine, intends to contribute to the achievement of the objectives of the UN Agendas and the challenges introduced by the recovery plans (such as the Next Generation EU and the Italian National Recovery and Resilience Plan) by operating on three interconnected research areas:

- sustainability of the production processes;
- energy and green economy;
- territorial resilience.

Figure 1 shows the structure of the *ESPeRT* project. Those listed above are three issues that constitute the main components of the ecological transition that is a fundamental part of the sustainability. Their transversal character requires the systemisation of various polytechnic skills in an interdisciplinary logic also open to the synergistic contribution of other disciplines present in other departments and institutions.
The project is designed to be functional for the implementation of the UN 2030 Agenda on Sustainable Development, the Next-Generation EU and of the National Recovery and Resilience Plan and, in particular, pursues the following aims:

1. provide research contributions contextualized and consistent with the recovery and post-pandemic COVID-19 recovery policies defined at the international, national and local level;
2. define a logical framework that allows to be best expressed the potential deriving from an interdisciplinary “polytechnic” approach on current and emerging issues;
3. facilitate the systemisation and capitalization of the experiences and skills present in the University of Udine, in order to proactively contribute to the ongoing change process;
4. make the multi-sectoral contributions more organic, in order to act as a guide and functional support to the reference territory in the process of change, outlining the possible synergies between Universities, Institutions and public and private subjects involved in the process.

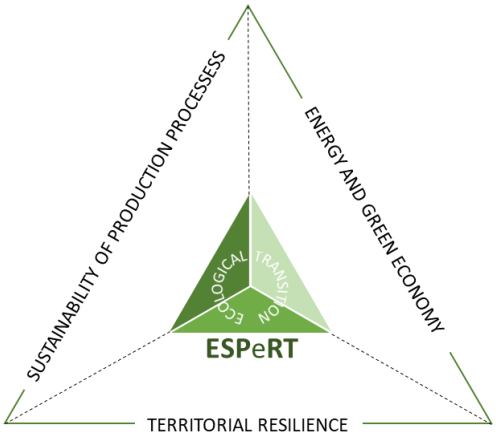

Figure 1. The structure of the *ESPeRT* project for sustainability.

The project is structured in Workpackages, Tasks and Sub-tasks, following a logical and functional framework in which the individual contributions research are nested. The three main WPs are:

- WP S - Sustainability of Production Processes;
- WP E - Energy and Green Economy;
- WP R - Territorial Resilience.

The triangular scheme shown in Figure 1, made up of three converging triangles which, joining together, point to a common goal, highlights the role of interdisciplinary synergy that underlies the project and at the same time constitutes the logical path that links organically the individual research activities.

The structure given to the project is designed to allow a certain degree of dynamism and adaptability over time in order to allow, where deemed appropriate and functional for the purposes of the project, to enrich the various WPs by integrating them by inserting new Tasks, Subtasks and new actions, also on the proposal of scientific representatives of other departments and institutions. The placement of these integrations in this pre-structured scheme ensures the maintenance of the overall logical coherence of the project and the finalization of the various contributions.

In the following subsections of the paper, the three Workpackages, involving a total of more than 100 researchers of different disciplines, will be described.

2.1 WP S – Sustainability of Production Processes

Sustainable development is a form of economic development compatible with the protection of the environment and of the resources for the future generations. It implies the simultaneous pursuit of economic prosperity, environmental quality and social equity.

An increasing number of organizations acknowledge environmental protection and responsibility towards others stakeholders as priorities of the company. Therefore, the design and management of processes cannot be limited to the sole perspective of profit, but must consider the effects on the environment (e.g. in terms of pollution, CO_2 production, creation of waste, etc.) and the effects on society (for example in terms of well-being at the workplace and improvement of the quality of life of the employees and of the society in general).

Consequently, sustainable production is an important driver of sustainable development and requires rethinking and innovating not only the production systems, but also the supply networks, the logistics systems and the characteristics of the products and services. In this sense, research on sustainable production is characterized by a strong interdisciplinarity.

Furthermore, the choices relating to sustainable production can be declined in the three characteristic areas of sustainability - economic, social, environmental - but also at different decision-making levels (strategic-managerial, infrastructural and operational).

The research activities of the WP S are aimed at the transfer and diffusion of technologies, methodologies and knowledge for strengthening the sustainability of production processes in terms of:

a) business models for sustainability (strategic-managerial level);
b) infrastructures for the control and monitoring of industrial plants and products (infrastructural level);
c) process and product prototyping for a sustainable industry (product-process operational level).

The WP S intends to study the innovation of products, processes and infrastructures and their alignment in order to create a business model for sustainability that describes the main strategic decisions and organizational structures that guide the introduction of product/process/infrastructure innovations. The goal is to provide the companies with a support for the improvement of products (for example in terms of functionality, resistance, reliability, duration, etc.) and processes not only in terms of economic and operational performance but also of well-being work and environmental impact.

2.2 WP E – Energy and Green Economy

The energy issue represents an essential element for any program aimed at achieving energy efficiency while respecting the environmental sustainability. Historically, every economic development has been supported by an increase in the energy availability, with clear correlations between the growth of gross national product and energy demand. Relying mainly on limited and non-renewable primary sources (such as fossil sources) leads to a vicious circle of increases in impacts and depletion of resources: reversing this process requires a redesign of the production chains in a broad sense, both in terms of energy production (renewable sources, energy efficiency energy conversion), and in terms of energy demand in the civil, industrial and transport fields (reduction of consumption, integrated systems, innovative distribution networks, waste reduction and circular economy).

This transition involves explicitly energy aspects, referred to in goal n.7 of the UN Agenda 2030 (Clean and accessible energy), while also maintaining the need for equity through the effort to ensure universal access to quality services. But the importance of demand-side optimization links to goals n. 11 and 12 (Sustainable cities and communities, Responsible consumption and production), requires innovation such as referred to in goal n. 9, and supports the fight against climate change (goal n. 13). This imposes important technological challenges, and the development of strategies to manage the transition with different interventions corresponding to the medium and long-term objectives. This project takes advantage of the internal skills of the Polytechnic Department of Engineering and Architecture of the University of Udine to develop suitable models and technologies, in terms of system analysis (with attention to the development of sustainable logistics networks of production and transport), in terms of technological choices (with a focus on the energy efficiency of buildings and plants), in terms of development of key technologies for overcome technological bottlenecks in the short, medium and long term (innovative heat exchange systems, use of carbon-free fuels, material recycling methodologies, innovative solar energy conversion technologies), in terms of numerical modelling and phenomenological analysis to support these objectives.

2.1 WP R – Territorial Resilience

The WP R intends to address, in an interdisciplinary way, the issue of territorial resilience. The UNDRR (United Nations Office for Disaster Risk Reduction) highlights how territorial resilience, in its various components, contributes decisively to the achievement of a large part of the development objectives sustainability defined by the UN Agenda 2030 and the fulfilment of the goals introduced by the Sendai Framework on Disaster Risk Reduction.

The theme of territorial resilience is central for a country like Italy, and in particular for its North-Eastern regions, which are exposed to a variety of natural and man-made hazards. The peculiar

geographical configuration, the economic development and the intensive use of the soil, the abandonment of certain territories and the intensive tourist activity in others, the widespread presence and growth of urban and productive settlements, combined with a multiplicity of interconnected infrastructures, make these territories particularly exposed and vulnerable. Particular attention should be paid to critical infrastructures and essential services (hospitals, lifelines, road infrastructures, schools, etc.). The presence of a heritage to be protected with reference both to its naturalistic-environmental and socio-economic values represents at the same time also a distinctive element for identity, culture, history and therefore with historical-cultural value.

Preventing and countering the hydrogeological instability phenomena, reducing the seismic vulnerability of buildings and making a careful and appropriate land use are actions that cannot be postponed. Interventions aimed at monitoring and prevention, the safety of the territory, the redevelopment of settlements, the adaptation of buildings and the improvement of energy efficiency require new conceptual paradigms. We must leave sectoral logics of action and adopt integrated approaches in order to define transversal strategies which, while acting in the immediate and short term, achieve results in the medium and long term. It is therefore important to act synergistically and according to an overall vision on the fronts of forecasting/foresight, prevention and planning, but also to improve knowledge and skills for emergency management, recovery and post-event regeneration. The disaster management cycle, proposed by the United Nations, is the main reference methodology for this purpose, also because it allows us to give an operational meaning to the term “territorial resilience”, not only in reactive terms, but also and above all in pro-active terms, such as the ability to anticipate and adapt to changes.

Central themes of territorial resilience are also the protection and restoration of ecosystems and the rational use of natural resources and, in particular, water resources. Security of supply and sustainable management of water resources along the entire cycle require action on the governance of the integrated water service and on the improvement of the environmental quality of inland and sea waters.

The theme of territorial resilience is therefore strongly interdisciplinary and requires the adoption of a holistic approach capable of systematizing technical-scientific, managerial, administrative and governance aspects in order to protect environmental, socio-economic, historical-cultural values and, where possible, to enhance them. In order to prevent, anticipate and deal with crises, it is necessary to combine in a synergistic way the most advanced knowledge of different sectors with those deriving from the lessons learned from past experiences, analysed and interpreted from a variety of points of view.

3. NEW TEACHING OFFER RELATED TO SUSTAINABILITY

The *ESPeRT* project yields a new teaching offer, too. Namely, a new Master course on "Industrial Engineering for Sustainable Manufacturing" has been designed and implemented, starting from the academic year 2023-24.

This initiative starts from the consideration that the territory, and in particular the sector of heavy manufacturing industry, has been asking for many years the institution of a high level course on sustainable manufacturing, applied to heavy industries. Several industries of the metal production sector are present in the territory of the Friuli Venezia Giulia region (such as the Danieli group, the Pittini group, the Cividale group, Trametal and the SMS groups). These companies require more specific preparation aimed at their needs, consistent with the innovation process they are undertaking, particularly in the field of digitization and sustainability.

The new didactic proposal foresees a new master's degree titled: "Industrial Engineering for Sustainable Manufacturing". This initiative would be the natural completion of the three-year course recently started in Industrial Engineering for Environmental Sustainability, whose access is also open to three-year graduates in management and mechanical engineering. However, it is believed that it can also present elements of attraction towards foreign students, in particular in the context of

agreements, already partially started, between foreign universities and local companies and therefore the course, once fully operational, will be held in English.
For the detailed planning of the course, a path has been envisaged involving the representatives of companies, not only to define the contents, but also the methods of teaching, such internships and laboratory activities in collaboration with companies, as well as integrated teaching modules with company technical staff.
This teaching initiative will have contents belonging to several fields, which are of uttermost importance for the University, for the territory, for the stakeholders of the project, for the companies involved, as well as for the society as a whole:

- Sustainability: training activities will be provided in the field of energy management, green design, sustainable circular economy, etc.
- Digitization: training activities will be planned in the field of automation and mechatronics and robotics, in the field of virtual prototyping and big data.
- Internationalization: the teaching offer will be in English, with agreements that involve foreign companies and universities.
- Third mission and social impact: the course was born from a request from local companies, it will be built together with these companies that will be involved in the training activity.

4. CONCLUSION

In this paper, a strategic research project, carried out by the Polytechnic Department of Engineering and Architecture of the University of Udine, and focused on sustainability, has been presented. The project, named “ESPeRT“, is focused on three interconnected research areas: sustainability of the production processes; energy and green economy; territorial resilience. The project has been designed so as to be functional for the implementation of the UN 2030 Agenda on Sustainable Development, the Next-Generation EU and of the National Recovery and Resilience Plan. The research activities carried out in the framework of the ESPeRT project have been complemented by a new teaching offer related to sustainability. Namely, a new Master course on "Industrial Engineering for Sustainable Manufacturing" has been designed and implemented, starting from the academic year 2023-24.

This research was supported by funds of the Strategic Plan of the University of Udine (ESPeRT project).

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ENVIRONMENT AND SUSTAINABLE DEVELOPMENT. MECHATRONICS. OCCUPATIONAL SAFETY AND HEALTH AND FIRE SAFETY. SMART MANAGEMENT SYSTEMS. GRAPHIC ENGINEERING. DESIGN. TRAFFIC ENGINEERING. BIOTECHNOLOGY AND HEALTHCARE. MECHANICAL ENGINEERING. ECOTOURISM AND RURAL DEVELOPMENT.

PHYSICAL-CHEMICAL CHARACTERIZATION OF WASTE GLASS OF GENERAL USE

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Abstract: *Waste glass is one of the significant environmental problems. Due to its wide application in everyday life, glass, and especially glass packaging of items of general use, represents a large share of communal waste. The production of glass packaging, especially from primary sources, requires a lot of energy. One of the ways to reduce the consumption of energy and natural resources in an efficient way is the application of circular economy principles, i.e. the reuse of waste glass. Waste glass as an effective auxiliary material for ceramic products is widely used depending on its properties and application conditions. In this paper, the physical-chemical characterization of waste glass of general use was carried out in the function of reuse by incorporation into the stable structure of the eco-sintered product.*
Keywords: waste glass, items of general use, environmental protection.

1. INTRODUCTION

Glass as a transparent, amorphous, solid, brittle and chemically stable material, thanks to its physical and chemical properties, is used for the production of packaging in almost all branches of industry. Nowadays, waste glass (glass cullet) represents a major environmental challenge in urban areas. Non-degradable glass waste occupies significant areas of landfills, which leads to serious environmental problems [1]. By reusing glass waste, it is possible to save primary raw materials and also a large amount of energy. The recovery of 100 million glass objects of general use will save: 30 thousand tons of glass sand, 100 thousand tons of soda, 18 thousand MWh of electricity and 76 million m3 of natural gas [2].
According to previous research, waste glass as a raw material or auxiliary material is used in many branches of industry, such as: replacement for concrete aggregate (pozzolanic additive), construction materials (filling layers for the construction of roads and parking lots), raw material in the technological process of making glass, raw material for sandblasting, raw material for the production of glass beads in reflective paint for marking highways, raw material for the production of glass fibers, fractionator for lighting matches,auxiliary material for obtaining sintered ceramic materials, etc[3-9]. Characteristic of the process of obtaining sintered products is the use of waste glass cullet as an auxiliary material due to the optimization of the sintering temperature. As its share in the mixture increases, the melting temperature of the ingredients decreases [10]. Accordingly, in the paper, a physical-chemical analysis of waste glass slag was performed with special reference to its use as an auxiliary material in eco-sintered ceramic products.

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2. MATERIALS AND METHODS

The material used in the research is glass cullet obtained from waste glass of general use, and due to the need to homogenize the ingredients and auxiliary materials in the sintering process, it was crushed to a powder form. The glass cullet was examined by FTIR and SEM-EDX analyses. FTIR spectra were recorded in the Spectroscopy Laboratory of the Faculty of Technology in Leskovac. The analysis was performed on a spectrometer BOMEM Michelson Hartman & Braun Series MB in the area 4000-400 cm-1 at a resolution of 2 cm-1. The preparation of the sample was done by the "potassium bromide" process, which involves pulverization and uniform dispersion in KBr (1.5 mg/150 mg KBr), then the mixture was vacuumed and pressed under a pressure of 200 MPa, whereby a suitable lozenge was obtained.
The structure of the glass cullet sample was recorded using the SEM-EDX technique in the Laboratory for Electron Microscopy at the Medical Faculty, University of Niš. The sample was analysed on a JOEL JSM-5300 scanning microscope with a Linx Analytic QX2000 probe.

3. RESULTS AND DISCUSION

The basic raw materials used in the production of glass are: quartz sand (about 56%), soda (about 12%), calcium carbonate (about 12%), resin (about 4%) and additives for colouring, i.e. for removing colour [2]. Consequently, the presence of silicon, sodium and calcium oxides in the largest mass fractions is expected in the waste glass cullet. Table 1 shows the chemical composition of waste glass of general use based on previous research [11-15].

Table 1. Optimum chemical composition of waste glass of general use items

Compound	Concentration [%]
SiO_2	66-88
Al_2O_3	0-7
Fe_2O_3	0-4
CaO	0-15
MgO	0-5
Na_2O	3-18
K_2O	0-6
P_2O_5	0-3
TiO_2	0-1

According to presented chemical composition, it can be seen that the dominant compound in waste glass is silicon dioxide with a mass share of over 60%. The basic oxides from which glass is formed (glass formers) are SiO_2 and Al_2O_3. CaO and MgO oxides are glass stabilizers, while Na_2O is glass modifiers. Researches by Keawthun et al. and Giovani et al. confirm the presence of silicon dioxide in amorphous form in waste glass shards of general use items [12,16].
Figure 1 shows the FTIR spectrum of the reference waste glass, which confirmed the chemical characterization of the waste glass.

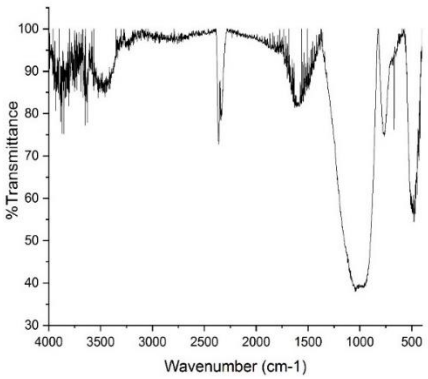

Figure 1. FTIR spectrum of waste glass

The FTIR spectrum of waste glass highlights a broad and intense band at 900-1100 cm^{-1}, which originates from asymmetric stretching vibrations of silicon and oxygen of silicate tetrahedral chains, which is in accordance with the researches of Torres-Carrasco et al. and Kouassi et al. [14, 17]. On the other hand, according to research by Rad et al., FTIR analysis of glass karst indicates specific silicate peaks from 800 to 1300 cm^{-1} and metal ion peaks from 400 to 550 cm^{-1} [18]. Vibrations between 400 and 550 cm^{-1} are due to the presence of metal oxides [18-19]. Figure 2 shows a SEM microphotograph of waste glass and an EDX spectrum.

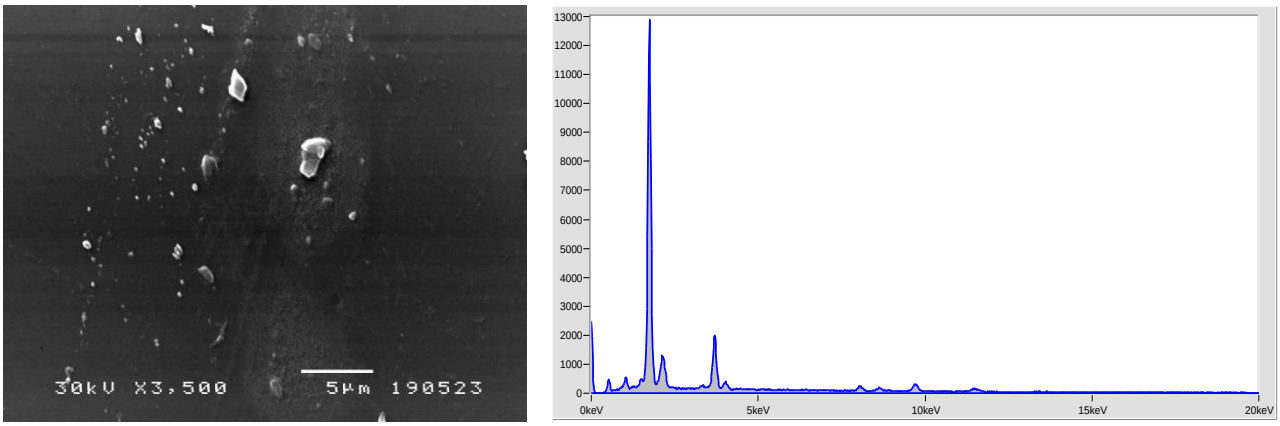

Figure 2. Microphotograph and EDX spectrum of waste glass

A photomicrograph of waste glass indicates relatively few pores unevenly distributed over the surface of the sample, which is in accordance with the research of Vance et al. [20]. Characteristic peaks of oxygen, silicon and calcium can be observed on the EDX spectrum of glass cullet, which confirms the chemical characterization of the glass [21,22].

Based on the characterization of the waste glass cullet, the dominant content of silicon dioxide in the tested sample can be determined. The characteristics of this compound, such as: stability at high temperatures, low-temperature coefficient of linear expansion, optical transparency in the spectral range from infrared to ultraviolet radiation, chemical inertness, hardness, mechanical strength and others, make it suitable for incorporation into sintered ceramic materials [23]. Glass cullet also has extraordinary pozzolanic characteristics, which is another advantage for use in the production of ceramic products.

In order to improve the characteristics of sintered products and increase environmental efficiency, other waste materials (galvanic sludge, ash, slag, cathode glass) are added as ingredients in the sintering process [25]. The obtained sintered product has such a structure that it can have a useful value, reducing and the risk of environmental pollution to its minimum.

4. CONCLUSION

Technological procedures for the reuse of waste glass cullet enable the recuperation of valuable raw material, which can be used for the same or similar purposes. The incorporation of glass cullet into an eco-sintered product has a multiple positive effect on the environment, considering that stable structures of eco-ceramic products are obtained by sintering. On the other hand, the newly obtained material has the possibility of practical application in many branches of industry due to the high mass fraction of glass cullet and good physical-chemical characteristics.

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ENVIRONMENT AND SUSTAINABLE DEVELOPMENT. MECHATRONICS. OCCUPATIONAL SAFETY AND HEALTH AND FIRE SAFETY. SMART MANAGEMENT SYSTEMS. GRAPHIC ENGINEERING. DESIGN. TRAFFIC ENGINEERING. BIOTECHNOLOGY AND HEALTHCARE. MECHANICAL ENGINEERING. ECOTOURISM AND RURAL DEVELOPMENT.

IMPACT OF WASTEWATER ANTIBIOTICS ON RIVER WATER QUALITY IN BELGRADE AREA

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Abstract: *Municipal wastewater in the Belgrade area is discharged into the Danube and the Sava Rivers without any treatment. This affects the quality of river water since wastewater is one of the most important sources of environmental pollutants, including pharmaceuticals. To assess the impact of this effect, the presence of three commonly used antibiotics in wastewater and receiving river water was determined. A previously developed liquid chromatography-tandem mass spectrometry method for the analysis of antibiotics in natural water matrices was validated for wastewater and applied in analysis of samples from the Belgrade area. All investigated antibiotics were detected in both wastewater and river water samples. The highest concentration of antibiotics in wastewater was found for sulfamethoxazole, while trimethoprim was detected at the highest level in surface water. The most frequently detected antibiotic in surface water was azithromycin. The environmental risk assessment was performed for surface water biota. Azithromycin was found to pose a high risk to aquatic organisms, while the risk level of sulfamethoxazole was medium or low. In conclusion, the obtained results show the detrimental impact of untreated wastewater discharge on the river water quality in the Belgrade area, emphasizing the need for urban wastewater treatment.*
Keywords: Antibiotic, Urban wastewater, River water, LC-MS/MS, Environmental Risk Assessment

1. INTRODUCTION

Antibiotics have been increasingly produced and used worldwide in human and animal medicine. As a result, significant amounts of antibiotics have been released into the environment through waste from households, hospitals, the pharmaceutical industry, and farms. Antibiotics are frequently detected in surface water samples in concentrations that could be hazardous to aquatic organisms [1, 2]. The increasing presence of antibiotic residues in the water environment is now a matter of great health concern. However, there are no regulations concerning the maximum allowed concentrations of antibiotics in the aquatic environment. The latest update of the Watch list of substances for Union-wide monitoring in the field of water policy [3] includes several antibiotics, which reflects the concern regarding the presence of these contaminants in aqueous media. Wastewater represents one of the most significant sources of pollutants, such as antibiotics, in the environment [1]. Due to the absence of wastewater treatment plants in Belgrade, municipal wastewater is directly discharged untreated into the Danube and Sava Rivers. Consequently, it is necessary to assess the presence of antibiotics in Belgrade's surface water and evaluate their adverse effects on water quality.

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The aims of the present study were (a) to validate liquid chromatography-tandem mass spectrometry (LC-MS/MS) method for the determination of selected antibiotics in wastewater; (b) to determine the concentrations of selected antibiotics in wastewater and receiving water in the Belgrade area; and (c) to assess the environmental risks of antibiotics found in river water samples.

2. MATERIALS AND METHODS

2.1 Chemicals and reagents

The pharmaceuticals selected in this study are among the most commonly used antibiotics in Serbia. Analytical standards (purity > 95%) of three chosen antibiotics (trimethoprim, sulfamethoxazole, and azithromycin) were supplied from Hemofarm (STADA Group, Vršac, Serbia). The stock standard solutions of every analyte were prepared in methanol at a concentration of 100 μg mL^{-1}. The working standard solutions were prepared by mixing the stock standard solutions of three drugs and diluting them with methanol. All solutions were preserved at –4 °C. All solvents used were HPLC grade from Sigma-Aldrich (St. Louis, US). Deionized water was obtained by passing the distilled water through a GenPure ultrapure water system (TKA, Niederelbert, Germany).

2.2 LC-MS/MS analysis

A previously developed LC-MS/MS method for the determination of pharmaceuticals was used in this study [4]. A Dionex UltiMate 3000 LC system (Thermo Fisher Scientific, Waltham, MA, US) coupled to a LTQ XL (Thermo Fisher Scientific) linear ion trap as a mass detector was used for LC-MS/MS analysis. A reverse-phase Zorbax Eclipse® XDB-C18 column, 75 mm × 4.6 mm i.d. and 3.5 μm particle size (Agilent Technologies, Santa Clara, US) was used for the separation of the analytes. A pre-column (12.5 mm × 4.6 mm i.d. and 5 μm particle size, Agilent Technologies) was installed in front of the separation column. The mobile phase consisted of methanol (A), deionized water (B), and 10% acetic acid (C). The mobile phase gradient was changing as follows: 0 min, B 33%, C 2%; 12 min, B 98%, C 2%; 15 min, B 98%, C 2%. The initial conditions were then re-established and held for 15 minutes. The flow rate of the mobile phase was 0.5 mL min^{-1}. The electrospray ionization (ESI) technique in the positive ionization mode was used. The optimal source parameters were as follows: source voltage (4.5 kV), sheath gas (25 au, i.e., 25 arbitrary units), and capillary temperature (290 °C). An aliquot of 10 μL of the final extract was injected into the LC system.

2.3 Method validation

Using wastewater samples spiked at two concentration levels (50 and 100 ng L^{-1}), a previously developed procedure for the determination of selected pharmaceuticals in surface water and groundwater [5] was validated. Validation was performed by evaluating recovery, repeatability, sensitivity, and linearity. The repeatability of the method was expressed as the relative standard deviation (RSD). The sensitivity of the method was evaluated by determining the limits of detection (LODs) and quantification (LOQs). LODs and LOQs of the method were obtained as the minimum detectable amount of analyte with a signal-to-noise (S/N) ratio of 3 and 10, respectively. The linearity of the analytical response was studied using the matrix-matched standards prepared at five concentration levels (10–250 ng L^{-1}). The linear regression analysis was performed in order to determine the correlation coefficient (R^2).

2.4 Sample collection and sample preparation

Wastewater and surface water samples were collected in the Belgrade area, around the confluence of the Danube and Sava Rivers (Figure 1). Samples of wastewater were collected at three locations of

municipal wastewater discharge. An automatic sampling device was used to collect samples continuously for 24 hours. Samples of surface water were collected at three locations downstream from wastewater discharge. Surface water samples were collected by direct sampling from a boat in the middle of the river flow at a depth of about 50 cm. Samples were kept at 4 °C until analysis.

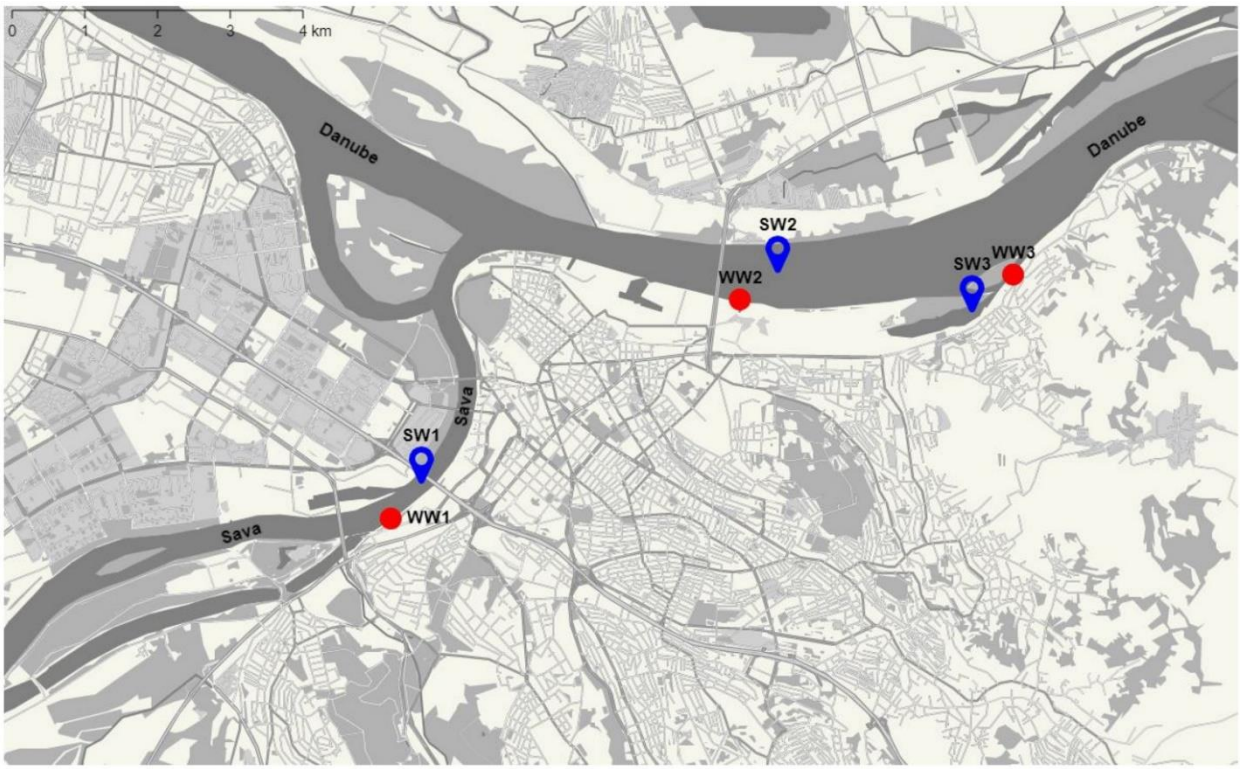

Figure 1. Map of wastewater (WW1–WW3) and river water (SW1–SW3) sampling sites
Source: https://www.stepmap.com/

A previously developed sample preparation method for the determination of pharmaceuticals in different aqueous matrices [5] was used for both wastewater and river water samples. In brief, water samples were prepared using solid-phase extraction: Oasis HLB column (Waters, Milford, MA, US) was preconditioned with 5 mL of a methanol-dichloromethane (1:1) mixture and 10 mL of deionized water. A 100 mL water sample with a pH value adjusted to 6.0 was applied. Then the column was dried for 10 min, and analytes were eluted using 15 mL of a methanol-dichloromethane (1:1) mixture. The obtained extract was evaporated and reconstituted to a volume of 1 mL with methanol. The final extract was filtered through a 0.45 µm polyvinylidene difluoride (PVDF) filter (Roth, Karlsruhe, Germany) and analyzed.

2.5 Environmental risk assessment

To assess the environmental risk of antibiotics detected in surface water, risk quotients (RQ) were calculated using the equation (1):

$$RQ = \frac{MEC}{PNEC} \quad (1)$$

where MEC is the measured environmental concentration and PNEC is the predicted no-effect concentration of the detected analyte [6]. The lowest available PNEC values (trimethoprim 120 µg L^{-1}, sulfamethoxazole 0.6 µg L^{-1}, and azithromycin 0.019 µg L^{-1}) were obtained from the NORMAN database [7]. Environmental risk was classified in three levels: $RQ \geq 1$ high risk, $0.1 \geq RQ > 1$ medium risk and $RQ < 0.1$ low risk [8].

3. RESULTS AND DISCUSSION

3.1 Method validation

The obtained validation parameters are presented in Table 1. The recoveries were in the range of 70–92% for trimethoprim and sulfamethoxazole. For azithromycin, the obtained values of recovery were not in this range, probably due to the pH value of the sample being adjusted to 6.0 which was optimal for other pharmaceuticals. The achieved RSD values were in the range of 5–11%. Low limits of detection (0.02–1.9 ng L^{-1}) and quantification (0.07–6.3 ng L^{-1}) indicate that the method is sensitive and suitable for the determination of trace levels of selected analytes in wastewater samples. Correlation coefficients (R^2) were in the range of 0.993–0.999, which implies that the developed method is linear in the tested concentration range (10–250 ng L^{-1}). Based on the values of the obtained validation parameters, it can be concluded that the applied method is appropriate for the determination of selected antibiotics in wastewater samples.

Table 1. Validation parameters of the analytical method
Source: *original copyright*

Analyte	Recovery, % (RSD, %)		LOD, ng L^{-1}	LOQ, ng L^{-1}	R^2
	50 ng L^{-1}	100 ng L^{-1}			
Trimethoprim	88 (8)	92 (5)	1.9	6.3	0.993
Sulfamethoxazole	83 (5)	70 (8)	0.2	0.7	0.999
Azithromycin	58 (7)	55 (11)	0.02	0.07	0.999

3.2 Sample analysis

Analyzed antibiotics were detected in wastewater in the concentration range from 122 ng L^{-1} (trimethoprim and sulfamethoxazole) to 1184 ng L^{-1} (sulfamethoxazole) (Table 2). All analyzed antibiotics were detected at the sampling site WW1, unlike samples WW2 (two antibiotics detected) and WW3 (none detected), which is likely due to WW1 being the largest wastewater discharge in the Belgrade area. In surface water, antibiotics were detected in the concentration range from 2 ng L^{-1} (azithromycin) to 334 ng L^{-1} (trimethoprim). The most frequently detected antibiotic was azithromycin, which was detected in all three river water samples.

Table 2. Antibiotics detected in Belgrade urban wastewater (WW1–WW3) and corresponding river water (SW1–SW3) samples (n = 2)
Source: *original copyright*

Analyte	Concentration (SD), ng L^{-1}					
	WW1	SW1	WW2	SW2	WW3	SW3
Trimethoprim	122 (12)	–	482 (72)	–	–	334 (54)
Sulfamethoxazole	122 (19)	–	1184 (152)	11 (1)	–	127 (7)
Azithromycin	318 (48)	9 (0)	–	2 (0)	–	58 (1)

In river water samples SW1 and SW2, collected downstream from the corresponding wastewater discharges, antibiotic concentrations were significantly lower than those detected in the wastewater, or analytes could not be detected, probably due to dilution. However, in the case of sampling site SW3, all analytes were detected at relatively high concentrations. SW3 was located in a small bay, away from the river mainstream, with limited water flow, consequently accumulation of contaminants occurs at this sampling site.

3.3 Environmental risk assessment

In order to assess the intensity of the environmental impact of wastewater discharge on aquatic biota, RQs were determined for analytes detected in surface water. It was determined that the presence of trimethoprim was related to a low environmental risk (RQ = 0.003, Figure 2). The risk level for sulfamethoxazole was low (RQ = 0.018) at the sampling site SW2 and medium (RQ = 0.212) at the sampling site SW3. It was determined that azithromycin presents medium environmental risk at sampling sites SW1 and SW2 (RQ = 0.474 and RQ = 0.105, respectively). However, azithromycin posed a high risk to the aquatic organisms at the sampling site SW3 (RQ = 3.053). A high environmental risk for azithromycin was previously reported, such as in the Bay of Biscay in Spain [9]. In addition to the risk to aquatic organisms, the presence of azithromycin in water is highly harmful as it induces microbial resistance [10]. Obtained results indicate that wastewater in the Belgrade area discharged into rivers without treatment negatively impacts the quality of the receiving water.

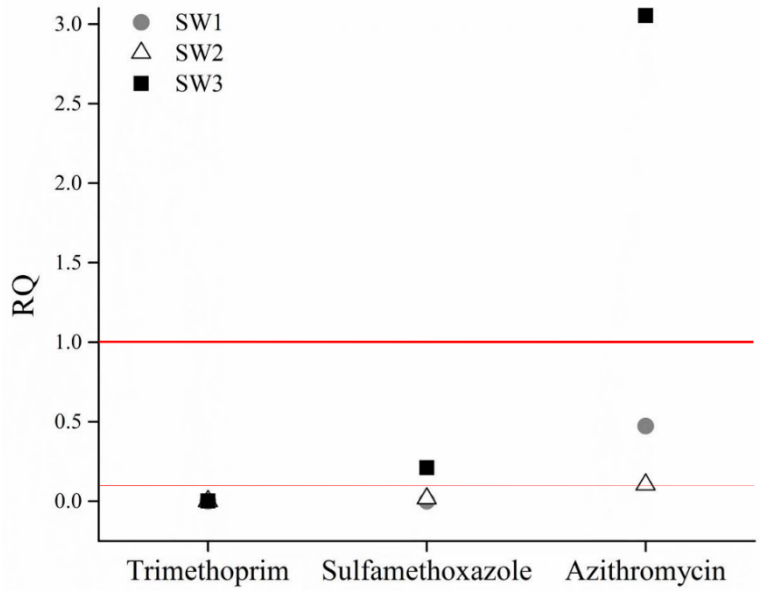

Figure 2. Risk quotients (RQs) calculated for antibiotics detected in river water
Source: original copyright

4. CONCLUSION

In this paper, a previously developed method for the determination of pharmaceuticals in various water matrices was successfully validated for wastewater. The content of selected antibiotics in municipal wastewater and corresponding surface water in the area of Belgrade was determined. Samples were collected at three locations of municipal wastewater discharges and at three locations in the Danube and Sava Rivers downstream from the wastewater discharges. Analyzed antibiotics were detected in both wastewater and surface water samples. Based on the determined RQ values, it was revealed that azithromycin posed a high risk to the aquatic biota. The obtained results demonstrate that the discharge of untreated municipal wastewater has a negative impact on the quality of river water in the area of Belgrade.

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ENVIRONMENT AND SUSTAINABLE DEVELOPMENT. MECHATRONICS. OCCUPATIONAL SAFETY AND HEALTH AND FIRE SAFETY. SMART MANAGEMENT SYSTEMS. GRAPHIC ENGINEERING. DESIGN. TRAFFIC ENGINEERING. BIOTECHNOLOGY AND HEALTHCARE. MECHANICAL ENGINEERING. ECOTOURISM AND RURAL DEVELOPMENT.

REMOVAL OF ORGANIC AND INORGANIC POLLUTANTS FROM AQUEOUS SOLUTIONS USING STARCH-DIATOMACEOUS EARTH ADSORBENT

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Abstract: *Organic and inorganic pollutants, accumulated in the environment, could pose a potential danger to living organisms. Some of these pollutants negatively affect the physiological activities of living organisms, and in certain concentrations, they can be lethal to biotic communities. In addition to the natural sources of emission of these substances in the environment, a large number of anthropogenic activities contribute to a sudden increase in their concentration. The development of new and improving existing ecologically sustainable techniques to prevent or reduce their outflow and retention in the environment is more necessary than ever. Therefore, the focus of this work will be examining the efficiency of environmentally friendly adsorbent based on modified starch and diatomaceous earth for the removal of selected organic and inorganic pollutants from aqueous solutions. The influence of the chemical modification of starch, followed by the addition of diatomaceous earth, on its structural, morphological, and adsorption properties, will be examined. The possibility of using starch-diatomaceous earth adsorbent for the removal of brilliant green dye, pharmaceutical compounds, and lead ions from aqueous solutions will be evaluated through the adsorption efficiency under the given conditions.*
Keywords: Adsorption, Potato Starch, Brilliant Green, Pharmaceutical Compounds, Pb^{2+} ions.

1. INTRODUCTION

Aware that the need for water is increasing, both due to the increase in the world's population and the increased exploitation of water resources, we see that providing sufficient amounts of water is becoming an increasingly demanding challenge [1]. Water surfaces are mostly polluted by anthropogenic activities, through industrial wastewater and municipal wastewater that are discharged directly into rivers, oceans, and other water bodies. These effluents contain different types of organic and inorganic pollutants. Contaminated surface and groundwater can be highly toxic if they enter the food chain for humans and animals [2]. Synthetic organic dyes are considered persistent bioaccumulative toxic substances. Their toxic effects include disruption of the ecological balance and carcinogenicity. They are widely used in the textile industry, as well as in the production of leather, cosmetics, paper, plastic, etc. Depending on the parent dye, its degradation can produce transformation products that can be more toxic than the original compound, or less toxic by-products can be formed instead [3]. Pharmaceuticals and their metabolites although mostly present in residual

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amounts in discharged water may have detrimental effects on living organisms and human health. Pharmaceuticals are developed to be biologically active and persistent to maintain their therapeutic activity in humans and animals. In this sense, the physicochemical properties of pharmaceutical products, such as high polarity, volatility, high lipophilicity, and persistence, can affect their removal efficiency during wastewater treatment [4]. Heavy metals enter wastewater through natural and anthropogenic sources. The former includes soil erosion, volcanic activities, and weathering of rocks and minerals, whereas the latter comprises mineral processing, fuel combustion, street run-offs, landfills, agricultural activities, and industrial activities (mining, printed board manufacturing, metal finishing and plating, semiconductor manufacturing, etc). Due to the high stability, solubility, and migration activity of heavy metals in aqueous media, untreated or inadequately treated metal-contaminated wastewater effluents cause a variety of health and environmental impacts [5,6]. The method for removing these pollutants from wastewater must meet the following conditions: a high percentage of removal, low operating costs, and a relatively fast process, without the creation of side products. As such, adsorption is distinguished, with the use of adsorbents that are available in nature in large quantities.

In this paper, the possibility of using modified starch for the removal of organic dye (brilliant green), pharmaceutical compounds (erythromycin and clopidogrel), and heavy metal ions (lead) was investigated. The starch was first chemically modified with melamine, a nitrogen-rich compound, and then in the second part of the modification, diatomaceous earth was added to investigate its effect on the adsorption properties of the modified starch.

2. EXPERIMENTAL PART

2.1 Materials

The following chemicals were used: potato starch (SuperLab, Serbia), melamine (2,4,6-triamino-1,3,5-triazine; 99 %, Fisher Scientific), diatomaceous earth (SiO_2 95%, Sigma-Aldrich), brilliant green dye (90%, Sigma-Aldrich), pharmaceutical compounds (erythromycin and clopidogrel), Pb^{2+} ions (solution of $Pb(NO_3)_2$).

In all modified samples, the base material is starch that has been chemically modified. The modification was carried out in two steps. In the first stage of modification, gelatinized starch was mixed with melamine at a temperature of 80 °C, while in the second stage of modification, amino-modified starch was mixed with diatomaceous earth at 40 °C. The materials thus obtained were dried in an oven at 50°C overnight and finally ground into powder.

Label of materials: S – native starch, de – diatomaceous earth, SM – starch modified with melamine, Sde – starch modified with diatomaceous earth, SMde – starch modified with melamine and diatomaceous earth.

2.2 Methods

The FTIR technique (Nicolet iS10, Thermo Scientific) was used to examine the type of functional groups on the surface of the adsorbent, while the SEM (FE-SEM, TESCAN Mira3 KSMU) was used to examine the morphological characteristics.

The investigation of pollutant adsorption by modified starch was performed in the batch mixing system, at 150 rpm, at room temperature. Adsorption of dye (brilliant green, BG) and heavy metal ions (Pb^{2+}) was investigated from individual aqueous solutions, and the measured initial pH value of both solutions was around 5. The adsorption experiments were conducted for 180 min, with a constant dose of adsorbent (0.05 g), initial concentration (10 mg dm^{-3}), and the volume of the solution (25 mL). The BG dye concentration in the solution was analyzed using a UV-VIS spectrophotometer for the visible range at 630 nm, while the concentration of Pb^{2+} ions in an aqueous solution was determined using atomic absorption spectroscopy at 283 nm. Adsorption of pharmaceutical compounds (erythromycin and clopidogrel) was investigated at constant adsorbent dosage (0.05 g),

initial concentration (500 mg dm^{-3}), and solution volume (25 mL) for 180 min. The separation of pharmaceutics was conducted using a Dionex UltiMate 3000® LC system (Thermo Scientific, USA). For detection and quantification of pharmaceutics LTQ XL (Thermo Scientific, USA) mass spectrometer was used with electrospray ion source and linear ion trap mass analyzer.
The removal efficiency (%) of selected pollutants from aqueous solutions, R, is calculated according to the equation (1):

$$\%R = \left(\frac{C_0 - C_t}{C_0}\right) \cdot 100 \quad (1)$$

where C_0 and C_t (mg dm^{-3}) are the concentration of pollutant at the initial time and after time t (min), respectively.

3. RESULTS AND DISCUSSION

FTIR is an effective technique to determine and characterize functional groups present in the material. The FTIR spectra of investigated adsorbents are shown in Figure 1., while the wavenumbers of characteristic bands in FTIR spectra are summarized in Table 1.

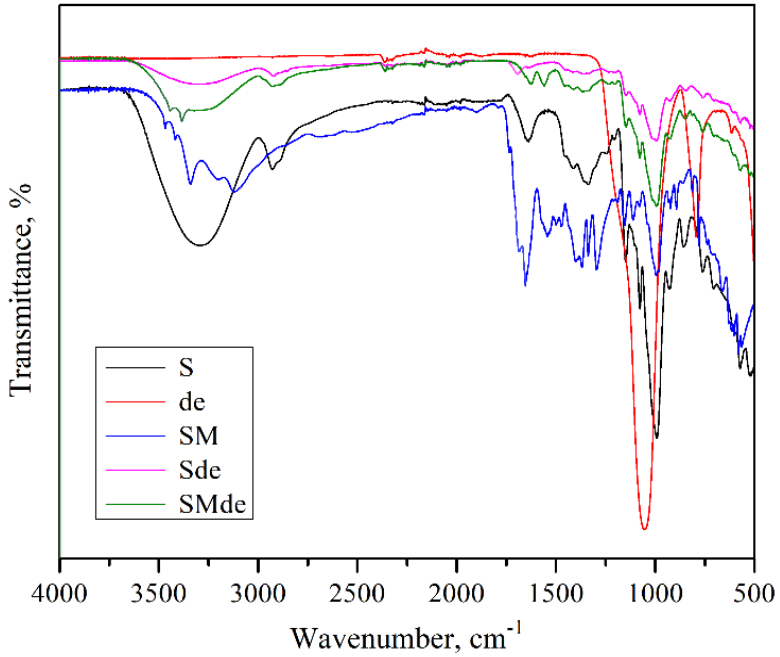

Figure 1. FTIR spectra of adsorbents
Source: original author's

By comparing the FTIR spectra, the presence of additional peaks on the FTIR spectra of modified materials was determined [7-10], which confirmed the successful synthesis of new starch-based adsorbents.

Table 1. FTIR wavenumber (cm^{-1}) of adsorbents
Source: original author's

Wavenumber (cm^{-1})	Adsorbent				
	S	**de**	**SM**	**Sde**	**SMde**
–OH stretching [7]	3335	-	3340	3335	3335
–CH_2 stretching [7]	2926	-	2926	2928	2926
–OH first overtone [8]	1643	-	1627	1619	1617
–C=O stretching [7]	-	-	1710	-	1714
–C–O stretching [7]	998	-	992	998	997
–NH– stretching [9]	-	-	3418	-	3412
–NH_2 stretching [9]	-	-	3469	-	3458

–$C_3H_3N_3$ ring stretching [9]	-	-	1552	-	1550
–Si–O stretching [10]	-	1072	-	1072	1075
–O–Si–O stretching [10]	-	814	-	816	816
–Si–O–Si stretching [10]	-	705	-	705	706

Through the micrographs obtained by SEM, it was possible to evaluate the morphological changes in modified starch granules. SEM micrographs of adsorbents are shown in Figure 2. The surface of unmodified potato starch granules is smooth, without pores and cracks, and spherical to oval in shape. SEM micrograph of diatomaceous earth (de) reveals a variety of rigid shapes and macropores, i.e. open cavities, which may be responsible for its adsorption properties. It can be noted that after the modification, there was no complete disruption of the starch granule structure (SM/Sde/SMde) compared to natural starch (S). In the case of starch modification with melamine (SM and SMde), particle agglomeration and coating of particles with melamine occur to the greatest extent. For starch modification with melamine and diatomaceous earth (SMde), it is observed that the surface of the starch granules is rougher, with ridges originating from diatomaceous earth. The starch modification with diatomaceous earth (Sde) resulted in the adhesion of diatomaceous earth to the starch surface, with the surface of the granules becoming rough with bumps and holes.

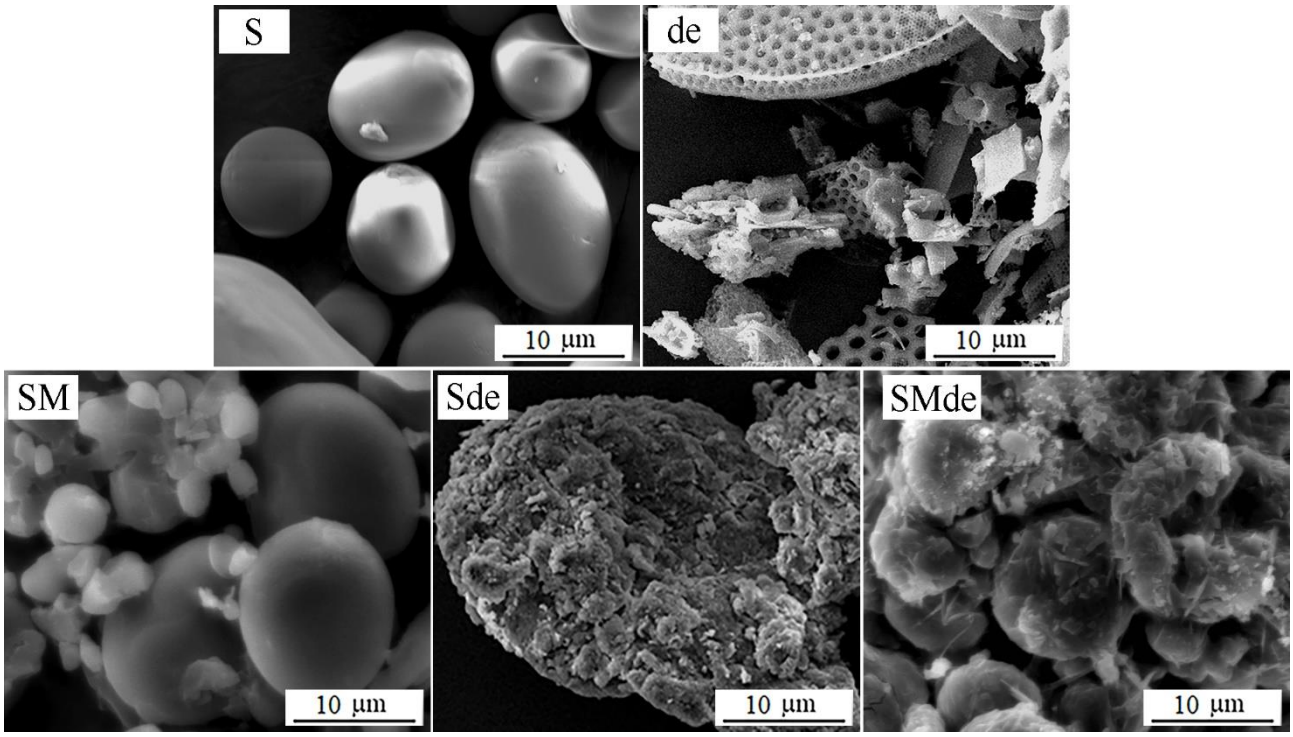

Figure 2. SEM micrographs of adsorbents
Source: original author's

The results of testing the adsorption properties of adsorbents based on modified starch are shown graphically in Figure 3. The results of the comparative analysis show that all examined materials show higher efficiency in removing organic pollutants compared to metal ions. The material SM, i.e. starch modified only with melamine, showed the highest efficiency in the removal of all selected pollutants. This means that the addition of diatomaceous earth after starch modification with melamine (SMde) has no effect on removal efficiency. On the other hand, the adsorbent obtained by modification of native starch with diatomaceous earth (Sde) showed better adsorption efficiency compared to the starting materials, i.e., native starch (S) and diatomaceous earth (de). The results of the adsorption experiments confirmed that the applied modification influenced the surface and morphological properties, contributing to the increase in the efficiency of modified starches to remove organic pollutants and metal ions from water.

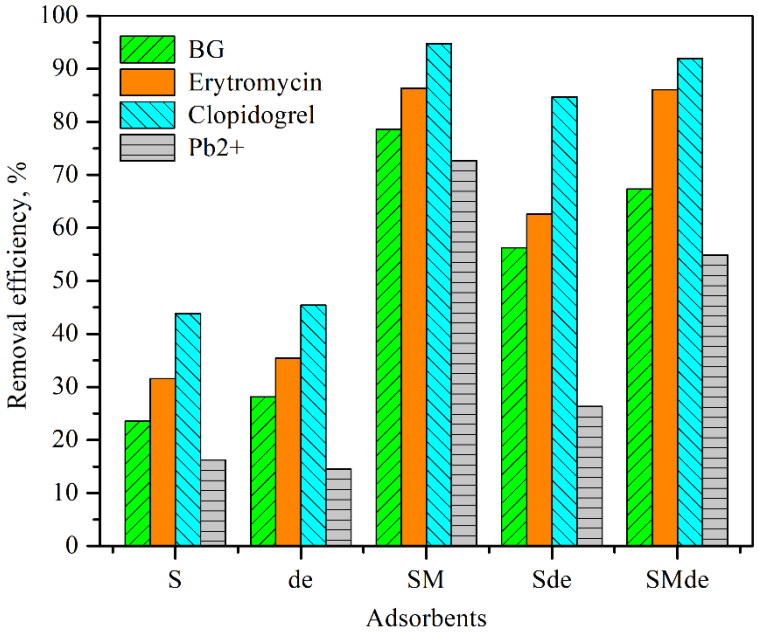

Figure 3. Adsorption efficiency of examined adsorbents toward BG dye, pharmaceuticals (erythromycin and clopidogrel) and Pb^{2+} ions
Source: original author's

4. CONCLUSION

In this study, the possibility of using adsorbents based on natural material, starch, for the removal of brilliant green dye, pharmaceutical compounds (erythromycin and clopidogrel), and Pb^{2+} ions was examined. The results of FTIR and SEM analysis showed the success of the modification process and the presence of melamine and diatomaceous earth in the structure of the new adsorbents, as compounds with which the modification was performed. Higher removal percentages were obtained for organic pollutants, especially pharmaceutical compounds, compared to metal ions. The removal efficiency of the clopidogrel drug was 95.7% for the adsorbent based on modified starch with melamine and 91.6% for modified starch with melamine and diatomaceous earth. It was shown that diatomaceous earth has no effect on the adsorption properties of the material after modification with melamine, which may be a consequence of coating the pores in the diatomaceous earth structure with melamine. As the tested adsorbents, especially the material based on modified starch with melamine, proved to be promising for the removal of organic pollutants from aqueous solutions, it is necessary to conduct more extensive tests of the adsorption properties of these materials with a special focus on the removal of pharmaceutical pollutants from wastewater.

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ENVIRONMENT AND SUSTAINABLE DEVELOPMENT. MECHATRONICS. OCCUPATIONAL SAFETY AND HEALTH AND FIRE SAFETY. SMART MANAGEMENT SYSTEMS. GRAPHIC ENGINEERING. DESIGN. TRAFFIC ENGINEERING. BIOTECHNOLOGY AND HEALTHCARE. MECHANICAL ENGINEERING. ECOTOURISM AND RURAL DEVELOPMENT.

ALKALI MODIFICATION OF FLY ASH FOR ADSORPTION OF SELECTED DYES

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Abstract: *Fly ash (FA) is an industrial waste material generated during coal combustion in thermal power plants. In order to reuse this kind of industrial waste, and at the same time to reduce its quantity, fly ash was used as a cheap material for the preparation of efficient adsorbents for the removal of selected dyes from water. For that purpose, different modification methods were used to obtain alkali-activated fly ash samples. The success of the modification process and characterization of the unmodified and modified materials was monitored by Fourier transform infrared spectroscopy, and scanning electron microscopy/energy dispersive spectroscopy. The adsorption properties of examined samples were studied through the adsorption of methylene blue, crystal violet, alizarin red, and methyl orange. All samples showed the highest adsorption efficiency for crystal violet removal, while the sample modified with a combination of NaOH, Na_2SiO_3, and diatomaceous earth (FA/geopolymer) was the most efficient adsorbent for all selected dyes. Therefore, the influence of initial pH value and contact time on adsorption was examined for the adsorption of crystal violet onto FA/geopolymer. It was found that alkaline modification improves the adsorption characteristics of fly ash making it a promising candidate to solve the problem of colored wastewater.*
Keywords: Fly Ash, Dyes, Alkali Modification, Adsorption.

1. INTRODUCTION

Discharge of water polluted with dyes from different industries leads to several problems in the environment. The presence of dyes in water affects its coloration, the permeability of sunlight, and thus the process of photosynthesis and the food chain, as well. Therefore, their removal from the environment is very important. Among the various methods (membrane filtration, photodegradation, ion exchange), adsorption stands out as a simple and energy-efficient technique [1,2]. The advantage of this method is reflected in the large number of available adsorbents. A significant amount of scientific research is focused on developing methods for repurposing agricultural, municipal, and industrial waste. In this way, waste materials gain a use value, their amount in landfills can be reduced, and thus, the harmful impact on the environment can be reduced as well. Fly ash represents a growing environmental problem, as it is an inevitable by-product of coal combustion. In Serbia, the share of coal in the production of electricity is 65 %. Large amounts of ash end up in landfills, and its

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disposal and transport represent a growing environmental problem. Therefore, numerous researches are focused on finding ways to reuse fly ash. One of the most important applications of fly ash is as a construction material, in the production of roads and various types of concrete. Today, fly ash is also used for the rehabilitation of surfaces degraded by mining activities, as a base and covering for sanitary landfills of municipal and other waste, for the production of activated carbon and artificial zeolite, etc. [3]. One idea is to use fly ash as an effective adsorbent for the removal of various pollutants, such as waste gases, heavy metals, dyes, and other organic compounds [4]. The adsorption efficiency of fly ash can be improved by its activation and modification [2,5].
In an attempt to reuse fly ash, in this work, an alkaline and thermal modification was applied to obtain cheap and efficient adsorbents for the removal of selected dyes from water. The influence of the applied modification method on the efficiency of obtained materials to adsorb methylene blue (MB), crystal violet (CV), alizarin red S (ARS) and methyl orange (MO) was examined. The adsorption process was studied through the influence of the initial pH value of the adsorbate solution, and contact time, and obtained experimental data were compared with the kinetic models.

2. EXPERIMENTAL

2.1 Material preparation

The starting fly ash, obtained from the power plant Nikola Tesla A (Obrenovac, Serbia), was sieved and washed with distilled water, and then modified, as it is shown in Table 1. After the modification, all samples were washed with distilled water to a neutral pH and dried overnight at 105 ^{o}C.

Table 1. Modified fly ash samples, labeling, and modification conditions
Source: original author's

Sample	Mass of fly ash	Modification agent	Modification condition
Ash	–	–	–
Ash_{300}	2.0 g	3.2 g NaOH pellets	300 °C, 3 h, electrical furnace
Ash_{ref}	2.0 g	20 ml 2M NaOH	5 h, reflux, boiling temperature
Ash_G	9.8 g	4.2 g diatomaceous earth 10 g of sodium silicate few drops 16 M NaOH	drying, 2 h, 105 °C aging, 7 days, room temperature
Ash_7	2.0 g	6.0 ml 2M NaOH	shaking (120 rpm), 7 days, room temperature

2.2 Material characterization

Scanning electron microscopy (SEM) with energy dispersive spectroscopy was used to examine the changes in surface and morphological characteristics induced by the modification of fly ash.
The presence of functional groups on the surface of unmodified and modified samples was determined by Fourier transform infrared spectroscopy (FTIR).

2.3 Adsorption experiments

All adsorption experiments were performed in a batch system with constant shaking (170 rpm) at room temperature. To determine the adsorption efficiency of unmodified and modified fly ash samples (0.05 g), 20 ml of the selected dyes (MB, CV, MO, ARS) aqueous solution (20 mg/dm^3) was used, and adsorption experiments were performed for 2.5 h. Adsorption of CV onto Ash and Ash_G (0.05 g) was conducted from 20 ml aqueous solution (20 mg/dm^3) with initial pH adjusted at 3, 5, 7, and 10, to reveal the influence of the initial pH value on the adsorption. The influence of contact time on the adsorption capacities of Ash and Ash_G samples (0.25 g) was examined through the adsorption of CV (20 mg/dm^3) from 100 ml of aqueous solution. During this experiment, the concentration of

CV was measured in the specified periods of time (5, 10, 30, 60, 120, and 180 minutes). For measuring the dye concentration visible spectrophotometry was used. Obtained data were examined by pseudo-first [6] and pseudo-second [7] order kinetic models, given by equations 1 and 2, respectively:

$$q_t = q_e \cdot (1 - e^{-k_1 t}) \tag{1}$$

$$q_t = q_e - \left(\frac{1}{q_e} + k_2 t\right)^{-1} \tag{2}$$

3. RESULTS AND DISCUSSION

The surface morphology of fly ash samples was analyzed by scanning electron microscopy/energy dispersive spectroscopy and obtained results are shown in Figure 1a-1e and Table 1. All fly ash samples are characterized by a similar porous surface with visible cavities and cracks. Nevertheless, applied modifications in the presence of NaOH increase surface porosity, whereby the surface of sample Ash_G is the most porous, which can favor the adsorption of dyes. According to the results of EDS analysis, unmodified fly ash does not contain Na, while in modified samples atomic percentage of Na increases with the concentration of NaOH added and with a temperature of modification. A high content of Na in the modified samples can also favor the adsorption when it occurs through the mechanism of ion exchange.

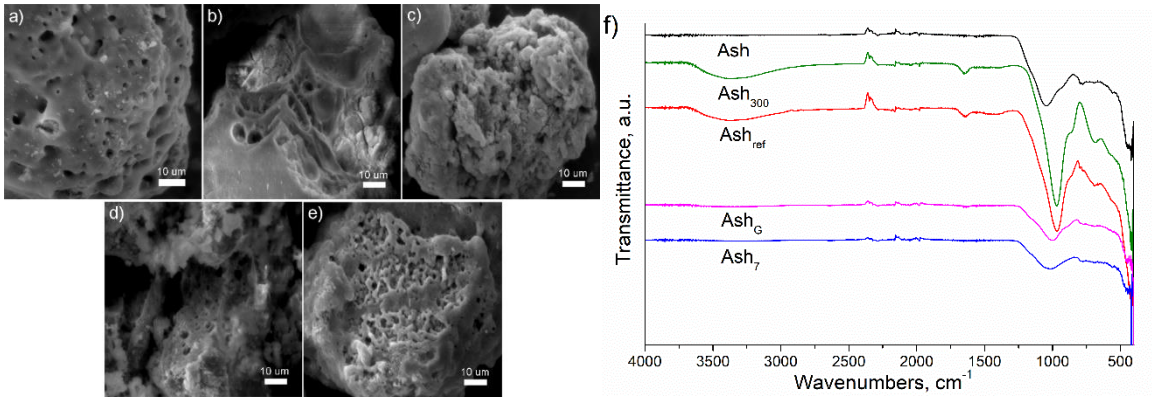

Figure 1. SEM photographs of fly ash samples: a) Ash, b) Ash_{300}, c) Ash_{ref}, d) Ash_G, e) Ash_7 and f) FTIR spectra of examined samples

Source: original author's

Table 2. The atomic percentage of elements obtained by EDS analysis

Source: original author's

Sample	O	Na	Mg	Al	Si	K	Ca	Ti	Fe
	atomic %								
Ash	69.87	-	0.81	9.47	16.43	0.55	1.06	0.19	1.62
Ash_{300}	62.02	5.20	0.87	10.43	18.08	0.28	0.80	-	2.31
Ash_{ref}	59.10	1.92	1.11	13.10	20.82	1.27	0.63	0.15	1.89
Ash_G	61.44	12.71	-	5.48	18.35	0.33	0.35	-	1.33
Ash_7	59.71	0.81	1.19	14.14	18.79	0.50	1.32	0.39	3.15

FTIR spectra of fly ash samples are (Figure 1f) characterized by sharp, distinguish peaks at around 1000 cm^{-1}, and bands of low intensity around 780 cm^{-1}, which originate from the stretching of asymmetric Si - O -Si and symmetric Si - O -Si bond, respectively. The observed shift of the band around 1000 cm^{-1} to the lower wavenumber values is more pronounced for the samples modified at higher temperatures. This small shift, along with the disappearance, or decrease in intensity of peak around 780 cm^{-1} (observed for Ash_{300} and Ash_G, respectively) indicates the formation of alkali-

activated materials. The bands around 3370 and 1630 cm^{-1} can be assigned to the stretching vibration of the O-H bond in hydroxyl groups from the material moisture.

The adsorption efficiency of unmodified and modified fly ash samples to remove cationic (CV and MB) and anionic (ARS and MO) dyes is given in Figure 2. Applied modifications increase adsorption efficiency for cationic dyes, up to 92 % for adsorption of CV onto Ash_G. On the other hand, these alkali treatments have no effect, or even decrease the adsorption efficiency for anionic dyes. Generally, all examined samples show the highest adsorption efficiency for CV, and Ash_G, as the sample with the highest efficiency in CV removal, was selected for further adsorption studies.

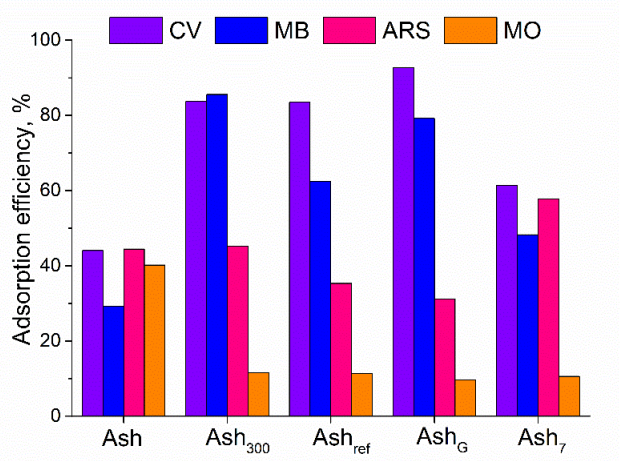

Figure 2. Adsorption efficiency of fly ash samples for removal of selected dyes
Source: original author's

The initial pH value of the dye solution can affect the adsorbent surface, as well as the distribution and the morphology of dye molecules, influencing the adsorption capacities of fly ash samples. The influence of the pH of CV solution on the adsorption capacities of Ash and Ash_G is shown in Figure 3a. Adsorption capacities increase with initial pH value, especially in the case of unmodified fly ash. The influence of contact time between adsorbent and adsorbate solution on adsorption capacities is shown in Figure 3b. The adsorption capacity for both samples increases with the contact time, reaching the equilibrium only for sample Ash.

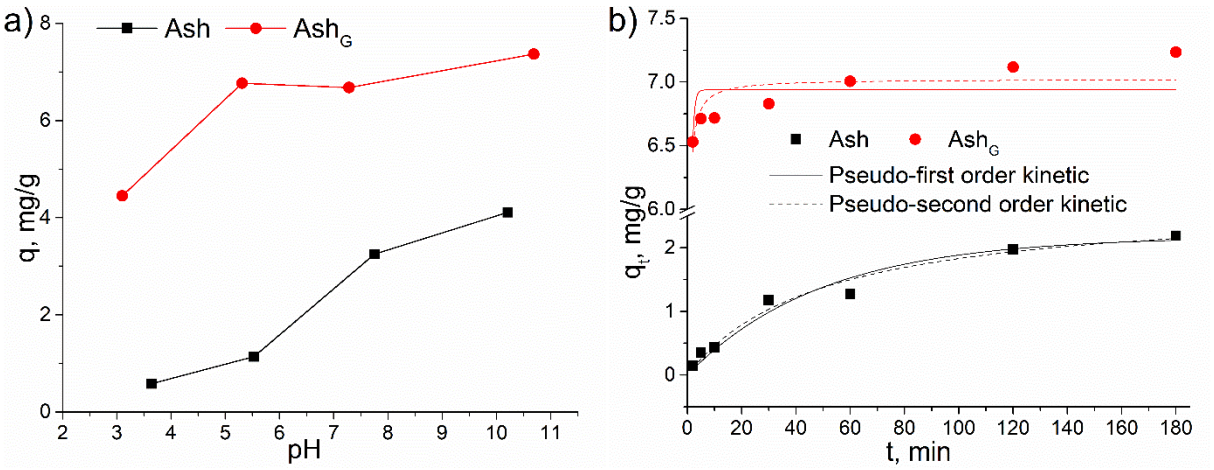

Figure 3. The influence of initial pH value (a) and contact time (b) on adsorption capacities of Ash and Ash_G
Source: original author's

Experimental data are fitted with pseudo-first and pseudo-second kinetic models and also shown in Figure 3b, while obtained kinetic parameters are summarized in Table 3. According to the correlation coefficients (R^2) adsorption of CV onto both samples fits better with pseudo-second order kinetic. However, a better agreement between the experimental adsorption capacity and the one calculated by

the pseudo-first order model, indicates that CV adsorption onto Ash can be better described by this model.

Table 3. Kinetic parameters of CV adsorption onto samples Ash and Ash_G
Source: original author's

Sample	Pseudo-first order			Pseudo-second order			$q_{e,exp}$, mg/g
	$q_{e,cal}$, mg/g	k_1	R^2	$q_{e,cal}$, mg/g	k_2	R^2	
Ash	2.175	0.02014	0.95994	2.735	0.0074	0.97308	2.190
Ash_G	6.938	1.40664	0.25695	7.023	0.8015	0.59680	7.235

4. CONCLUSION

Fly ash, obtained from the power plant Nikola Tesla A, was modified using different alkali treatments and used as an adsorbent for the removal of selected dyes from water. Material characterization showed that applied modifications led to the formation of alkali-activated materials, the increase of the surface porosity, and the atomic percentage of Na. Changes in material structure induced by applied treatments led to an increase in material efficiency in adsorb cationic dyes. All samples showed the highest adsorption efficiency for crystal violet removal, while the sample modified with the combination of NaOH, Na_2SiO_3, and diatomaceous earth (Ash_G) was the most efficient adsorbent for all selected dyes. Adsorption of crystal violet onto unmodified fly ash and Ash_G increases with initial pH value and contact time, following the pseudo-first, and pseudo-second order rate, respectively. It was found that alkaline modification improves the adsorption characteristics of fly ash making it a promising candidate to solve the problem of colored wastewater.

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CARBON FOOTPRINT OF BIO-BASED AND RECYCLED PLASTIC MATERIALS

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Abstract: *In recent years, there has been a shift in plastics production by replacing conventional fossil-based plastics with bio-based alternatives, in order to reduce their carbon footprint (CF). In this study, an analysis of the CF associated with ten commonly utilized bio-based and recycled polymer families has been conducted. The analysis relies on available reports published from seven major polymer producers.The results have revealed a noteworthy reduction in the carbon footprint of the selected bio-based and recycled materials, with reductions of up to 97%. Furthermore, there is substantial variability both between and within polymer families. This underscores the importance of not only selecting the appropriate base polymer but also making effort in choices of reinforcement fibers and production methods in order to achieve the maximum possible reduction in carbon footprint.*
Keywords: GWP, Bio-based plastics, Recycling, Carbon Capture & Utilization

1. INTRODUCTION

From food packaging, to medical equipment and consumer electronics, plastics have become one of the most used materials globally. In order to allow future generations to enjoy the benefits of these materials, it is necessary to maximize their sustainability. In recent years, there has been a notable shift towards replacing conventional fossil-based plastics with bio-based alternatives, partially or entirely derived from biomass. While currently bio-based and biodegradable plastics make up only about 1% of the total plastic production, the global outlook for bioplastics production capacity indicates significant growth, with projections rising to 7.6 million tonnes by 2026, thereby more than tripling the current capacity.
Plastics have had a substantial environmental impact, contributing with estimated 1.7-2 gigatons of CO_2-equivalent emissions (4.5% of global carbon emissions) throughout their lifecycle in 2015, and this figure is expected to quadruple by 2050 if existing systems are not improved [1]. Mechanical recycling, chemical recycling, bio-recycling (enzymatic degradation) of biodegradable plastic, burying in landfills or incineration are currently the most commonly used methods for managing polymer waste [2]. To ensure sustainable and circular plastics production, recycling methods must be more pronounced in future years as the main approach for the reduction of raw material consumption and carbon emissions. Hence, this paper is focused on global warming potential (GWP) of commercially available bio-based and recycled plastics grades and on benchmark of their environmental performance with the fossil fuels made grades.

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2. BIO-BASED AND RECYCLED PLASTIC PRODUCTION

The production of bio-based and recycled plastics is essential for reducing the environmental impact of plastics. Bio-based plastics are made from renewable resources like plant-based materials, while recycled plastics are derived from plastic waste, both contributing to a more sustainable and circular plastics economy, which is depicted in Figure 1. Through mechanical recycling, end-of-life products are used as raw materials, therefore this is the most effective method for reducing plastic waste and virgin feedstock consumption [3]. Mechanical recycling does not change the chemical structure of the material, which permits multiple re-use/recycling of polymeric materials, creating a closed loop. For plastics that cannot be recycled mechanically, chemical recycling is applied, which breaks down the polymer waste into its constituents or directly transforms it into other useful materials for direct repolymerization or other applications [4]. Furthermore, the fossil feedstock used in polymer production is substituted with the bio-based feedstock, whereby the production of biodegradable materials ensures that those will be decomposed by composting, effectively reducing plastic waste. Another step in reducing carbon footprint (CF) of plastic production is the carbon capture and utilization (CCU) technology to remove CO_2 from the flue gas and recycle it in the polycarbonate manufacturing process [5]. This directly reduces greenhouse gases emissions and create a circular system where all by-products are recycled [6].

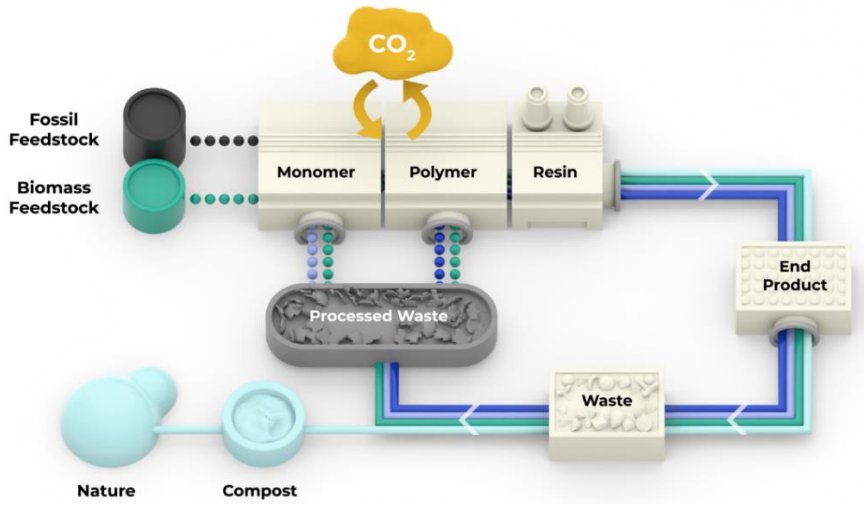

Figure 1. Sustainable plastics production
Source: Adopted from https://www.chimeicorp.com/en-US?page=ecologue

3. MATERIALS AND METHODS

In order to evaluate the environmental impacts of a plastic production and use, Life Cycle Assessment (LCA) methodology was utilised. LCA assessment considers all stages of plastic's life, from raw materials and production through transportation, use, and ultimately disposal or recycling. The primary purpose of LCA is to quantify and analyze various environmental factors and their effects, such as energy consumption, greenhouse gas emissions, water usage, resource depletion, and other ecological impacts [7]. The key components and steps of LCA include [8]:

1. Goal and Scope Definition -the first step in LCA involves defining the objectives of the assessment and specifying the boundaries of what will be studied.
2. Life Cycle Inventory (LCI) - involves collecting data on all relevant inputs (e.g., materials, energy, water) and outputs (e.g., emissions, waste) associated with the product or process at each life cycle stage.
3. Life Cycle Impact Assessment (LCIA) - where environmental indicators and characterization factors are applied to the data collected in the LCI phase. This step helps quantify the potential environmental impacts, such as global warming potential, acidification, eutrophication, and more.

4. Interpretation - the results of the LCA are analyzed and interpreted to draw conclusions and make recommendations.

In practice, performing LCA is associated with a lot of challenges and issues, where main five are:

1. Data Quality and Availability – data is often limited, outdated, or dependent on geographical location or production methods.
2. System Boundaries – decisions about which life cycle stages and environmental impacts to include can significantly impact the results and interpretation of the assessment.
3. Allocation – refers to the process of assigning environmental burdens to multiple products or co-products within a system.
4. Temporal and Geographical Variability – environmental impacts can vary over time and in different geographic regions.
5. Selecting Impact Categories and Indicators – the choice of indicators can affect the outcome of the assessment and may not capture all relevant impacts.

There are also various LCIA methods, such as ReCiPe, EDIP, CML, EPS, TRACI, that provide the mathematical and computational framework for assessing the specific environmental impacts within various categories. In order to compare two products from different producers we need to have same boundaries (e.g. cradle to gate), to use the single LCI source and the same indicator from single LCIA method. All of this makes crosschecking of LCIA values obtained from various producers almost impossible, and imposes the external evaluation of reported values. In this paper, the evaluation of producers reported GWP values was made using Total Materia Green Line LCA (Figure 2) which performs LCIA calculations according to five methods for 41 indicators in total, whereby single source of LCI data is used, namely Ecoinvent [9,10]. For the current carbon footprint assessment it was used environmental reports from 7 major producers (Acro-Plastics, DOMO, EMS-GRIVORY, Evonik, Ineos, LG-Chem and MOCOM). Those reports were supplemented with Climate change (GWP 100) according to IPCC 2021 no LT obtained using Total Materia Green Line LCA.

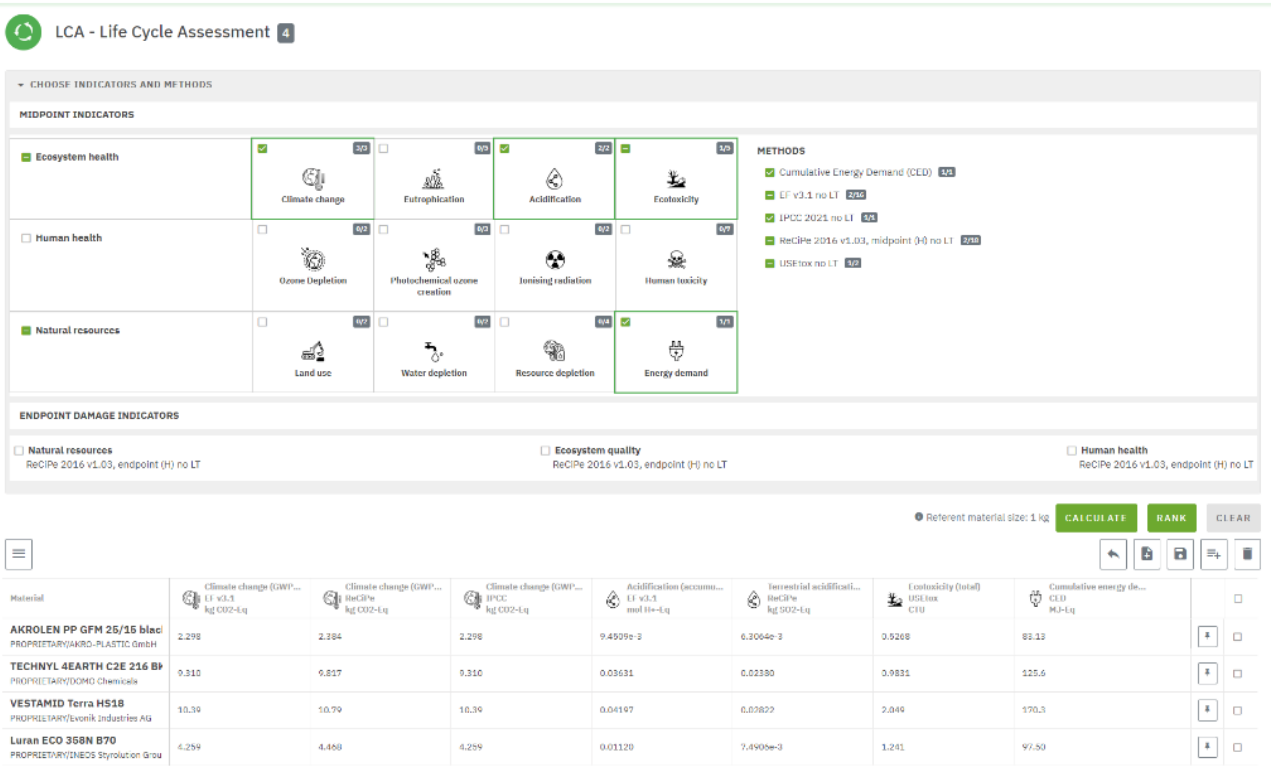

Figure 2. Total Materia Green Line LCA

Source: https://www.totalmateria.com/page.aspx?ID=GreenLine&LN=EN

4. RESULTS AND DISCUSSION

The carbon footprint for 10 commonly used bio-based and recycled polymer families along with the reduction rate based on comparison with conventional grades is summarised in Table 1. Those values are obtained using producers reports for grades given in Table 2. As can be observed in Table 2, only two producers (Acro-Plastics and EMS-GRIVORY) have provided all data needed for the analysis, while in the case of other producers the reduction rate or the actual GWP value were estimated using Total Materia Green Line LCA.

The results demonstrate a great range in the reduction within the same family, e.g. in the case of PA1010 the reduction range from 48% to 77%, as well between studied families, i.e. PA1012 showed a moderate reduction rate of 35%, while PA66 can be produced with reduced CF up to 97%. In absolute numbers, bio-based and recycled polymer materials have CF from 0.25 kg CO_2-Eq to up to 5.8 kg CO_2-Eq, with significant dependence on the polymer family. Also, within the same family CF can vary significantly, e.g. for PA66 CF from 0.25 to 1.95 kg CO_2-Eq, which implies that added fibres and additives, as well as the production method with applied CCU technology to remove CO_2 can make a significant difference.

Table 1. Carbon footprint for bio-based and recycled plastics and the reduction rate

Polymer family	CF (kg CO_2-Eq)	Reduction (%)
ABS	2.68	41
PA1010	1.56 – 4.6	48 – 77
PA1012	5.2 – 5.8	35 – 50
PA6	0.33 – 0.99	87 – 96
PA610	2.1 – 5.1	43 – 66
PA66	0.25 – 1.95	70 – 97
PC	0.69	88
PP	0.51	70
PPS	0.81	88
SAN	0.30	93

Further analysis based on the carbon footprint calculation (cradle to gate) for a 30% glass fibre reinforced PA6.6 compound shows, that the polymer has by far the highest impact on the carbon footprint, followed by the filler content, while everything else can contribute to up to 10% (Figure 3a). Therefore, since polymer families can differ in carbon footprint up to 4 times (Figure 3b), the appropriate selection of base polymers and filler to preserve mechanical and physical properties, is the key point in the quest for more sustainable plastic materials.

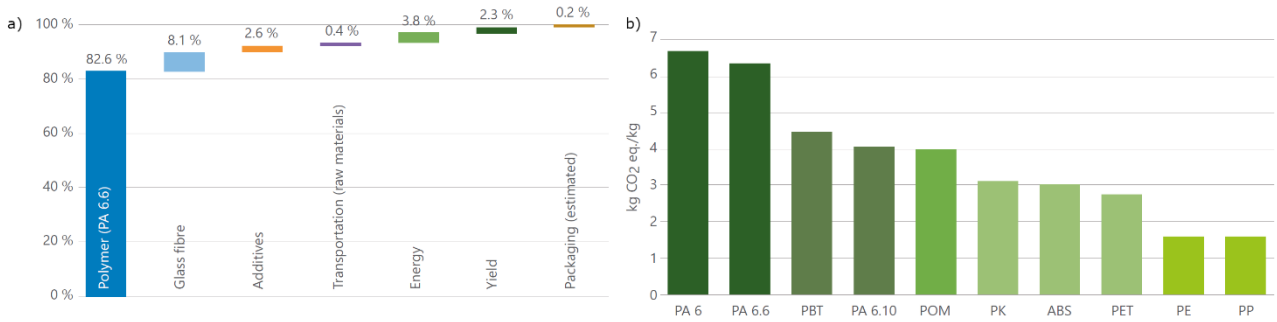

Figure 3. The CF (cradle to gate) for: a) PA6.6 30 % glass fibre reinforced polymer material, b) different polymer families

Source: https://akro-plastic.com/sustainability/

Table 2. Producer reported and estimated (marked in bold style) eco grades CF per kg of material

Producer	Polymer family	Eco grade and its CF (kg CO_2-Eq)		Standard grade and its CF (kg CO_2-Eq)		Reduction (%)	TM GL CF (kg CO_2-Eq)
Acro-Plastic	PP	AKROLEN NEXT PP LGF 40 2 CI black (8560)	0.51	AKROLEN PP LGF 40 2 black (8488)	1.70	70	2.3
DOMO	PA6	TECHNYL 4EARTH C2E 216 (COLOR) H	0.33	-	-	**96**	9.3
	PA6	TECHNYL 4EARTH C2E 216 V30 (COLOR) H	0.99	-	-	**87**	7.4
	PA66	TECHNYL 4EARTH A2E 216 (Color) H	0.25	-	-	**97**	8.25
	PA66	TECHNYL 4EARTH A2E 216 V30 (Color) H	0.88	-	-	**88**	7.19
EMS-GRIVORY	PA1010	Grilamid XE 4019	1.56	PA1010 grades	6.8	77	8.92
	PA1010	Grilamid 1SVX-50H	2.00	Grivory GV-5H	5.4	63	8.92
	PA66	Grilamid XE 1306	1.95	PA66 grades	6.5	70	8.25
	PA610	Grilamid 2SV-30H	2.10	PA610 GF 50% grades	6.2	66	8.92
Evonik	PA610	VESTAMID Terra HS16 or HS18 or HS22	4.60	-	-	**56**	10.39
	PA610	VESTAMID Terra HS18-GF30	5.10	-	-	**43**	8.92
	PA1010	VESTAMID Terra DS16 or DS18 or DS22	4.00	-	-	**62**	10.39
	PA1010	VESTAMID Terra DS18-GF30	4.60	-	-	**48**	8.92
	PA1012	VESTAMID Terra DD16 or DD18 or DD22	5.20	-	-	**50**	10.39
	PA1012	VESTAMID Terra DD18-GF30	5.80	-	-	**35**	8.92
INEOS	SAN	Luran ECO 358N B70	**0.30**	Luran 358N	-	93	4.26
LG Chem	ABS	CRI558M3	2.68	-	-	**41**	4.58
MOCOM	PC	ALTECH PC ECO 1000/100	0.69	-	-	**88**	5.76
	PPS	TEDUR R 9519	0.81	-	-	**88**	6.84

5. CONCLUSION

Is this paper, the carbon footprint for 10 commonly used bio-based and recycled polymer families has been analysed using available reports obtained from 7 major polymer producers. Since 5 out of 7 producers haven't provided sufficient data to perform the analysis, estimations have been made using Total Materia Green Line LCA.

The performed analysis has demonstrated a significant decrease of carbon footprint for the selected bio-based and recycled materials, with the reduction up to 97%. Also, there are significant variations between and within polymer families, suggesting that the proper selection of base polymer must be followed, together with the appropriate selection of reinforcement and production method, in order to achieve the maximum reduction of carbon footprint.

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ENVIRONMENT AND SUSTAINABLE DEVELOPMENT. MECHATRONICS. OCCUPATIONAL SAFETY AND HEALTH AND FIRE SAFETY. SMART MANAGEMENT SYSTEMS. GRAPHIC ENGINEERING. DESIGN. TRAFFIC ENGINEERING. BIOTECHNOLOGY AND HEALTHCARE. MECHANICAL ENGINEERING. ECOTOURISM AND RURAL DEVELOPMENT.

APPLICATION OF MACHINE LEARNING FOR THE SIMULATIONS AND MODELING IN ENVIRONMENTAL SCIENCE

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Abstract: *In order to protect and improve the environment, promote sustainability, and enhance the quality of life, environmental science relies on simulation and modelling tools. Due to the complexity and non-linear behavior of parameters used to describe quality of the environment, artificial intelligence, i.e. machine learning, models became popular in recent years. In this paper, the application of probabilistic neural network for air pollution prediction regarding ozone exceedances of 120 µg/m³ more than 25 times a year in European urban centers in four countries (Germany, Poland, Romania and Switzerland) is presented. Available ozone data, along with climate data (temperature, solar radiation and precipitation) for the period 2006-2012 were used as inputs. The created classification model has made predictions with satisfactory accuracy (>75%) and precision (>60%). Performed scenario analysis revealed that an increase of temperature for 2°C pronounce climate conditions that favors ozone exceeding of 120 µg/m, whereby probability of such event rise to more than 90%.*
Keywords: Ozone, Probabilistic ANN, scenario analysis, modelling

1. INTRODUCTION

Environmental science aim to protect the environment, enhance sustainability, and improve the well-being of both current and future generations, and therefore modelling and analysis of pollutant concentrations is of immense importance in order to gain insights on environmental quality parameters needed to generate sustainable environmental policies [1]. In recent years, there has been a significant increase in the interest and utilization of artificial neural networks (ANNs) for the forecasting of ambient air pollution [2]. This heightened focus on ANNs stems from the growing recognition of the severe health consequences associated with poor air quality in urban areas. Such detrimental effects include the development of chronic diseases and premature deaths, particularly among vulnerable individuals within the population [3]. Urban population exposure to tropospheric ozone is consider as serious health concern in Europe countries [4]. Hence, ozone levels are monitored regularly, and the European target value for the protection of human health is based on the daily maximum 8-hour mean ozone concentration. Averaged over 3 years, this daily maximum 8-hour mean should not exceed 120 µg/m³ more than 25 times a year.
This paper is focused on air pollution modelling and simulation of ozone concentration in European urban areas, including scenarios based on climate change effects onto the weather patterns. The model aims to predict the frequency of the event of 25 times exceedance of 120 µg/m³, using the classification of main climate factors.

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2. LITERATURE REVIEW

The process of ozone formation in the lower layers of the atmosphere is nonlinear, which makes ANNs a very suitable method for modelling. By using ANNs, it is possible to capture all the nonlinearities that exist between the ozone formation and other atmospheric variables, which traditional statistical techniques may not be able to provide. Therefore, among other methods, ANNs have been extensively used for the predicting of ozone concentrations:

1. In Zagreb, Croatia, a study has used neural networks to predict ozone concentrations in urban areas [5],
2. In Bilbao, Spain, ozone prediction was carried out using neural networks at six locations eight hours in advance, using traffic data and meteorological parameters. The results were unsatisfactory (R^2=0.15) compared to other pollutants (e.g., R^2=0.88 for NO_2), indicating the complexity of ozone prediction [6],
3. Narasimhan and colleagues predicted ozone concentrations using meteorological parameters. The most significant input variables were found to be nitrogen dioxide, temperature, relative humidity, and solar radiation (sunshine). The agreement between measured and predicted values was R^2=0.88 [7],
4. Radial Basic Function models were applied to predict ozone in the city of Arosa, Switzerland, with a relative error below 12% [8],
5. Goulier et al. focused on predicting ozone focusing on the impact of traffic, demonstrating that traffic significantly influences ozone concentration in urban areas [9],
6. Maximum daily ozone concentrations have also been predicted using artificial neural networks, which outperformed other statistical regression models [10].

3. METHODOLOGY

Probabilistic neural networks (PNNs) were introduced by Donald Specht in the late 1980s [11]. PNNs are particularly well-suited for pattern recognition and classification tasks. These networks belong to the family of radial basis function networks and use different approach compared to traditional feedforward neural networks, i.e. instead of sigmoid activation functions, PNNs use radial basis functions for processing. PNNs consist of 4 layers that provide a probabilistic output by calculating the probability that the input data belongs to each class, based on the similarity scores calculated by the radial basis functions. They are trained using competitive learning algorithm, which adjusts the prototype vectors for each class using the training data. During training, the network learns to adapt its radial basis functions to better represent the input data distribution.
They have several notable advantages, including their ability to handle non-linearly separable data, simple architecture, and fast training. They are particularly useful for pattern recognition tasks, such as classification and clustering yielding applications in various fields: image recognition, speech recognition, medical diagnosis, and financial modelling. More details can be found in relevant literature [12].

4. RESULTS AND DISCUSSION

4.1 Ozone data

Ozone data expressed as the number of days where the ozone concentrations had exceeded 120 µg/m³ were collected from Eurostat [13] for four EU countries for the period 2006-2012, which is presented in Figure 1. Since the major impact on the concentration of ozone is made by temperature, solar radiation and precipitation, the parameters that quantify their changes in the atmosphere were selected as the model inputs (Table 1). Data for the selected countries and parameters were obtained from Eurostat [13] and their descriptive statistic is provided in Table 2.

Figure 1. Study scope

Table 1. Links between selected climate factors, ozone formation and model inputs [14]

Climate factor	Factor effect	Ozone concentration	Model input	Unit
Temperature increase	Faster chemistry Increase of precursors emission	Increase	Average temperature of warmest month (T_w)	°C
			Average temperature of coldest month (T_c)	°C
Solar radiation increase	Faster photochemistry	Increases (high NOx) Decreases (low NOx)	Total number of hours of sunshine per day (S)	h/day
Precipitation increase	Scavenging of soluble precursors	Decrease	Rainfall (P)	mm

Table 2. Descriptive statistic of ozone data

Criteria	Total	Germany	Poland	Romania	Switzerland
>25 days having O_3>120 µg/m³	112	76	5	15	16
<25 days having O_3>120 µg/m³	432	270	35	106	21
Share of cases with exceed O_3 (%)	21	22	13	12	43

Descriptive statistics of selected model inputs (Table 3) shows that there are no significant differences in the number of sunny hours per day throughout the year, with and without ozone exceedances. However, in the years when temperature exceedances occurred in the hottest month, it was higher by 1.6°C, while in the coldest months, it was only 0.1°C higher compared to years without exceedances. Additionally, in the years when there were ozone concentration exceedances >120 µg/m³, higher precipitation amounts of about 10% were also observed compared to the years without exceedances. The values of the observed parameters also indicate the influence of heatwaves on the ozone formation, which ultimately leads to exceedances in the number of days throughout the year.

Table 3. Descriptive statistic of selected model inputs

Criteria	Value	*S (h/day)*	T_w *(°C)*	T_c *(°C)*	*P (mm)*
>25 days having O_3>120 µg/m³	Mean	5.07	21.92	-0.60	766.34
	Min.	3.98	17.40	-5.90	352.70
	Max.	6.90	27.20	4.30	2,188.60
<25 days having O_3>120 µg/m³	Mean	5.05	20.33	-0.71	708.73
	Min.	3.70	16.70	-10.10	324.10
	Max.	7.30	29.00	4.20	1,380.60

4.2 Model performance

PNN model was created with 4 neurons in the input layer, 358 neurons in hidden layer, 3 in summation layer, and 2 neurons in the output layer. It was trained with 358 datapoints (65% of available data), validated with 107 datapoints (20%) and tested 82 datapoints (15%). Its performance

is given in Table 4, and can be noted that during the training, the model achieved an accuracy rate of over 90% for correctly predicted cases. However, during the validation, the accuracy dropped to a range between 75-90%, but it remained stable during the model testing. This is an indicator that the model is well-trained. The same trend was observed in the terms of precision for this model.

Table 4. PNN model performance

Criteria	Dataset	*Total*	*Predicted*	*Accurate predictions*	*Accuracy (%)*	*Precision (%)*
>25 days having O_3>120 μg/m³	Training	72	95	72	100	76
	Validation	25	27	19	76	70
	Test	17	21	13	76	62
<25 days having O_3>120 μg/m³	Training	286	263	263	92	100
	Validation	85	83	77	91	93
	Test	65	61	57	88	93

It is also noticeable that both accuracy and precision are higher when predicting cases where there are no exceedances (accuracy at 88%, precision at 93%) compared to cases with ozone concentration exceedances. In cases of exceedances, the accuracy during model testing was 76%, and precision was 62%. These results can be attributed to the significantly larger number of cases without exceedances compared to those with exceedances, which increases the model's ability to accurately predict non-exceedance cases of ozone concentration.
PNN model also allows estimation of the significance of particular input to the model prediction by analysing the values of individual smoothing factors (ISFs). The value of ISFs are unique to each network having value up to 3, whereby the larger value indicates that the particular input is more important to the model [15]. The values for the particular model (Table 5) indicate that the temperature of the coldest month in the year and the average number of sunny hours in the year significantly contribute to ozone formation, while the temperature of the hottest month and the amount of precipitation have a proportionally lower impact.

Table 5. Selected ozone data descriptive statistic

Model input	T_c	S	T_w	P
ISF value	2.45	2.28	1.36	0.75

4.3 Scenario analysis

Climate change is expected to affect ozone concentrations in the future, due to changes in meteorological conditions, as well as due to increased emissions of specific ozone precursors (e.g. increased isoprene from vegetation on higher temperatures) and/or emissions from wildfires that can increase under the periods of extensive drought [11]. By understanding the significance of individual model inputs from the previous section, favourable and unfavourable meteorological conditions for the formation of ozone can be defined. For example, a series of high temperatures during the hottest months and lower precipitation levels reduce the likelihood of ozone formation. Considering global climate changes, one can expect a change in these two parameters in an unfavourable direction.
Two scenarios can be defined:

a) favourable meteorological conditions: T_w=20°C and precipitation of 710 mm,
b) unfavourable meteorological conditions: increased temperature (T_w=22°C) and increased precipitation of 770 *mm,*

where remaining two inputs have kept their typical observed range.

The probability of ozone exceedance for each of described scenario is provided in Figure 2., with the probability of exceeding >25 days having O_3>120 μg/m, where the weather conditions favourable for exceedance are shown in light and dark red colour (probability >50%).

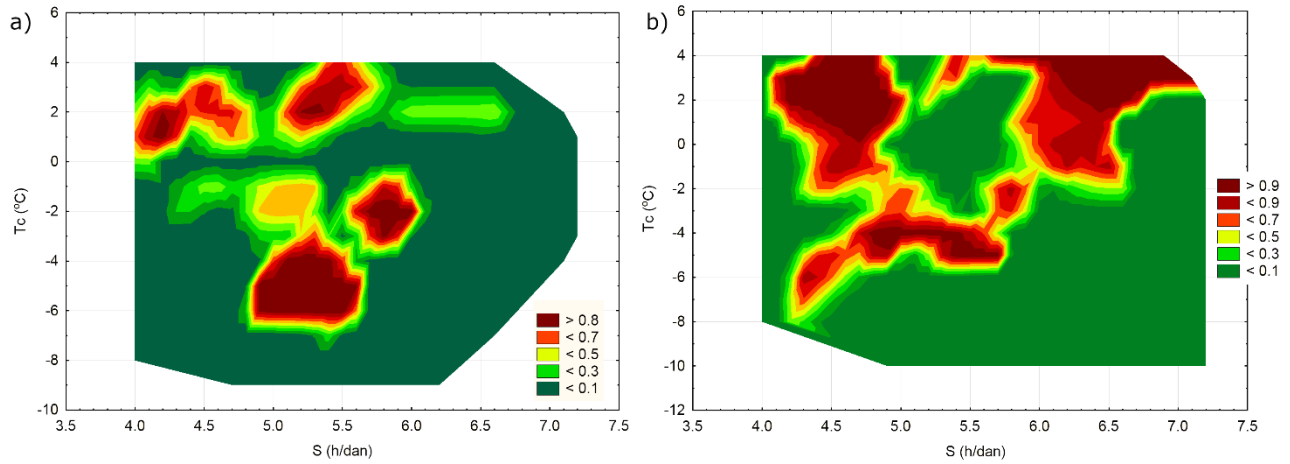

Figure 2. Probability of ozone exceedance for scenario:
a) favourable and b) unfavourable meteorological conditions

It can be observed that the areas with a probability >50% for exceeding the number of days with ozone concentration >120 µg/m³ are more pronounced compared to the favourable scenario. Additionally, there are conditions where the probability of exceeding the number of days with ozone concentration greater than 120 µg/m³ is greater than 90%.

5. CONCLUSION

Is this paper, ANN approach was used for the forecasting of the exceedance of ozone concentration, for cities located in 4 European countries (EU Members), using available climate data (temperature, solar radiation and precipitation) recorded from 2006 to 2012. The obtained model has shown satisfactory accuracy (>75%) and precision, which makes it suitable for the analysis of scenarios.
The performed scenario analysis has demonstrated a significant increase of the probability (>90%) of exceeding the ozone concentration if temperature of warmer months increases for the expected 2°C, followed with increased precipitation, comparing to the initial scenario (T_w=20°C and precipitation of 710 mm).

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AIR QUALITY ACCORDING PM CONCENTRATION IN THE CITY OF BELGRADE IN SEPTEMBER 2023.

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Abstract: *Air quality in urban areas has a greater impact on the health than other environmental factors, and one of the main pollutants are suspended particles PM_{10} and $PM_{2.5}$. In this paper air quality was monitored in terms of the concentration of $PM_{2.5}$ and PM_{10}, for 09/04/2023, 09/05/2023. and 09/06/2023. in the territory of the city of Belgrade. This period of year was taken due to the assumption that increased air pollution was caused in large connection with the heating season and presence of a large number of individual combustion plants. The Environmental Protection Agency monitors air quality, defined by the CAQI index (The Common Air Quality Index) in real time. Data indicates that the air can most often be characterized as* ***exellent*** *values for $PM_{2.5}$(0 µg/m3 - 15 µg/m^3), and for PM_{10} (0 µg/m^3 – 25 µg/m^3). In a small number of cases, for $PM_{2.5}$ particles (15.01 µg/m^3 - 30 µg/m^3), for PM_{10} particles (25.01 µg/m^3 - 50 µg/m^3), which is characterized as* ***good*** *air quality. From 29 measurement points in Belgrade, the air quality was not characterized as* ***acceptable*** *($PM_{2.5}$: 30.01 µg/m^3 - 55 µg/m^3, or for PM_{10}: 50.01 µg/m^3 - 90 µg/m^3, neither* ***polluted*** *($PM_{2.5}$ 5.01 - 110 µg/m^3; PM_{10} 90.01-180 µg/m^3), nor* ***highly polluted*** *($PM_{2,5}$ above 110.01µg/m^3 ; PM_{10} above 180.01 µg/m^3). Exposure to PM particles has a very bad effect on the respiratory, cardiovascular and nervous systems, including carcinogenic risk.*
Keywords: air pollution, particulate matter, $PM_{2.5}$, PM_{10}, health, air quality

1. INTRODUCTION

It is considered that air quality in urban areas has a greater impact on the health of the population than other environmental factors, and that ambient air pollutants represent one of the most significant causes of health problems in general [1]. A pollutant is any substance present in the air that can have a harmful effect on human health and the environment [2] (4). Air quality is determined not only by the concentration, but also by the type of pollutants [3,4] . One of the main air pollutants are Particulate Matter, PM_{10} and $PM_{2.5}$. $PM_{2.5}$ and PM_{10} particles are suspended particles whose dimensions are less than 2.5 µm and 10 µm, respectively. The most important sources of PM particle can be volcanic eruptions, forest fires, industrial use and burning of coal and oil for the production of electricity and heating, then fuel burning in aviation, car and ship traffic, burning of industrial and communal waste, as well as various agricultural activities.

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2. PARTICULATE MATTER ($PM_{2.5}$; PM_{10})

2.1 Chemical composition of suspended particles

The chemical composition of PM particles has a very significant role in terms of impact on human health and air quality. The typical chemical composition of $PM_{2.5}$ particles in urban areas includes: elemental (EC) and organic carbon (OC), sulfates (SO_4^{2-}), nitrates (NO_3^-), ammonium (NH_4^+) ion, chlorides (Cl^-), dust elements and substances of biological origin. The analysis of the composition of $PM_{2.5}$ particles in a large number of studies showed that the largest share in the total mass of particles has OC and water-soluble ions, NO_3^- and SO_4^{2-} [5] . PM_{10} represent a mixture of smoke, soot, dust, salt and acid, along with heavy metals such as lead, cadmium, nickel and arsenic, and are created as a result of the combined impact of heating, traffic and industry.

2.2 Impact of suspended PM particles on human health

The pathogenic properties of PM particles are determined by the size, chemical composition, solubility, source and other characteristics of PM particles (shape, surface area, number). Effects on health as a result of inhalation of PM particles also depend on the way of breathing, the volume of inhaled air, the presence of respiratory diseases, physical activity and age. After inhalation of PM particles, the immune response begins in respiratory macrophages, within the bronchioles. Activated macrophages produce interleukin IL-6, IL-1, tumor necrosis factor alpha, and other proinflammatory cytokines [6], resulting in local inflammation. Induced cell death is another mechanism for causing respiratory diseases caused by PM particles. Oxidative stress, a cascade of inflammatory mediators, and deoxyribonucleic acid (DNA) damage are thought to be involved in PM-induced cell death. Research shows that the mechanism of promoting carcinogenesis by PM particles is based on causing DNA damage and genomic instability [7] . A strong link between PM particles and cardiovascular disease deaths has been established, and several pathways have been identified that explain the link between PM particles and cardiovascular disease. The direct pathway involves the absorption of PM particles into the bloodstream and distant target organs. Systemic inflammation is a well-known risk factor for the progression of atherosclerosis, and proinflammatory mediators are associated with increased blood coagulation and endothelial dysfunction, which can worsen myocardial ischemia [8] . Local inflammation of lung tissue, followed by systemic inflammation, can also lead to disruption of the blood-brain barrier and transfer of PM particles to brain structures. In vitro studies show that certain chemical constituents of PM particles are also neurotoxic.

3. AIR QUALITY MONITORING IN THE REPUBLIC OF SERBIA

In accordance with the Law on Air Protection ("Official Gazette of the RS" No. 36/09 and 10/13) [9] (11), the Serbian Environmental Protection Agency (SEPA) has jurisdiction over the state network for air quality monitoring in Republic of Serbia [10] . Quality monitoring is carried out by applying automatic reference methods in accordance with the Decree on determining the air quality control program in the state network ("Official Gazette of RS" No. 58/11) [11] and the Decree on conditions for air quality monitoring and requirements ("Official Gazette of RS " No. 11/10, 75/10 and 63/13) [12] . Air monitoring is defined by the CAQI index (*The Common Air Quality Index*), developed within the European Commission project. SEPA presents the results of automatic air quality monitoring in real time.

Preliminary, unverified values of air quality parameters within each hour are presented. Verified values and assessment of air quality in agglomerations and zones are given in the Annual report on the state of air quality in the Republic of Serbia [10] . As part of writing this paper, the air quality in the territory of the city of Belgrade was monitored in terms of the concentration of $PM_{2.5}$ and PM_{10} particles, for the beginning of September 2023, for three dates: September 4, 2023, September 5, 2023. and September 6, 2023 (Table 1,2), which is presented in tabular form on the SEPA website.

Analyzing the data, it can be seen that the air in terms of the concentration of PM particles can most often and in the largest number of measurement be characterized as ***excellent***, values for $PM_{2.5}$ particles in concentrations: 0 $\mu g/m^3$ - 15 $\mu g/m^3$, and for PM_{10} particles in concentrations: 0 $\mu g/m^3$ - 25 $\mu g/m^3$. Only September 5th, a smaller number of measurement cases include concentrations for $PM_{2.5}$ particles: 15 $\mu g/m^3$ - 30 $\mu g/m^3$, and for PM_{10} particles 25 $\mu g/m^3$ - 50 $\mu g/m^3$, which can be characterized as ***good*** air quality. Out of 29 measurement points for these three dates, in different municipalities on the territory of the city of Belgrade, the air quality was not characterized as ***acceptable***, neither ***polluted***, nor ***highly polluted*** in any measurement..

Table 1. Consolidated display of automatic monitoring of air quality in the RS according PM_{10} - Territory of the city of Belgrade for September 4,5,6. 2023. Year, between 12:00 and 1:00 pm

Source:[10]

Belgrade	PM_{10}		
Date	4.9.2023	5.9.2023	6.9.2034.
Belgrade Old Town	14.5	15.6	18.7
Belgrade New Belgrade	10.5	17.1	16.7
Belgrade Mostar	23.3	11.2	11.3
Belgrade Vračar	10.7	16.3	14.5
Belgrade Green Hill	7.66	16.6	16.8
Belgrade Ovča	10.1	16.3	16.5
Belgrade Zemun TB	14.5	17.2	18.5
Belgrade Despota Stefana	10.3	17	17.8
Belgrade Oml. brigada	16.9	17.8	16.1
Belgrade Obrenovac	10.1	13.9	14.7
Belgrade Obrenovac Ušće	9.45	11.9	15.5
Belgrade Lazarevac	12	16	11.7
Belgrade Banovo Hill	10.5	14.2	18.4
Belgrade Franša Deperea	12.5	16.9	21.7
Belgrade Leštane	11.7	25	15.8
Belgrade Stojčino Hill	9.52	18.7	13.4
Belgrade Barajevo	8.23	18.2	12.6
Belgrade Vinča	7.86	20.7	13.2
Belgrade Dragiša Mišović	9.05	16.7	21.2
Belgrade Topčider Star Zvezda	10.7	16.6	12.2
Belgrade Ada petlja	9.57	16.1	22.6
Belgrade Surčin	7.89	14.1	10.6
Belgrade Zemun Ugrinovačka	9.48	17.4	14.9
Belgrade Borča	8.36	17.4	13.3
Belgrade Ada Marina	10	13.9	18.7
Belgrade Mladenovac	18.6	23.5	16.7
Belgrade Sopot	12.8	33.2	11.3
Belgrade Vračar Dom zdravlja	9.97	16.2	14.5
Belgrade Bežanijska kosa	15.3	16.8	16.8

Table 2. Consolidated display of automatic monitoring of air quality in the RS according $PM_{2.5}$ - Territory of the city of Belgrade for September 4,5and 6, 2023. year, between 12:00 and 1:00 pm

Source:[10]

Belgrade	$PM_{2.5}$		
Date	4.9.2023	5.9.2023	6.9.2023
Belgrade Stari grad	7.02	13	7.53
Belgrade Novi Belgrade	5.85	14.1	6.72
Belgrade Mostar	7.38	10.4	5.33
Belgrade Vračar	7.32	13.2	7.57
Belgrade Zeleno brdo	5.63	13.4	10.4
Belgrade Ovča	5.34	12.3	7.15
Belgrade Zemun TB	5.5	12.3	7.22
Belgrade Despota Stefana	6.26	13.9	9.1
Belgrade Oml. brigada	7.07	15	8.16
Belgrade Obrenovac	5.41	10.2	7.6
Belgrade Obrenovac Ušće	5.86	11.1	9.53
Belgrade Lazarevac	9.05	11.4	6.81
Belgrade Banovo brdo	7.43	11.9	8.38
Belgrade Franša Deperea	7.81	13	8.96
Belgrade Leštane	7.72	16.9	7.17
Belgrade Stojčino Brdo	6.98	14.4	7.1
Belgrade Barajevo	5.19	12.6	6.76
Belgrade Vinča	6.22	15.5	7.57
Belgrade Dragiša Mišović	6.01	13.6	8.17
Belgrade Topčiderska Zvezda	5.93	13.3	7.3
Belgrade Ada petlja	6.05	13.7	7.87
Belgrade Surčin	5.42	11.9	6.41
Belgrade Zemun Ugrinovačka	5.55	12.2	6.96
Belgrade Borča	5.3	12.8	7.31
Belgrade Ada Marina	5.53	11.7	7.53
Belgrade Mladenovac	7.09	17	6.72
Belgrade Sopot	9.33	25.1	5.33
Belgrade Vračar Dom zdravlja	6.37	13	7.57
Belgrade Bežanijska kosa	6.12	12,8	10.4

Table 3. Air quality index CAQI (The Common Air Quality Index) according to the Environmental Protection Agency of Serbia

Source:[10]

Pollutant	Time	EXCELLENT	GOOD	ACCEPTABLE	POLLUTED	HIGHLY POLLUTED
$PM_{2.5}$	1h	0μg/m^3 - 15μg/m^3	15.01μg/m^3 - 30μg/m^3	30.01μg/m^3 - 55μg/m^3	55.01μg/m^3 - 110μg/m^3	Above 110.01μg/m^3
PM_{10}	1h	0μg/m3 - 25μg/m^3	25.01μg/m^3 - 50μg/m^3	50.01μg/m^3 - 90μg/m^3	90.01μg/m^3 - 180μg/m^3	Above 180.01μg/m^3

In September 2021, the World Health Organization (WHO) issued new recommended values for all major pollutants, so the new recommended value for $PM_{2.5}$ on an annual basis is 5 μg/m^3, while for a period of 24 hours it is 15 μg/m^3. Similarly, recommendations are given for PM_{10}: 15 μg/m3 and

45 μg/m^3 for annual and 24-hour average values, respectively. This change represents a significant tightening of the criteria even in relation to EU standards, which in a short period of time caused the announcement of changes in the corresponding regulation by the European Commission [13] . According to the currently available data on the European Commission's website, the air quality in terms of the concentration of $PM_{2.5}$ particles is categorized as [14]:

- good for levels of fine particles that do not exceed the annual reference value of the World Health Organization of 5 μg/m^3,
- acceptable for levels above 5 and not exceeding 10 μg/m^3
- medium for levels above 10 and not exceeding 15 μg/m^3
- bad for levels above 15 and not above 25 μg/m^3; and
- very poor for levels of and above 25 μg/m^3.

Although according to the data available on the SEPA website, air quality can most often be described as ***excellent***, the measurement of the air quality index - CAQI (Common Air Quality Index) on the national air quality portal, in comparison with European regulations (EEA_European Environmental Agency) and WHO recommendations shows significant deviations.

4. CONCLUSION

In June 2021, the European Environment Agency published a list of 323 cities in the EU where concentrations of $PM_{2.5}$ suspended particles were measured. The city of Belgrade with an average concentration of 21.8 μg/m^3 (5 stations) is the most polluted multi-million city compared to similar cities in the EU. The concentration of suspended PM particles is the main cause of excessive air pollution, and Belgrade generally records the duration of elevated average daily concentrations of PM_{10} [13] . Bad air quality is explained by intensive traffic and a large number of cars older than 12 years and without catalytic converters, the presence of a large number of individual combustion plants, as well as unfavorable meteorological conditions (low temperatures and few days where there was no strong wind). Systematic solution to the problem of air pollution requires long-term planning, cooperation of a wide range of different actors - state institutions, public companies, health system, economy, science, civil society organizations and citizens.In order to reduce pollution and improve air quality in the territory of the city of Belgrade and the entire RS, it would be necessary to harmonize the Limit values prescribed by the Law of the RS, with the values prescribed by the legislation of the European Union, the European Air Quality Index (EU AQI) created by the European Environment Agency, that is, WHO recommendations.

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MULTIVARIATE ANALYSIS OF THE MORAVA RIVER PLAIN GROUNDWATER

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Abstract: *One of the most significant sources of drinking water is groundwater. Therefore, it is crucial to assess groundwater quality and ascertain potential causes of contamination to address pollution and provide people with clean drinking water. In this paper, groundwater in the Morava River plain is investigated and analyzed for 14 physicochemical parameters, such as pH, EC, HCO_3^-, NO_3^-, PO_4^{3-}, Cl^-, SO_4^{2-}, Na^+, K^+, Mg^{2+}, Ca^{2+}, Fe, Mn, and As. To determine groundwater facies and sources of pollution, three multivariate statistical analysis techniques were applied. Hierarchical Cluster Analysis (HCA) was used to group groundwater samples based on their similar chemical characteristics and to determine the dominant hydrochemical groundwater type. According to HCA results, groundwater samples were clustered into three groups, including Cluster 1 (72.3%), Cluster 2 (19.7%), and Cluster 3 (7.9%), and the main groundwater type was Ca-HCO_3 type. Factor Analysis (FA) incorporated with Pearson correlation analysis was conducted to determine the main sources of pollution. Water-rock interactions and agricultural practices were identified as primary pollution sources in the investigated area.*

Keywords: Pearson correlation, Hierarchical cluster analysis, Factor analysis, rock weathering, water pollution

1. INTRODUCTION

Globally, groundwater pollution has emerged as an environmental concern. Generally, groundwater quality depends on the dissolution of minerals, including processes such as water-rock interactions, rock weathering, and ion exchange. These processes represent natural sources of groundwater pollution. On the other hand, groundwater quality has recently been more affected by anthropogenic activities. Excessive use of pesticides and chemical fertilizers, industrial and municipal wastewater discharge, and traffic are anthropogenic activities that influence groundwater quality. These activities represent artificial groundwater contamination sources. Groundwater is used for numerous purposes, including domestic, industrial, irrigation, and drinking [1]. Due to the constant rise in population numbers, the demand for clean water is expanding. In addition, using polluted water for domestic purposes is responsible for over 80% of health problems and illnesses in the world [2]. Therefore, it

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is of great importance to assess the quality of groundwater, detect potential pollution sources, and take appropriate measures to prevent pollution. Multivariate techniques are commonly applied to determine groundwater characteristics and pollution sources [3–7]. They involve determining the interaction between chemical parameters, grouping groundwater samples based on their chemical properties, grouping groundwater parameters according to their similar origin, ascertaining groundwater facies, as well as finding the main sources of contamination. This study aims to determine groundwater facies and main factors impacting groundwater quality, combining three multivariate analyses, including Pearson correlation, hierarchical cluster analysis, and factor analysis.

2. MATERIALS AND METHODS

2.1 Study area

The study area (Figure 1) consists of three river plains: the South Morava, the West Morava, and the Great Morava river plain. Together, they form the Morava River plain. Zapadna Morava is formed in Western Serbia by joining the Golijska Moravica and Djetinja rivers. It flows 184 km from west to east, joining the South Morava near Stalać to form Velika Morava. South Morava is formed by the merging of Binačka Morava and Preševska Moravica near Bujanovac, South Serbia. It flows from south to north for 246 km as the longer headwater of Velika Morava. Velika Morava is 185 km long and represents Danube's tributary. The investigated area experiences a moderate continental climate.

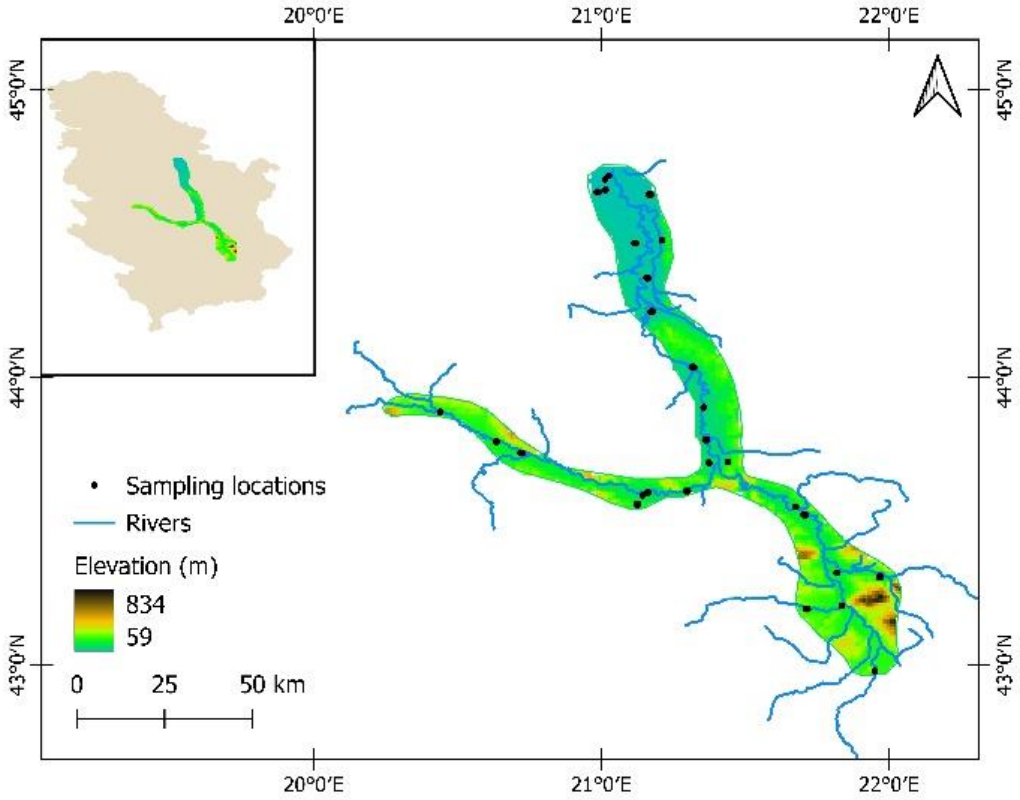

Figure 1. The study area

2.2 Sampling and chemical analysis

In the investigated area, 177 groundwater samples were collected and analyzed for 14 physicochemical parameters, including pH, EC, HCO_3^-, NO_3^-, PO_4^{3-}, Cl^-, SO_4^{2-}, Na^+, K^+, Mg^{2+}, Ca^{2+}, Fe, Mn, and As. High-density polypropylene bottles of 500 mL volume were used for sampling. EC and pH were measured *in situ* using a portable multimeter (YSI 556 MPS, YSI, USA), while HCO_3^- was determined by titrimetry. Before laboratory analyses samples were kept at 4 °C. Major ions (Na^+,

K^+, Mg^{2+}, Ca^{2+}, NO_3^-, PO_4^{3-}, Cl^-, SO_4^{2-}) were determined using ion chromatography (DX-500, Dionex, USA). Inductively coupled plasma optical emission spectrometry (ICP-OES, iCAP 6500, Thermo Scientific, USA) was used to measure Fe and Mn, and As were determined using inductively coupled plasma mass spectrometry (ICP-MS, iCAP Qc, Thermo Scientific, USA).

2.3 Pearson correlation analysis

Pearson correlation analysis is used to determine the interaction between chemical parameters through the calculation of Pearson correlation coefficient (r) [5]. Prior to calculation, data was normalized. Pearson correlation coefficient is calculated as follows.

$$r = \frac{\sum_i^n (x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_i^n (x_i - \bar{x})^2} \sqrt{\sum_i^n (y_i - \bar{y})^2}} \quad (1)$$

Where n is the number of samples; x_i and y_i are chemical parameters; and $\bar{x}$ and $\bar{y}$ are their mean values. Pearson correlation coefficient ranges from -1 to 1. If $0<r<1$, that means a positive correlation between two variables, whereas $-1<r<0$ indicates a negative correlation. In addition, the correlation is stronger if the absolute value of r is higher. Furthermore, the correlation is strong if $|r|>0.7$, moderate if $0.5<|r|<0.7$, and weak if $|r|<0.5$ [6, 7].

2.4 Hierarchical cluster analysis

Hierarchical cluster analysis (HCA) is employed to group groundwater samples into similar groups, called clusters. Samples within the same cluster experience similar chemical characteristics, while being different from the other clusters. Ward linkage and Euclidean distance were used to determine the distance between clusters and the distance between water samples, respectively. A graphical representation of the HCA results is called a dendrogram [8].

2.5 Factor analysis

Factor analysis (FA) is a commonly used multivariate statistics technique in which data dimensions are reduced without losing any of the data's information. FA converts the dataset into parameters called factors, where the first factor accounts for the majority of the variance in the dataset, with other factors accounting for the remainder. In order to maximize factor loadings, Varimax rotation was utilized. In this work, FA was employed to determine sources that control groundwater chemistry and their impact on groundwater quality.

3. RESULTS

3.1 Correlation analysis

Table 1 presents the Pearson correlation matrix for the 14 selected chemical parameters. For further interpretation, only parameters showing moderate correlation ($0.4<r<0.7$) or strong correlation ($0.7<r<1$) are selected and in bold.

EC showed strong positive correlation with HCO_3^-, Cl^-, SO_4^{2-}, Ca^{2+}, and Mg^{2+}, and moderate correlation with Na^+ and K^+. Strong positive correlations were also observed between HCO_3^- Ca^{2+}, and Mg^{2+}, while moderate correlation was present between HCO_3^- and Na^+, Cl^-, and SO_4^{2-}. There was also a moderate positive correlation between Mg^{2+}, Na^+, and Ca^{2+}. These findings suggest that rock-water interaction plays an important role in controlling groundwater chemistry. NO_3^- was moderately correlated with PO_4^{3-} and K^+. SO_4^{2-} also showed a moderate correlation with Mg^{2+}. These indicate the influence of agricultural activities.

Table 1. Pearson correlation analysis of the physicochemical parameters

	pH	EC	HCO_3^-	NO_3^-	PO_4^{3-}	Cl^-	SO_4^{2-}	Na^+	K^+	Ca^{2+}	Mg^{2+}	Fe	Mn	As
pH	1													
EC	-0.19	1												
HCO_3^-	-0.16	**0.86**	1											
NO_3^-	0.07	0.36	0.26	1										
PO_4^{3-}	-0.08	0.36	0.18	**0.41**	1									
Cl^-	-0.18	**0.79**	**0.6**	0.29	0.31	1								
SO_4^{2-}	-0.14	**0.83**	**0.64**	0.26	0.34	**0.72**	1							
Na^+	-0.15	**0.6**	**0.50**	0.14	0.1	**0.51**	**0.53**	1						
K^+	-0.11	**0.43**	0.23	**0.46**	0.26	0.36	0.37	0.31	1					
Ca^{2+}	-0.25	**0.82**	**0.71**	0.26	0.36	**0.6**	**0.69**	**0.43**	0.29	1				
Mg^{2+}	-0.16	**0.74**	**0.77**	0.29	0.14	**0.65**	**0.64**	**0.47**	0.28	**0.41**	1			
Fe	0.02	0.17	0.13	-0.16	-0.04	0.18	0.23	0.24	0.05	0.17	0.13	1		
Mn	-0.05	-0.11	-0.07	-0.2	-0.05	-0.08	-0.11	0.04	-0.07	-0.07	-0.05	0.07	1	
As	0.01	-0.05	-0.04	-0.1	0.14	-0.12	-0.05	-0.01	-0.02	-0.12	0.01	0.32	0.07	1

3.2 Cluster analysis

Hierarchical cluster analysis was applied in order to classify groundwater samples according to their similar chemical properties. To create a dendrogram of groundwater samples, Ward linkage incorporated with Euclidean distance is used (Figure 1). Results show that groundwater samples were classified into three clusters: Cluster 1 (72.9%), Cluster 2 (19.7%), and Cluster 3 (7.9%). All three clusters are characterized by dominance of Ca^{2+} cation and HCO_3^- anion. Therefore, groundwater in the investigated area shows a dominance of Ca-HCO_3 hydrochemical type. Cluster 1 characterizes the highest average values of NO_3^- and PO_4^{3-} concentrations, suggesting that anthropogenic activities, such as agricultural practices, highly influence these samples. Cluster 2 showed the highest average concentrations of HCO_3^-, Cl^-, Na^+, Ca^{2+}, Fe, and As, indicating that these samples are highly influenced by natural or geogenic sources, such as water-rock interactions and rock weathering [9]. Considering average concentrations of examined chemical parameters in Cluster 3, this cluster shows the impact of both natural and anthropogenic sources.

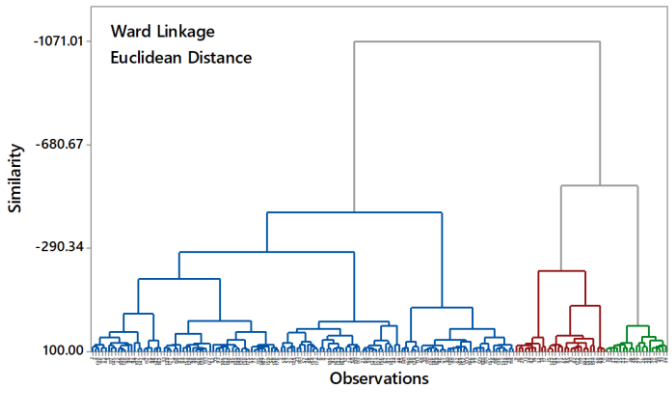

Figure 2. Dendrogram of the groundwater samples

3.3 Factor analysis

Factor analysis was conducted to identify the main pollution sources of groundwater. Varimax rotation was applied, and 14 factors were obtained. Furthermore, only factors with eigenvalues greater than one are extracted (Figure 2a), accounting for 59.50% of the total variance. Extracted factors with

their loadings are presented in Table 2. Parameter values greater than 0.7 are considered significant and are in bold. Factor 1 explains 35.10% of the total variance, with high loadings of EC, HCO_3^-, Cl^-, SO_4^{2-}, Na^+, Ca^{2+}, and Mg^{2+}. Major cations and anions mainly reach groundwater due to water-rock interactions, weathering of rocks, or ion exchange processes. Therefore, Factor 1 can represent the influence of natural sources on groundwater contamination. Factor 2 comprised 14.40% of the total variance, showing high loadings of NO_3^- and PO_4^{3-}. Nitrates and phosphates may originate from anthropogenic sources, such as agricultural practices, wastewater disposal, or sewage intrusion. The investigated area is known for its fertile land. In addition, large amounts of fertilizers are used in order to increase the yield of cultivated crops. Therefore, Factor 2 demonstrates the influence of agricultural practices on groundwater contamination. Factor 3 showed high loadings of Fe and As, explaining 10.0% of the total variance. Contents of Fe and As in groundwater are usually controlled by geomorphology. Thus, Factor 3 represents a geogenic source. Loading plot of Factor 1 vs. Factor 2 is shown in Figure 2b.

Table 2. Extracted factors after Varimax rotation

Parameter	Factor 1	Factor 2	Factor 3
pH	-0.322	-0.164	0.073
EC	**0.918**	-0.313	0.025
HCO_3^-	**0.860**	-0.112	-0.019
NO_3^-	0.152	**-0.806**	-0.185
PO_4^{3-}	0.144	**-0.721**	0.172
Cl^-	**0.801**	-0.247	0.003
SO_4^{2-}	**0.819**	-0.268	0.085
Na^+	**0.688**	-0.020	0.163
K^+	0.300	-0.584	0.047
Ca^{2+}	**0.774**	-0.236	-0.012
Mg^{2+}	**0.788**	-0.130	0.019
Fe	0.251	0.174	**0.735**
Mn	-0.001	0.341	0.247
As	-0.153	-0.117	**0.831**
Eigenvalue	5.478	1.580	1.265
Variance (%)	35.10	14.40	10.00
Cumulative variance (%)	35.1	49.50	59.50

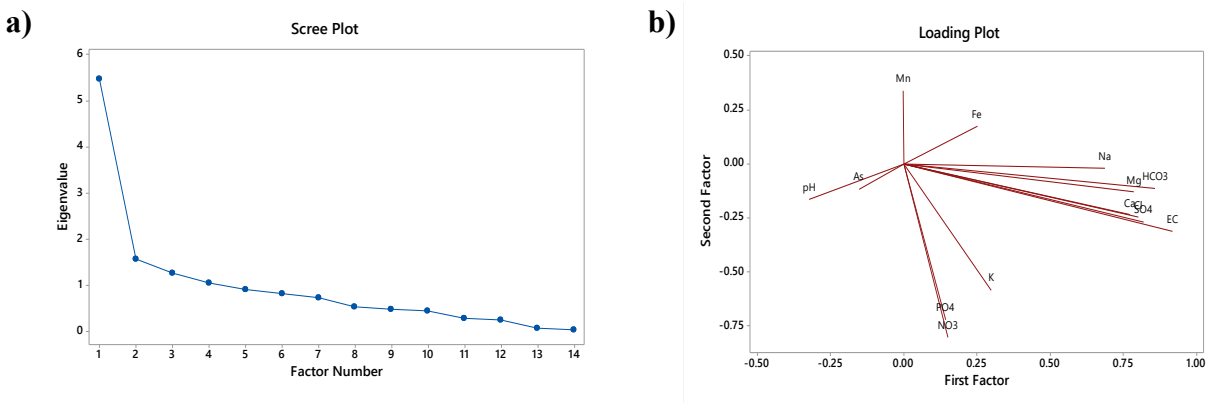

Figure 3. (a) Scree plot, (b) Loading plot

4. CONCLUSION

This work uses three multivariate statistical techniques to examine groundwater in the Morava River Plain, Serbia. HCA clustered groundwater samples into three groups, with Ca-HCO_3 being the prevailing hydrochemical type in all groups. HCA also revealed that both natural and anthropogenic factors impact groundwater chemistry. Pearson correlation matrix and FA results were consistent with the HCA results. FA extracted three factors, accounting for 59.50% of the total variance. Water-rock interactions, geogenic sources, and agricultural activities were identified as the main sources of pollution.

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ECOLOGICAL RISK ASSESSMENT OF ASPARTAME AND NEOTAME IN RIVER SEDIMENTS

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Abstract: *Artificial sweeteners are high-priority emerging contaminants that are widespread in surface waters worldwide as a result of municipal wastewater discharges into the aquatic environment. Given that these substances can cause toxic effects on aquatic organisms, they represent a potential risk for the river ecosystem as a whole. Although sediments have not often been the subject of scientific research on pollution with artificial sweeteners, there is a possibility that these substances pose a risk to sediment-dwelling organisms. Aspartame and neotame are sweeteners that have a high sorption affinity for organic-rich particles and partition to sediment in the water-sediment system. In order to determine the possible risk for benthic biota, an ecological risk assessment of detected aspartame and neotame in sediments from five rivers in Serbia was performed. In addition to the risk assessment of individual sweeteners, "the cocktail effect" of their mixture was also estimated. Detected levels were compared with the lowest predicted no-effect concentration (PNEC) values for sediment organisms from the Norman Ecotoxicology Database, based on experimental ecotoxicity data and QSAR model predictions for aquatic organisms.*
Keywords: Artificial Sweeteners, Ecological Risk Assessment, River Sediments, Benthic Organisms

1. INTRODUCTION

Artificial sweeteners are metabolically inert, calorie-free sugar substitutes widely used in food and pharmaceutical products [1]. These substances enter the environment in unchanged form through sewage system and their presence in natural waters has been documented worldwide [2,3]. Some ecotoxicological research has shown that artificial sweeteners can cause toxic effects on aquatic organisms, affecting the growth, behaviour and metabolism [4,5]. For this reason and their unknown long-term environmental fate, they belong to a new class of high-priority emerging contaminants [2]. In scientific literature, ecological risk assessment based on the detected levels of these compounds in river ecosystems has been evaluated only for water organisms [3]. Since sediments represent a functional part of aquatic ecosystems, determination of toxicological risk on benthic biota is a necessary step in a comprehensive overview of river ecosystem contamination with artificial sweeteners.

In this paper, ecological risk of aspartame and neotame was estimated to sediment-dwelling organisms in five rivers in Serbia (the Sava, the Danube, the Tisza, the Morava and the Veliki Lug). These sweeteners were selected for analysis based on their specific physical and chemical properties (high log K_{ow} and log K_{oc} values and low water solubility) [6], with a high sorption affinity for organic-rich particles and partitioning to sediment in the water-sediment system. Detected

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concentrations were compared with the lowest predicted no-effect concentration (PNEC) values for sediment organisms obtained from the Norman Ecotoxicology Database, based on experimental ecotoxicity data and QSAR model predictions for aquatic organisms [7]. In addition to the risk assessment of individual sweeteners, "the cocktail effect" of their mixture was also evaluated. The instrumental analysis of the prepared extracts was performed using liquid chromatography with tandem mass spectrometry (LC–MS/MS), as sensitive and reliable method for the detection of traces of artificial sweeteners in complex environmental matrices.

2. EXPERIMENTAL PART

2.1 Chemicals and reagents

Aspartame and neotame, as high purity (≥ 98%) analytical standards, were purchased from Sigma-Aldrich (Buchs, Switzerland). These sweeteners are approved for use as food additives in the Republic of Serbia (Regulation No. 53/2018) [8]. The solvent methanol (HPLC grade) was obtained from J.T. Baker (Gliwice, Poland). Ammonium acetate was of analytical grade.

2.2 Sampling and sample preparation

Five sediments samples were collected from the following rivers in Serbia: the Sava (SED1), the Danube (SED2), the Tisza (SED3), the Morava (SED4) and the Veliki Lug (SED5). Approximately 1 kg of the sediments was collected in plastic containers and kept in a freezer. After defrosting, the sediment samples were air-dried at room temperature, for several days, in the dark. Samples were then homogenized and sieved through 500 μm pore size sieve. Sediments were prepared for analysis using optimized ultrasonic extraction (USE) method with methanol as extraction solvent. The detailed preparation procedure is shown in a previous study of Gvozdić et al. 2020 [6].

2.3 LC–MS/MS analysis

LC analysis was performed using a Dionex UltiMate 3000 HPLC system (Thermo Fisher Scientific, Waltham, USA). Chromatographic separation of analytes was carried out on a Luna® C8 reverse-phase column, 150 mm × 3.0 mm i.d. and 3 μm particle size (Phenomenex, Torrance, USA). The mobile phase consisted of deionized water, methanol, and 0.1 mol L^{-1} aqueous solution of ammonium acetate. MS/MS analysis was performed using LTQ XL (Thermo Fisher Scientific) linear ion trap mass spectrometer, coupled with a HPLC system. Electrospray ionization (ESI) in negative mode was used as the ionization technique. LC–MS/MS operating parameters for the determination of aspartame and neotame were developed and optimized in a previous study [6].

2.4 Ecological risk assessment

Ecological risk to benthic organisms was evaluated based on risk quotients (RQs) calculated by dividing the measured environmental concentration (MEC) of selected sweetener with the corresponding predicted no-effect concentration (PNEC) for sediment organisms [3]. The PNEC values used in the study were obtained from the Norman Ecotoxicology Database as the lowest PNECs, based on experimental ecotoxicity data or predicted by QSAR (quantitative structure–activity relationship) analysis for freshwater organisms [7]. The lowest PNECs for sediment organisms ($PNEC_{sed}$) were calculated using the following equation (Eq. (1)):

$$PNEC_{sed} = PNEC_{freshwater} \times 2.6 \times (0.615 + 0.019 \times K_{oc}) \quad (1)$$

Ecological risk to benthic organisms is classified into four categories: "negligible/no risk" (RQ < 0.01), "low risk" (0.01 < RQ < 0.1), "moderate/medium risk" (0.1 < RQ < 1), and "high risk" (RQ ≥

1) [3,9]. In order to evaluate "cocktail effect" of the mixture of artificial sweeteners detected in each sediment sample, the RQ_{mix} was calculated, based on the concentration-addition method for risk assessment of mixtures, as the sum of the RQ values obtained from the individual sweetener concentrations (Eq. (2), [9]):

$$RQ_{mix} = \sum_{i=1}^{n} RQ_i \quad (2)$$

3. RESULTS AND DISCUSSION

Aspartame and neotame were found in all river sediment samples. The high detected levels of aspartame (Table 1) reflect high consumption of this sweetener in the human diet in Serbia. The highest concentrations of aspartame detected in rivers the Sava (sample SED1, 568 ng/g) and small river the Veliki Lug (sample SED5, 355 ng/g) point to their high contamination by municipal wastewater. On the other hand, neotame was recorded at significantly lower levels which can be explained by the lower use in food and beverages of this relatively new artificial sweetener. Neotame was found at the highest concentrations in the Veliki Lug River (sample SED5, 56 ng/g) and the Danube (sample SED2, 48 ng/g) indicating high sewage input in these water bodies. In predominantly agricultural regions of sampling sites on rivers the Tisza and the Morava (samples SED3 and SED4), levels of neotame were significantly lower (2 and 6 ng/g, respectively).

Table 1. Ecological risk assessment of aspartame and neotame for sediment-dwelling organisms detected in sediment samples of five rivers in Serbia

River	Sample	Aspartame (ng/g)	RQ*	Ecological risk	Neotame (ng/g)	RQ*	Ecological risk
Sava	SED1	568 ± 71	1.47	high risk	12 ± 3	0.57	medium risk
Danube	SED2	117 ± 20	0.30	medium risk	48 ± 9	2.30	high risk
Tisza	SED3	210 ± 31	0.54	medium risk	2 ± 0	0.09	low risk
Morava	SED4	184 ± 16	0.47	medium risk	6 ± 1	0.29	medium risk
Veliki Lug	SED5	355 ± 42	0.92	medium risk	56 ± 10	2.68	high risk

*$PNEC_{sed}$ values (385 μg/kg for aspartame and 20.9 μg/kg for neotame)

Ecological risk assessment based on the detected levels of aspartame and neotame in five rivers in Serbia indicates low (0.01< RQ < 0.1) to a high risk (RQ ≥ 1) for sediment-dwelling organisms. According to the $PNEC_{sed}$ value for aspartame (385 μg/kg), noticeably high environmental risk (RQ ≥ 1) was recorded in the Sava River (sample SED1). The RQ values for aspartame in other investigated rivers in Serbia were ranging from 0.30 to 0.92, implying medium risk (0.1 < RQ < 1) for benthic biota.

As for neotame, taking into account its $PNEC_{sed}$ value (20.9 μg/kg), high ecotoxicological risk was observed in rivers the Veliki Lug and the Danube, while detected levels in the Sava and the Morava pointed to medium ecological risk. Low risk was determined for sediment from the Tisza, probably as a consequence of lower wastewater burden. In addition, according to the mixture risk approach, calculated RQ_{mix} have shown that the "cocktail effect" of detected sweeteners should be taken into account when assessing the risk to environment. The most pronounced "cocktail effect" was observed for the rivers the Veliki Lug (RQ_{mix} = 3.60) and the Danube (RQ_{mix} = 2.60), both heavily impacted by untreated municipal wastewater (Figure 1).

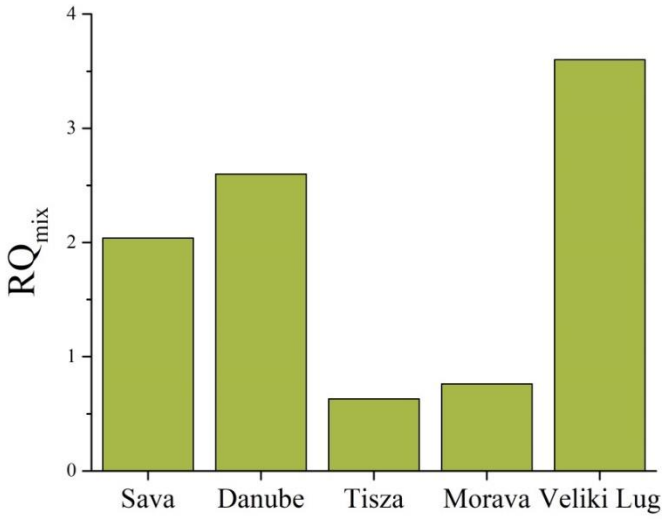

Figure 1. The risk quotients for a mixture (RQ_{mix}) of artificial sweeteners detected in sediments of five rivers in Serbia

The obtained results clearly show that sediments of river ecosystems in Serbia are of great concern in terms of detected artificial sweeteners. Because sediments are a major sink of organic pollutants, they can be a secondary source of pollution in the case of resuspension. Since wastewater treatment in Serbia is generally rare, continuous accumulation of these contaminants in sediments is inevitable. Therefore, investments in the construction of municipal wastewater treatment plants and introduction of new treatment processes, as well as stricter control of sewage pollution in Serbia are necessary.

4. CONCLUSION

The levels of aspartame and neotame detected in rivers the Sava, the Danube, the Tisza, the Morava and the Veliki Lug indicate a significant ecological risk for benthic organisms. The highest ecotoxicological risk was recorded in the Veliki Lug, the Danube and the Sava, as a result of extensive municipal wastewater discharges. This was determined according to risk quotients of the mixture of the two detected artificial sweeteners. The ecological risk was less pronounced in the agricultural regions of the Tisza and the Morava Rivers. The results presented in this study clearly show that untreated wastewater discharges in Serbia affect the quality of river ecosystems and threaten the benthic biota. The estimated high risk to the aquatic environment requires the improvement of municipal wastewater treatment and management and the inclusion of artificial sweeteners in routine monitoring programs.

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IMPACT OF URBAN HEAT ISLAND ON BUTTERFLY-BUSH (*BUDDLEJA DAVIDII* FRANCH.)

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Abstract: *Urban vegetation serves multiple functions beyond aesthetics, including a pivotal role in shaping the microclimate of modern cities. The ongoing climate change and extreme temperature variations affect the growth and development of plants. As a result, investigating the adaptive potential of plant species to temperature variations within urban environments is gaining critical importance. While researchers worldwide have delved into the influence of biotic and abiotic factors on plants, the variability of plant organisms within urban ecosystems remains unexplored. Therefore, this paper seeks to assess the impact of the urban heat island (UHI) within a humid continental climate (Belgrade, Serbia) on Buddleja davidii Franch. A comparative analysis of interpolated temperatures sourced from meteorological stations in urban, sub-urban and rural zones for all four seasons was undertaken. The causal relationship was confirmed: not only the influence of vegetation on temperatures but also the impact of UHI on the presence and sustenance of vegetation. Namely, a substantial increase in temperature affects the seasonal changes of the butterfly-bush, particularly during extreme climatic events. The obtained results provide an essential foundation for planning and design of urban landscapes that should be adapted to the changed dynamics to ensure the ecosystem services provided by urban shrubs.*
Keywords: Urban Heat Island, Urban Meteorology, Climate Change, Benefits of Plants, Urban Shrubs

1. INTRODUCTION

While investigating the urban climate of 19th century London, Howard [1] became the pioneer in analysing the Urban Heat Island (UHI) effect. These "heat islands" remain relatively stable over time, creating warm air domes above buildings, roads, and other impermeable surfaces. These surfaces enhance the absorption of short-wave radiation, reduce energy loss through the emission of long-wave radiation, and diminish evapotranspiration compared to the natural land cover of the surrounding rural areas. Thermal homogeneity can be disrupted or altered by the presence of green and water surfaces, as noted by Walker et al. [2].

Although urban areas constitute a small portion of local and global ecological systems, their impact on these ecosystems is considerable. Conversely, urban vegetation plays a crucial role in mitigating local temperatures through shading and transpiration. Furthermore, it offers valuable ecosystem services, including carbon sequestration and the provision of habitats for various flora and fauna [3] . Given that phenology, specifically the annual cycle of leafing, leaf development, and senescence, is tightly regulated by temperature in numerous ecosystems, extensive research efforts are directed towards analysing the effects of climate change on these ecosystems [4].

UHI effects have the potential to alter the seasonal vegetation changes in urban areas, particularly affecting exotic and ornamental shrubs [5]. Therefore, our study examines the impact of UHI on the spatial complexity of butterfly bush phenology. We achieved this by recording phenological patterns

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across urban, suburban, and rural zones. Within this general framework, our study aimed to quantitatively assess and define the nature of UHI and its influence on phenological patterns. The final goal was to address the challenges of urban design and the utilisation of ornamental shrubs, such as the butterfly-bush.

2. MATERIALS AND METHODS

The research encompasses an area of 446 km^2 within the city of Belgrade, Serbia (Figures 1 and 2). The sites selected for the study of the variability of *Buddleia davidii* Franch. seasonal changes were chosen to represent the broader environment, with a focus on varying degrees of urbanisation and coverage of urban, suburban, and rural settings.

To achieve the objectives of this study, three specific sites were examined in the following municipalities: (1) Vračar (Karadjordjev Park, adjacent to Bulevar Oslobođenja), (2) Surčin (alongside the M266 highway), and (3) Čukarica (Ostružnica, alongside the M19 highway). Each site had 3 to 5 shrubs registered. A more detailed description of the research sites can be found in Table1.

Table 1. Research area description

Location	Latitude φ	Longitude λ	Altitude H (m)	Aspect	Slope*
1.	44º 47' 39.07 " N	20º 27' 57.94" EGr	108	SW	5.2°
2.	44º 49' 49.94" N	20º 16' 47.31" EGr	93	N	0.8°
3.	44º 43' 06.58" N	20º 18' 43.15" EGr	97	W	4.5°

* Slope angles: 0-1° (flat terrain), 3-5° (slightly inclined terrain) and 5-8° (fairly inclined terrain)

An analysis of the impact of the urban heat island on this species was conducted utilising climatological data for the thirty-year period from 1991 to 2020, as well as the autumn of 2022 and the winter of 2022/2023. The data were sourced from the Main Meteorological Stations (MMS) at three locations: Belgrade (44º47' 54.44" N; 20º27' 53.35" EGr; altitude: 132m), Surčin Airport (44º49'27.37" N; 20º17'27.82" EGr; altitude: 99m), and Košutnjak (44º46'15.57" N; 20º25'27.75" EGr; altitude: 203m) [6].

The assessment of temperature normality and diurnal temperature trends followed the methodology proposed by Fries et al. [7], according to which the final interpolation included a digital elevation model and the temperature data from the stations. The interpolation process was executed using ArcGIS/ArcMap 10. To assess the impact of UHI on this ornamental shrub, phenological patterns and events were monitored from 2012 to the summer of 2023 across three distinct locations: (1) an urban (2) a rural and (3) a suburban zone. The BBCH scale [8] was employed for phenological observations over a span of 10 consecutive years. The date of End of Leaf-Fall (ELF) was noted at intervals ranging from 2 to 4 days.

Throughout the autumn, winter, and spring of 2022/2023, the growth and development of twigs and leaves were recorded in the cold part of the year (19 January 2023) and in the first half of the growing season (May 2023). Shoot Length (SL) marking the beginning of shoot growth, Shoot Final Length (SFL) when shoots reach approximately 90% of their final length, Leaf Length (LL) and Leaf Width (LW) were measured. The material was collected during field research, with an aim to obtain 50 leaf and 10 shoot samples for quantitative analysis from each individual within Site 1. Consequently, the cumulative sample encompassed 250 leaves and 50 shoots. For the purpose of morphological structure assessment, herbarium specimens were employed to measure attributes such as shoot length, leaf length, and maximum leaf width using the UTHSCSA Image Tool. Quantitative parameters were processed using descriptive statistics and a one-way Analysis of Variance (ANOVA) analysis. The analysis was conducted using the Statgraphics Centurion 19 software package.

3. RESULTS AND DISCUSSION

By utilising interpolated mean daily air temperatures from the thirty-year reference period, the average seasonal air temperatures were determined for each site, as follows:
Autumn: Site 1: 13.37°C, Site 2: 12.74°C, and Site 3: 12.93°C.
Winter: Site 1: 2.89°C, Site 2: 2.04°C, and Site 3: 2.29°C.
Spring: Site 1: 13.44°C, Site 2: 12.71°C, and Site 3: 12.75°C.
Summer: Site 1: 23.24°C, Site 2: 22.65°C, and Site 3: 22.64°C (Figure 1).

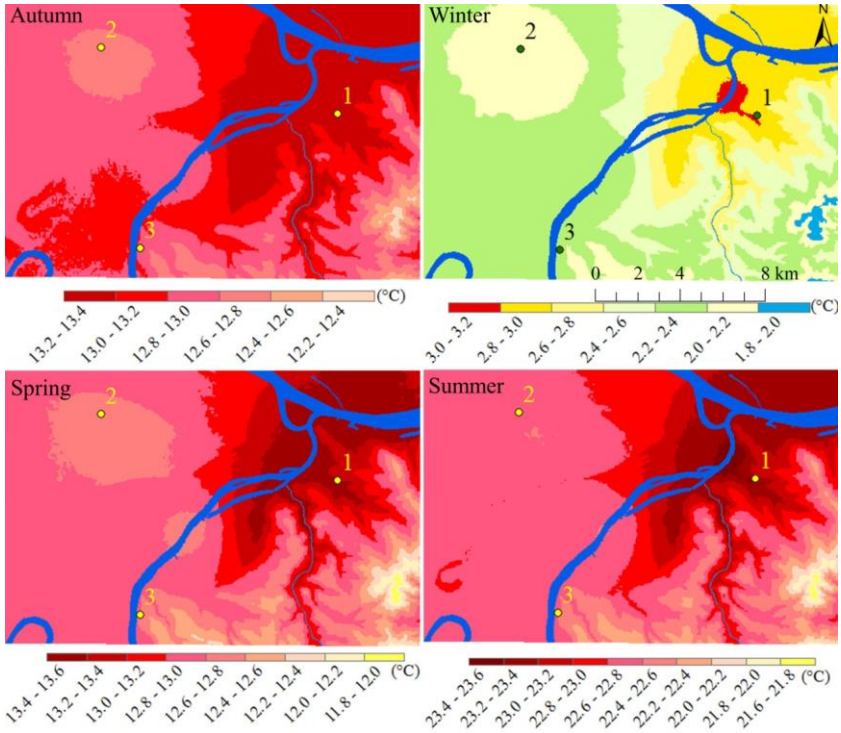

Figure 1. Spatial distribution of mean seasonal air temperatures (ºC) in the research area for the reference period 1991-2020

The research area had the following mean seasonal air temperatures by site for the autumn of 2022: Site 1: 14.32°C, Site 2: 13.55°C, and Site 3: 13.75°C. During the subsequent winter of 2022/2023, the mean seasonal air temperatures were: Site 1: 5.89°C, Site 2: 5.24°C, and Site 3: 5.39°C (Figure 2). Deviations from the normal (1991-2020) for the mean seasonal air temperatures during the autumn of 2022 and winter 2022/2023 were positive. This indicates that temperatures were higher than the normal means. Specifically, for the autumn period, temperature deviations by site were as follows: Site 1: 1.42°C, Site 2: 0.81°C, and Site 3: 0.82°C. Similarly, during the winter period, deviations were as follows: Site 1: 3.00°C, Site 2: 3.20°C, and Site 3: 3.10°C.
The findings of the research support the conclusion that the autumn of 2022 was warm, including a heat wave occurring in late October and early November. The winter in Belgrade was the second warmest since 1888, and it was marked by a record low number of frost days. Applying the percentile method, the mean seasonal temperature for the winter in Belgrade fell into the extremely warm category, as classified by RHMS. Several periods of warm weather were observed, with air temperatures exceeding the multi-year average. These warm intervals included the end of the first decade, the middle and the third decade of December, as well as the first decade, the end of the second decade of January, and the end of the second and the beginning of the third decade of February. Conversely, cold periods, characterised by temperatures below the multi-year average, occurred in mid-December, and at the end of the first and the beginning of the second decade of February [9]

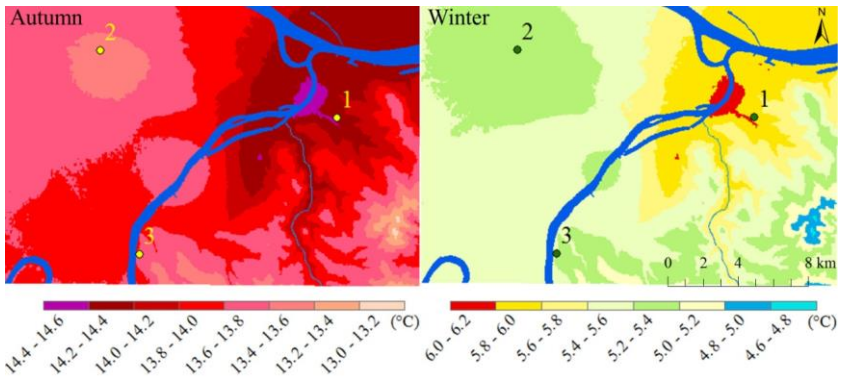

Figure 2. Spatial distribution of mean seasonal air temperatures (ºC) in the research area for autumn of 2022 and winter of 2022/2023

The research conducted in these three locations revealed that between 2012 and 2021, all specimens of the butterfly-bush exhibited deciduous habit in urban, sub-urban, and rural areas. The phenophase of early leaf fall (ELF) during this ten-year period occurred from 2 December to 28 December. Each site had butterfly-bush specimens whose characteristics and clustering tendencies were typical of the plant aged between 17 to 23 years. Studies by Kunick [10] and Ocokoljić & Petrov [11] suggest that these plants can live up to 40 years. However, an evergreen growth mode was recorded for the first time in the autumn and winter of 2022/2023, but only at Site 1. This specific site clearly identified as an Urban Heat Island (UHI) based on temperature data from the reference period and the last year (Figures 1 and 2). The butterfly-bush is recognised as capable of developing both as a deciduous and an evergreen shrub [12]. However, the evergreen form was observed for the first time in the Belgrade urban environment within the UHI zone. In contrast, specimens within sub-urban and rural zones remained deciduous, with the ELF phase registered at Sites 2 and 3 from 4 December to 27 December 2022.

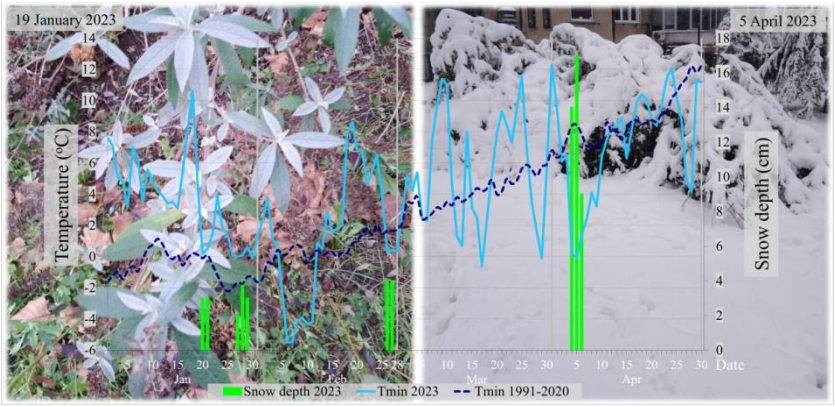

Figure 3. Butterfly-bush at Site 1 with an overview of snow depth, minimum daily air temperatures from 1 January to 30 April 2023 and their normals for the reference period 1991-2020

Taking into consideration species' application, it is stressed that the most notable plant responses to climate change are seasonal variations, including a prolonged growing season, an earlier onset of spring, and delayed autumn phenophases [13]. The findings of the conducted research confirm that the effects of the UHI led to an evergreen mode of growth and shoot development in December and January at Site 1. These findings align with the observations made by Denny et al. [14], who emphasised that phenology exhibits variations in response to local climate conditions. Low temperatures and snowfall during the winter and spring of 2023 did not lead to leaf fall (Figure 3).

A comparative analysis of winter and spring growth reveals the distinctive traits and general characteristics of the species. Statistically significant differences were determined for all three traits through a one-way ANOVA test, yielding p-values below 0.0001 and F-values of 224.426 (shoot length), 39.855 (leaf width), and 21.250 (leaf length). These findings were substantiated by low

standard deviation values and coefficients of variation for all variables. Figure 4 presents the key elements of descriptive statistics. This research unveiled that for the first time in eleven consecutive years of study, the UHI effect brought about the evergreen nature of the butterfly-bush and triggered an early onset of the growing season (growth and leafing) in 2023.

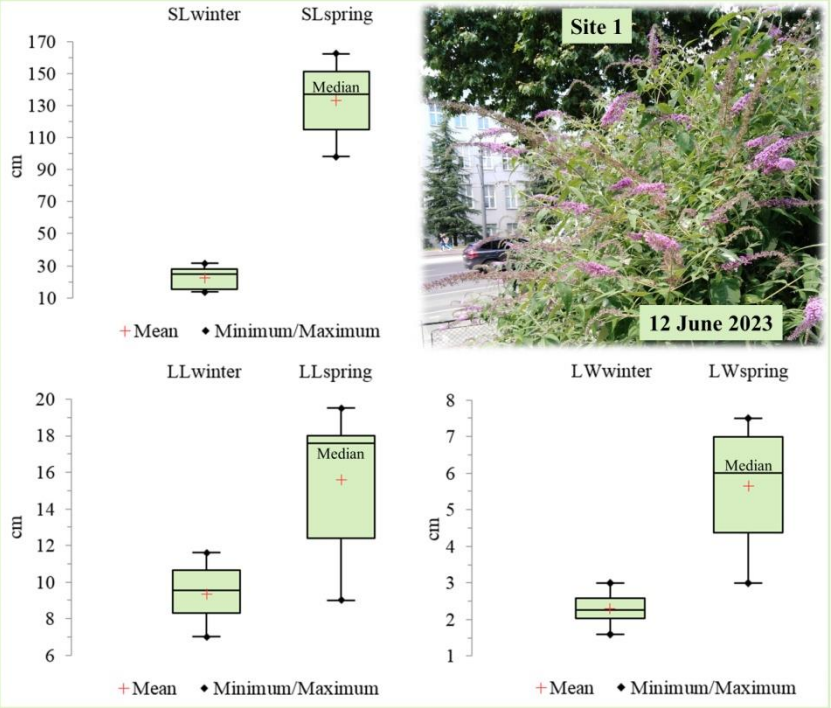

Figure 4. Morphological and metric characteristics: shoot length (SL), leaf length (LL) and leaf width (LW) of butterfly-bush for winter (winter, 19 January 2023) and spring (spring, 25 May 2023) for Site 1

The obtained results form the foundation for the operationalisation of landscape design that plays a pivotal role in the management of local landscapes and the assurance of environmental sustainability [15]. The novelty in this study lies in evaluating the response of the butterfly-bush to heat, particularly in regions affected by the Urban Heat Island (UHI) effect. This assessment holds promise for its potential application in the redesign of urban landscapes since the butterfly-bush serves as a significant nectar source, attracting butterflies during its flowering phase, while also providing sustenance for birds during cold months.

4. CONCLUSIONS

Based on research conducted in urban, suburban, and rural zones in Belgrade, it was confirmed that the UHI has an impact on the phenology of the butterfly-bush. Considering the anticipated widespread effects of climate change in urban areas, it is imperative that further research be undertaken in the upcoming period. While the exact implications of these changes remain unclear, the ongoing reality of global warming underscores the increasing responsiveness of urban areas to climate change. Consequently, urban ecosystems are certain to undergo significant functional and structural transformations. The results of this study stress the potential of the butterfly-bush to yield significant social benefits within cities not only through the reduction of UHI intensity but also through the provision of ecosystem services of urban shrubs.

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ENVIRONMENT AND SUSTAINABLE DEVELOPMENT. MECHATRONICS. OCCUPATIONAL SAFETY AND HEALTH AND FIRE SAFETY. SMART MANAGEMENT SYSTEMS. GRAPHIC ENGINEERING. DESIGN. TRAFFIC ENGINEERING. BIOTECHNOLOGY AND HEALTHCARE. MECHANICAL ENGINEERING. ECOTOURISM AND RURAL DEVELOPMENT.

EFFECTS OF URBANISATION ON *SIMPHORICARPOS ORBICULATUS* MOENCH IN THE GREEN INFRASTRUCTURE OF BELGRADE

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Abstract: *Despite the well-documented intra-urban variability of Urban Heat Island (UHI) effects, little is known regarding the spatial and temporal variability in coralberry's response to UHI. The beginning and conclusion of the growing season were determined using hourly and daily climate data sourced from the Republic Hydrometeorological Service of Serbia (RHMS). This study deals with the impact of urbanisation on coralberry phenology in Belgrade from 2007 to 2023. Among various components of green infrastructure, we analysed urban parks and a city cemetery. Urban parks exhibited a less pronounced change in the duration of their growing seasons, owing to the interaction between the UHI and the cooling effect within parks. These research findings address two crucial gaps in urban phenological studies: the influence of urban composition on phenology and the role of micrometeorological observations in shaping coralberry phenological patterns. Furthermore, they shed light on shifts in coralberry's phenological patterns under the influence of urbanisation, a matter of significance due to its impact on biodiversity, ecosystem services, and implications of land use, management, restoration, and landscape planning and design.*
Keywords: Urban Ecology, Temperature, Urban Green Spaces, Phenology, Sustainability

1. INTRODUCTION

The conversion of natural and agricultural land into urban areas is on the rise every year. Projections for urbanisation in 2030 indicate that it will reach 81% of the total population, compared to 1960, when it stood at just 34% and 2014, when it increased to 54%. This rapid urbanisation, driven by the high demand for land use change, has detrimental effects on the environment, particularly on the urban climate, giving rise to Urban Heat Islands (UHIs) that increase temperatures within urban centers [2]. However, green spaces or green infrastructure (GI) can help ameliorate these adverse impacts by reducing both the maximum temperatures and temperature fluctuations in cities. Previous research primarily relied on on-site observations and focused on measuring air temperatures to quantify the cooling effects of specific structures and types of green spaces. It's worth noting that the degree of cooling is affected by the type, structure, and size of green spaces. For instance, diverse types and compositions of green spaces in urban areas tend to have more pronounced cooling effects than green spaces with simple, less intricate structures [3]. However, the effect of UHIs on specific plant species, particularly shrubs, continues to pose a challenge. To address the gaps in the existing research literature, this study aims to identify and classify heat-resistant coralberry individuals within GI in the context of intensive urbanisation in Belgrade. Furthermore, it aims to analyse how UHI affects coralberry plants growing in various types and structures of green areas located within the UHI zone of Belgrade, with varying degrees of urbanisation. The findings of this research will

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contribute to the planning and designing of GI elements, optimising their size and distribution to develop the most adequate coralberry compositions.

2. MATERIAL AND METHODS

The research was conducted in the territory of Belgrade, Serbia (Figure 1), specifically in the municipalities of Savski Venac (Site 1: Milutin Milanković Park and Site 2: Three Keys Park (*Ser. Park tri ključa*)) and Palilula – (Site 3: New Cemetery (*Ser. Novo groblje*)). The sites were selected based on cartographic material, urbanisation degrees, and on-site investigations. The primary criterion for choosing these sites was the presence of coralberry, aiming to determine its adaptability, which positions it as a potentially valuable addition to the urban GI. Furthermore, the study examined various approaches to its implementation, including solitary, group, and linear arrangements, with the aim of ensuring balanced and harmonious spatial development from the perspectives of landscape architecture, ecology, and art [4].

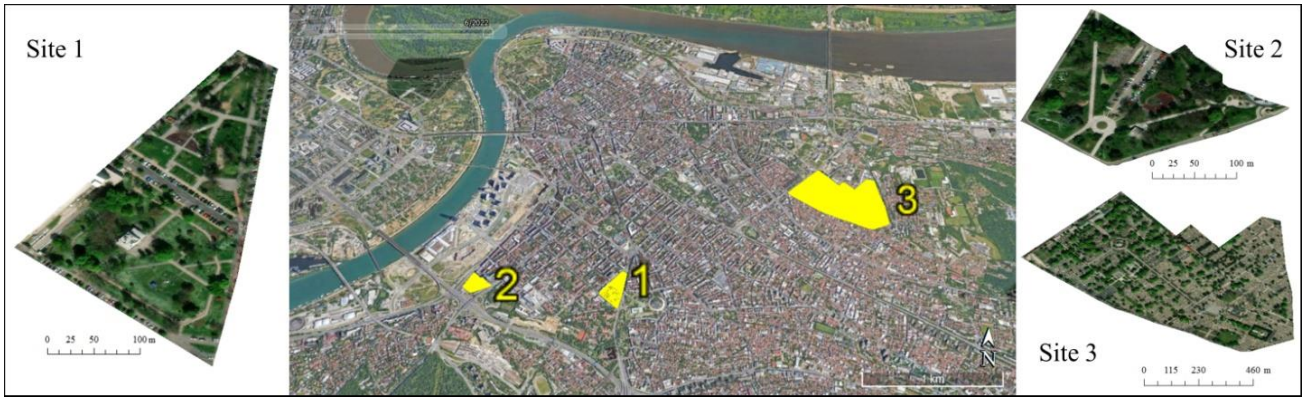

Figure 1. Research area

Site 1, spanning an area of 33.376 m^2, lies in the GI of Belgrade commonly known as Western Vračar (*Ser. Zapadni Vračar*). It is situated between Tiršova Street, Pasterova Street, and the Boulevard of Liberty (*Ser. Bulevar oslobođenja*). The park hosts 14 coralberry plants, all belonging to a 20-year-old group planting. It encircles the First Serbian Meteorological Observatory and underwent reconstruction in 2010 (source: JKP Zelenilo Beograd, https://www.zelenilo.rs/publikacije/zeleni-informator). Site 2, with a total area of 21.394 m^2, is in proximity to the E75 road, Kneza Miloša Street and some local roads. This area is within the Three Keys Park, formerly known as Beautiful Appearance (*Ser. Lep izgled*), which underwent reconstruction in 2022. Within this park, a solitary, mature coralberry plant, aged 23 years, has been recorded. Site 3, boasting an area of 310.102 m^2, is the New Cemetery situated on Ruzveltova Street. This cemetery, established in 1886, was the first planned and regulated burial ground in Belgrade. It is protected as an immovable cultural asset of Belgrade [5]. A line of 16 coralberry specimens, aged 27 was recorded. The total sample counts 31 selected plants which all remained healthy and undamaged throughout the 17-year research period, during which they were pruned in the cold part of the year before the growing season.

Phenological data spanning from 2007 to 2023 were obtained through visual observations conducted twice a week on the same day at all sites, using the extended *BBCH* scale, as defined by Meier [6]. The following dates were determined: the day of bud break (BB), i.e. flower bud scale opening in 2023, the beginning of flowering (BF), i.e. the day with more than 10% of the flowers open, the end of flowering (EF), marking the day when the flowering process was completed, and fruit abscission (FA) for the period spanning 2007 to 2023. Using the digital messaging system introduced by Koch et al. [7], these dates were converted into days of the year (DOY), with 31 January corresponding to 31 DOY. The calculation of the required number of cold hours (CH) for flower bud scale opening was based on the methodology of Cosmulescu & Ionescu [8], which entailed summing the hours when temperatures were below 7°C and above 0°C. This calculation began on 1 November, as the stated authors suggest that temperatures before this date are too high to contribute to the accumulation

of cold hours in a humid continental climate. We calculated the growing degree days (GDD) for the period after the bud break in 2023 and from 1 January to the beginning of flowering (BF) for 2007-2022. We followed the methodology outlined by Lalić et al. [9] and used a temperature threshold of 5°C, as recommended by the World Meteorological Organization (WMO) [10]. For the years 2007 to 2022, BF and EF were expressed as mean values determined based on data collected from the observed sites. The data obtained from phenological observations were statistically analysed employing descriptive statistics and the relationships between temperature and phenological events were examined using Spearman's correlation coefficient (ρ).

In addition, the fruit analysis comprised two diameters (R_1 and R_2), the length and width of the fruit clusters (LC), and the number of fruits in each cluster (№F). Fruits for analysis were handpicked in early autumn from the southern part of the canopy at the time when they had reached full maturity. To maintain the fruit moisture content, they were packed carefully in appropriate containers designed to prevent them from heating up. Each individual yielded a sample of 100 fruits whose diameters were measured using a Starrett 727 series digital calliper (Athol, NE, USA). The total number of sampled fruits stood at 3,100.

Quantitative data underwent statistical analysis, which included descriptive statistics, Spearman's correlation coefficient (ρ), one-way ANOVA, and cluster analysis. These statistical procedures were carried out using IBM SPSS Statistics 21, XLSTAT 2020, and ArcGIS/ArcMap 10.3. Meteorological data for the reference period of 1991-2020 and 2021/23 were sourced from the Main Meteorological Station in Belgrade (44º 47' 54.44"N; 20º 27' 53.35"EGr). This data was retrieved from RHMS (Republic Hydrometeorological Service of Serbia) on June 30, 2023.

3. RESULTS AND DISCUSSION

Green Infrastructure (GI), and its relationships with urban fabric patterns in highly urbanised environments, play a significant role in the planning and design of urban green spaces. Examination of GI within central Belgrade reveals its fragmented nature (Figure 1). Moreover, this densely built-up area is characterised by the limited number and size of green spaces. The urban vegetation predominantly comprises trees and lawns, with a relatively lower presence of shrubs such as coralberry in the overall composition.

Based on 16 years of records, it was determined that the lowest GDD for coralberry BF occurred in 2022 (530.3°C), while the highest was recorded in 2018 (876.1°C). In the case of EF, the lowest GDD was observed in 2011 (1825.8°C) and the highest in 2022 (3699.8°C). The mean GDD value for BF over the 16-year period was 714.2°C, while it was 2307.8°C for EF (Figure 2). Regarding BF, the lowest average DOY was 125 in 2022, while the highest was 147 in 2021. In the case of EF, the lowest DOY was recorded in 2011 (201), and the highest was in 2022 (325). The mean DOY value for BF over the 16-year period was 133, while it was 224 for EF (Figure 2). Linear trends and Spearman's correlation coefficient (0.930) indicate that over 16 consecutive years, there was a direct correlation between DOY and GDD for BF. Furthermore, the low values of standard deviation and variation coefficients suggest that there were no statistically significant differences between the research years. The obtained results align with Réaumur's findings [11], indicating that plant growth and development are more closely linked to the accumulation of heat units (GDD) than to daily air temperatures during phenophases. Linear trends for EF indicate growth in both DOY and GDD. However, Spearman's correlation coefficient of 0.141 suggests a relatively weak correlation. EF GDD exhibits substantial standard deviations alongside a low coefficient of variation. There is clear evidence of an increase in mean annual temperatures during the phenophases, which affects their duration [12]. Furthermore, these results affirm the impact of extreme climatic events and climate changes on the prolongation of phenophases [10].

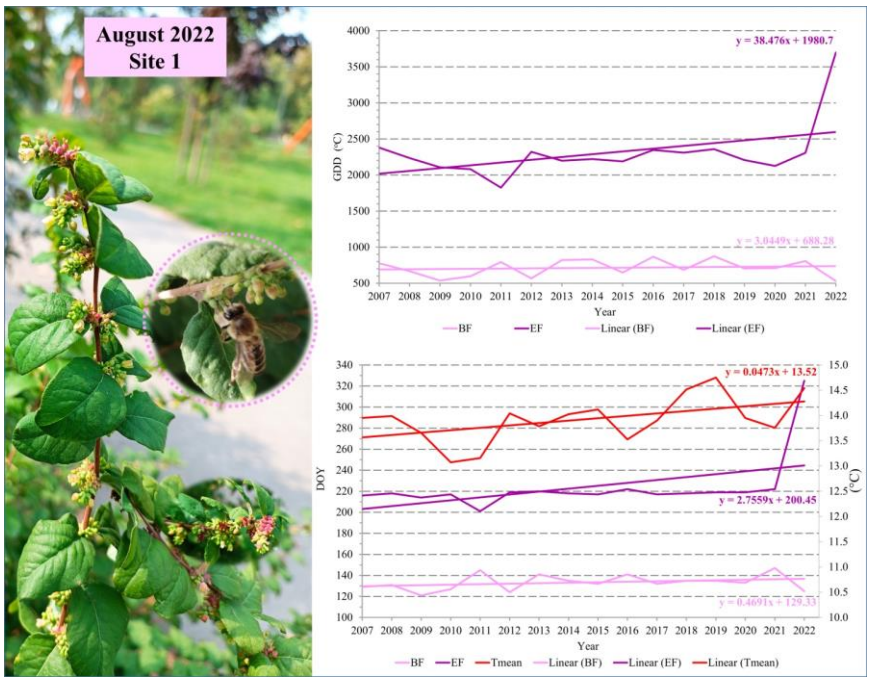

Figure 2. Coralberry Phenogram – DOY and GDD for BF and EF parameters from 2007 to 2022 at research sites, mean annual air temperatures, and linear trends

Given that 2022 marked the second-warmest year in Belgrade since 1888 (RHMS), the research in 2023 was conducted on the sites whose number of accumulated cold hours (CH) between 1 November 2022 and the bud break in 2023 varied from 1763 hours at Site 1 to 1776 hours at Sites 2 and 3. It should be noted that bud break varies with individual plants and locations, as well as the requirement for growing degree days (GDD) after dormancy [13]. The lowest value for BF was recorded at Site 1 (10.5°C), followed by Site 3 (17.5°C), and Site 2 (28.5°C). Spearman's correlation coefficients computed for BF, with a probability of $p<0.05$, confirmed the statistically significant positive correlation between CH and the number of days from 1 November. However, no other correlations were found to be significant. These findings provide a crucial foundation for the planning and sustainability of green infrastructures that include coralberry as a species whose flowers serve as a source of nectar for bees, wasps, and flies (Figure 2). The fruits, displaying hues of purple, pinkish-purple, and coral-pink, ripened successively. Their dispersion (FA) started in late autumn, primarily due to consumption by birds. Throughout all the years of our research, they persisted until the summer of the following year. These findings contrast with the conclusions presented in Link [14] and Hidayati et al. [15] that the fruits typically endure until spring, which may be indicative of the impact of urbanisation or the Urban Heat Island (UHI) effect across all research sites. Our study aligns with the hypothesis that fruits of red hues represent an evolutionary trait associated with bird preferences for these specific colours [16].

The research has provided insights into the morphological traits of fruits and their clusters, contributing to our understanding of the acclimatisation of the coralberry, a non-native species introduced from North America, in the GI of Belgrade [13]. Since the fruits of the coralberry persist through the winter, a period when a small number of species in GI Belgrade bear fruits, we investigated the metric and morphological features of these fruits and their clusters.

The minimum R_1 ranged from 2 mm (Site 2) to 6 mm (Site 3), while R_2 ranged from 1 mm (Sites 1 and 2) to 5 mm (Site 3). Conversely, the maximum R_1 was between 9 mm (Sites 2 and 3) and 10 mm (at Site 1), while R_2 ranged from 7 mm (Site 2) to 8 mm (Sites 1 and 3). Both diameters exhibited low standard deviations and correlation coefficients, indicating low variability within the study sites. Compared to the results reported by Link [14] and Hidayati et al. [15] that the diameter variation typically ranges from 4 mm to 4.5 mm, the recorded mean diameters were larger at all sites, ranging from 5.4 mm to 7.6 mm. One-way ANOVA test, with a p-value of <0.0001, and F-values of 8.070 for R_1 and 5.325 for R_2 confirmed the lack of statistical significance between the sites. Moreover, the

dimensions of fruit clusters and the number of fruits per cluster had not been previously studied. Our research revealed that the average length of the clusters ranged from 22.74 mm (Site 3) to 25.26 mm (Site 1), while the width ranged from 14.04 mm (Site 3) to 17.59 mm (Site 1). Statistical insignificance was confirmed by the small values of the standard deviation, correlation coefficients, as well as the values of the F of the one-way ANOVA test ($p<0.0001$) of 1.292, and 11.098, respectively. The mean number of fruits per cluster ranged from 11.370 (Site 3) to 19.22 (Site 1). The small values of standard deviation and coefficient of variation suggest approximately the same number of fruits per cluster within each location. Furthermore, the F-test of one-way ANOVA yielded a value of 17.641, indicating relatively low significance in the differences between the study sites. Spearman's correlation coefficients (0.653, 0.718, and 0.719) indicate a significant correlation between the length of the cluster and the number of fruits per cluster in 2022, as expected. However, for the other parameters, Spearman's correlation coefficients were either insignificant or of very low significance.

According to Reyers et al. [17], it is essential to adapt to the local context and apply an approach that includes mutual relations. To achieve this goal, and to determine the extent of additional services of GI ecosystems with coralberry, a cluster analysis was conducted using the morphometric characteristics of clusters and fruits (Figure 3). Based on the morphometric characteristics of coralberry fruits and their clusters, Sites 1 and 2 were identified as a closely related pair. Both sites are parks within the municipality of Savski Venac, where the urbanisation rate stands at 91.89%. In contrast, Site 3 – the New Cemetery in the municipality of Palilula, with an urbanisation rate of 10.33%, exhibits significant differences regarding the analysed characteristics (https://land.copernicus.eu/local/urban-atlas/urban-atlas-2018).

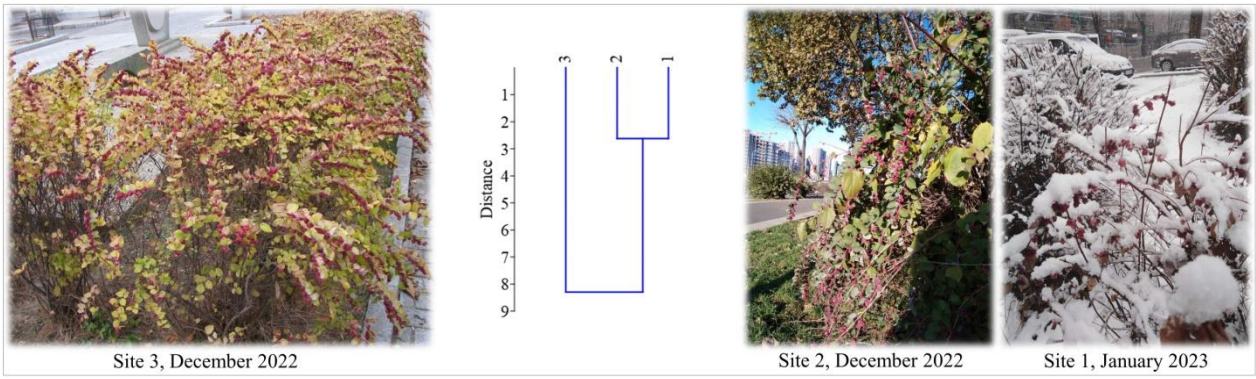

Figure 3. Cluster analysis conducted using morphometric traits of fruits and clusters with accompanying personal photographic material from the studied GI elements in Belgrade

4. CONCLUSION

The obtained results confirm the significance of coralberry as a component of GI in highly urbanised areas. It enables the creation of vibrant and cascading visual effects (with its arched branches) during autumn and winter and its fruits serve as a valuable food source for birds and small mammals. This research contributes to our expanding understanding of coralberry's interactions with the environment and its impact on ecosystem services. The findings suggest that when selecting plant species for GI in UHI areas, fruit colour should be taken into consideration. This applies to both new elements and the reconstruction of existing ones, as it can expedite the ecological succession process and optimise additional ecosystem services.

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CHEMICAL VARIABILITY OF PERSONAL CARE AND COSMETIC PRODUCTS

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Abstract: *Personal care and cosmetic products (PCCPs) are diverse group of products designed to maintain a good personal hygiene and health, enhance the appearance, and promote overall well-being. Today, the cosmetic industry is offering a vast number of PCCPs, but although the field is regulated and constantly evolving, it is necessary to be aware of various chemical ingredients. Based on the EU Cosmetic Regulation 1223/2009, around 26,000 common ingredients are present in PCCPs and approx. 1,300 substances are currently prohibited in the EU.*
Within the Erasmus+ project GreenGate, which addresses the safety use and healthy choice of cosmetics, we studied the chemical variability of commercially available PCCPs. The number of chemicals was quantified using the data from ingredient lists, and a detailed analysis was performed based on the categorization of PCCPs into seven groups according to their intended use. The average number of ingredients among 458 PCCPs was 19. Decorative cosmetic products were the most diverse and variable group of PCCPs based on the chemical composition. On the other hand, hair care products possessed the highest average number of ingredients (22) with a maximum of 51. Through a brief survey, the unawareness of the average cosmetics users was highlighted.
Keywords: Personal Care and Cosmetic Products, Chemicals, Ingredient List, Survey, Awareness

1. INTRODUCTION

The skin is more than just another simple biological barrier membrane. It is a selectively permeable barrier which encounters various substances and agents from the environment daily and serves several vital functions that are crucial for our overall health and well-being. Additionally, it is the most visible aspect of the human phenotype and the largest organ of the human body [1,2]. It comes in direct contact with various of chemicals daily and can acts as a gateway through which these chemicals may infiltrate our bloodstream.
Personal care and cosmetic products (PCCPs) are also such kind of products, produced and applied in a huge amount worldwide. For some, cosmetic products may seem like a recent invention because of their mass production, availability, and consumers' growing demands. However, discoveries and benefits of their use go back thousands of years. Throughout history, civilizations have used cosmetics for different purposes. Today, there are many different PCCPs, with thousands of brand names and chemical compositions. These chemical mixtures can be derived from natural or synthetic sources. In accordance with Art. 2 of Regulation (EC) No 1223/2009 on cosmetic products, a 'cosmetic product' means *"any substance or mixture intended to be placed in contact with the external parts of the human body (epidermis, hair system, nails, lips and external genital organs) or with the teeth and the mucous membranes of the oral cavity with a view exclusively or mainly to cleaning them, perfuming them, changing their appearance, protecting them, keeping them in good condition or correcting body odours"* [3, 4]. The key difference between cosmetics and personal care products is that cosmetics are chemical compounds used for the enhancement of the appearance of a person, whereas personal care products are chemical compounds that are used to maintain good personal

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hygiene and health as well the enhancement of appearance. So, cosmetics are also a type of personal care products [4].
In recent years, the PCCP industry has been booming in Europe as more and more consumers become increasingly aware of the importance of their health. According to the Cosmetics Europe association data, 60 % of people believe that cosmetics have a positive impact on their life, and as many as 88 % find it difficult to imagine life without cosmetics [5]. Within the European cosmetics market, Germany consumed the largest number of cosmetics in 2021, followed by France and Italy, the three countries together valued at approx. 40 billion euros. Among all, skin care is still the dominant force in the cosmetic industry in Europe, capturing more than 27 % of the European cosmetics market in 2019 [5].
There are a vast number of PCCPs on the market with numerous brands, offering a diverse selection of products for different preferences, needs and trends. The cosmetic industry is also very dynamic and is evolving constantly, since new products are introduced regularly, reflecting advancements in formulation technologies, emerging beauty trends, and consumer demands. But being aware of chemicals in cosmetics is very important for several reasons, from personal health and safety to environmental risks. Cosmetics typically contain a variety of chemical compounds that serve different purposes, such as preserving the product, enhancing its texture, providing colour, or delivering specific skincare benefits. These chemicals can include preservatives, emulsifiers, fragrances, colorants, antioxidants, and active ingredients, among others. While cosmetics can be beneficial for skin health and aesthetics, it's essential for individuals to be aware of the ingredients in the products they use, as well as any potential sensitivities or allergies, to ensure that cosmetics are used safely and effectively. Based on EU Cosmetic Regulation (No. 1223/2009) there are around 26,000 common ingredient names for PCCPs and only approx. 1,300 substances are currently prohibited in cosmetic products in the EU [3]. In terms of numbers, there is still considerable room for improvement in terms of chemical safety and possible healthier alternatives. Additionally, since PCCPs can be consumed only for external usage, they are more likely to enter the environment in large quantities due to human activities and can cause more damage to different ecosystems. No matter the type, leave-on or rinsed-off products, these products enter the environment depending on the ability and efficiency of the sewage treatment plants to remove them [6]. Some chemicals used in cosmetics have also the potential to cause adverse effects on our health.
The main objective of the research was to quantitatively highlight the presence of chemicals in our everyday care and raise the awareness on safety use and healthy choice of cosmetics among the adults.

2. METHODOLOGY

The research was partly conducted within the international project entitled *"GreenGate - Towards responsible choice and healthy use of cosmetic products"*, founded by the EU Erasmus+ Programme. It addresses the problem of insufficient education and awareness of adults of harmful substances in cosmetics, cleaning and washing products and is in line with the *"EU's chemicals strategy for sustainability towards a toxic-free environment"* that is a part of the EU's zero pollution ambitions, a key commitment of the EU Green Deal [7]. By educating adults through innovative learning content and related tools, project aims to prevent the use of harmful cosmetic products, positively impact their health, and protect the environment. The consequences of insufficient solving of this issue lead to increase in allergies, diseases, and consumer hypersensitivity to certain substances in products and increased environmental pollution due to the use of products containing harmful substances. As an upgrade of the project activities the determination and evaluation of the chemical variability in randomly selected PCCPs was performed. From all of 500 collected products, cleaning products were eliminated, and the remaining 458 products were analysed for chemical composition based on the ingredient list. 34,4 % of products were of Slovenian origin. Due to the large number of data, products were categorized into 7 groups based on their characteristics and use:

- ✓ **Category 1: SKIN CARE** (Facial creams, Body lotions, Hand & Foot creams, Moisturisers, Eye creams, Toners, Hydrating & anti-aging creams, Serums, Sun Protection products)
- ✓ **Category 2: BODY CARE** (Shower gels, Body washes, Soaps, Oils)
- ✓ **Category 3: HAIR CARE** (Shampoos, Conditioners, Serums, Hair colourants and Lotions)
- ✓ **Category 4: DEODORANTS**
- ✓ **Category 5: PEELING & CLEANING** (Facial masks, Cleansing lotions, Scrubs, Exfoliators)
- ✓ **Category 6: ORAL CARE** (Toothpastes, Mouthwashes)
- ✓ **Category 7: DECORATIVE COSMETICS** (Lip & eyeliner, Lipstick & glosses, Foundations, Powders, Eye shadows, Mascaras, Blushes, Nail varnishes)

Among all, the "Skin care" category was the most represented with 36,2 % of products, while the representation of remaining categories varied between 5,7 and 14,8 % (Figure 1). After grouping products, we quantified the number of chemicals using the ingredient lists and determined the variability, diversity, and frequency of chemicals in each category. Additionally, short survey about the public awareness was performed to check their opinion and raise their awareness on the topic. 207 people of different age groups collaborated in the online survey and two thirds of respondents were women. All data were analyzed using Microsoft Excel 2011.

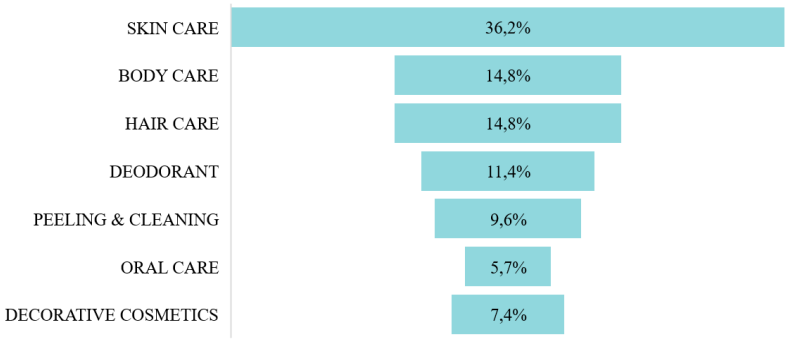

Figure 1. PCCPs categories included in the analysis of chemical variability
Source: A. Bubik

3. RESULTS

The average number of ingredients among 458 of randomly selected PCCPs was 19. Hair care products possess the highest average number of ingredients (22) with a maximum of 51 (Table 1). Skin care products also contain 22 chemical ingredients on average with a bit lower maximum value (48) compared to hair care products. The category of oral care product contained the fewest chemicals on average – 13. Chemical diversity was the highest among the skin care products (Table 1*).

Table 1. Chemical diversity and variability within the PCCPs categories
Source: *A. Bubik*

		Chemical Diversity/Variability		No of Chemicals/product		
				AVERAGE	MIN	MAX
1	**SKIN CARE**	**663***	4,0	22	1	48
2	**BODY CARE**	316	4,6	19	10	33
3	**HAIR CARE**	438	6,4	**22**	9	**51**
4	**DEODORANTS**	225	4,3	18	6	28
5	**PEELING & CLEANING**	330	7,5	20	5	40
6	**ORAL CARE**	127	4,9	13	2	24
7	**DECORATIVE COSMETICS**	264	**7,8****	20	4	48

As this category is composed of various products for the skin care and is also the dominant force in the cosmetic industry in Europe, the results were expected. The variability of chemicals was the

highest in the category “Decorative cosmetics”, as it was calculated that almost 8 different ingredients are used in each product on average (Table 1**).
Among the ingredients five the most commonly presents chemicals of each category were collected and are listed in the Table 2. As expected, water (“Aqua”) is the most commonly present ingredients in PCCPs. Regardless the category of “Deodorants”, water is presents in majority of products; in the category “Peeling & skin cleaning products” even in 95,5% of products. Second the most found ingredients is “Parfum”. In oral care products parfums were not found. It is just a speculation, that those products are free of parfums. It is very well known that the term "parfum" or "perfume" in cosmetics typically refers to a mixture of fragrant essential oils and aroma compounds, along with solvents and fixatives. Cosmetic companies often list "parfum" or "perfume" as an ingredient on product labels to protect their proprietary fragrance blends, which are considered trade secrets. This means that the exact composition of the fragrance mixture is not disclosed to consumers. This information is of a sensitive nature and necessitates a careful costumer approach. If a costumer possesses specific concerns about allergies or sensitivities to fragrance ingredients in cosmetics, it's advisable to choose products that are free of fragrance. Limonene (citrus scent) and linalool (lavender scent) are among the most common fragrance terpenes used in multiple household products and PCCPs. They both oxidize upon contact with air forming hydroperoxides as primary oxidation products, and these have been recognized as important contact allergens [8]. On interesting founding was CI 77499 as the 5th most common component in decorative cosmetics. CI 77499 or a black iron oxide is a colouring agent in cosmetic products, which typically offer enduring colour with no frequent reapplication once applied.
Using short survey in the last part of the research we confirmed, people are unaware of the real extent of the chemical ingredients in PCCPs. Survey was focused on the categories, which showed the highest numbers regarding ingredients in the 1st part of the research, like hair care product. Results showed that almost all respondents (94%) of our survey agree, that commercial shampoos contain a lot of chemicals, but majority of them (79,3%) meant, that they possess less than 20 ingredients (Figure 2). Our research revealed opposite; hair care products contain 22 different chemicals on average (Table 1).

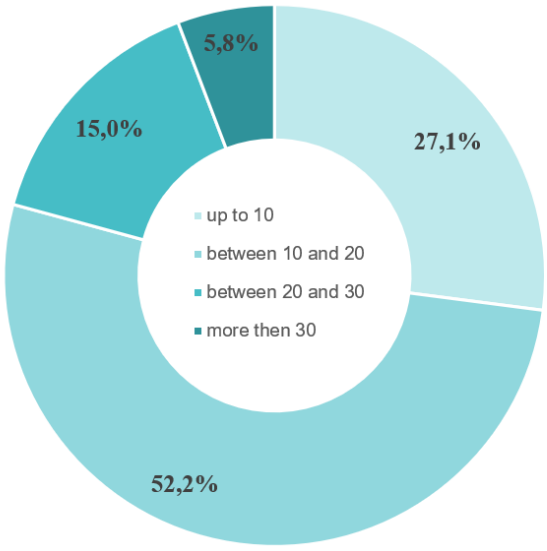

Figure 2. Survey respondent opinion about the number of chemicals presents in our shampoos
Source: A. Bubik

Table 2. Five most common ingredients within the PCCPs categories

Source: *A. Bubik*

	SKIN CARE	BODY CARE	HAIR CARE	DEODORANTS	PEELING & CLEANING	ORAL CARE	DECORATIVE COSMETICS
1	**Aqua**	**Aqua**	**Aqua**	**Limonene**	**Aqua**	**Aqua**	**Aqua**
	84,3%	**94,1%**	**86,8%**	**88,5%**	**95,5%**	**73,1%**	**76,5%**
2	Glycerin	**Parfum**	**Parfum**	Linalool	Glycerin	Sodium Fluoride	**Parfum**
	18,1%	**82,4%**	**80,9%**	88,5%	84,1%	61,5%	**55,9%**
3	**Parfum**	Citric Acid	Citric Acid	**Parfum**	**Parfum**	Aroma	Linalool
	59,0%	73,5%	69,1%	**71,2%**	**77,3%**	57,7%	52,9%
4	Phenoxyethanol	Glycerin	Linalool	Citral	Citric Acid	Limonene	Limonene
	44,6%	72,1%	60,3%	65,4%	50,0%	57,7%	47,1%
5	Cetearyl Alcohol	Cocamidopropyl Betaine	Limonene	**Aqua**	Sodium Hydroxide	Sodium Saccharin	CI 77499
	42,2%	70,6%	52,9%	**59,6%**	45,5%	50,0%	44,1%

4. CONCLUSION

It's important to note that commercial cosmetic products contain a variety of synthetic chemicals, which can have various effects on our skin, overall health, and the environment. But it is also crucial to emphasize that not all chemicals in cosmetics are harmful, and many have been thoroughly tested for safety. However, the safety of cosmetic chemicals is a key concern, and regulatory agencies in many countries establish guidelines and regulations to ensure that cosmetics are safe for consumer use. Additionally, consumers should be proactive in researching and understanding the ingredients in the products they use, especially if they have specific skin sensitivities or allergies. To stay informed about chemicals in cosmetics, individuals can read ingredient labels, research specific ingredients or product formulations, and refer to resources such as databases or guides provided by regulatory authorities or trusted organizations focused on consumer safety and health. Many companies are now also offering products with natural and organic ingredients, catering to individuals seeking alternatives to synthetic chemicals. Moreover, by creating homemade products, individuals can have full control over the ingredients used, ensuring that they are natural and safe.
Ultimately, the choices we make as consumers can play a significant role in shaping the cosmetic industry, encouraging transparency, safety, and sustainability. Being informed and conscious consumers can lead to healthier choices for ourselves and the environment.

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TECHNICAL-TECHNOLOGICAL DISASTERS, RISK ASSESSMENT AND ENVIRONMENTAL SECURITY

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Abstract: *Modern complex production systems are based on newer technologies, technologically advanced production machines and plants, and modern monitoring and surveillance systems. Oversights occasionally occur in work and functioning, which result in minor or major malfunctions, sometimes breakdowns, which are followed by accident situations that lead to technical-technological disasters. In the modern concept of security for the timely prevention of tragic consequences for people and material goods or their reduction to a minimum, an appropriate risk assessment is carried out, in order to implement risk management and more secure and more efficient production in practice. On the basis of risk indicators, modern risk management standards, integrated risk management and production processes management is applied. In the analysis of the accompanying security aspects, a particularly important place holds the analysis of the conditions and ways of achieving the required level of environmental security, especially in the part related to the working and living environment, including plant and animal life and environmental media.*
Keywords: technical-technological disasters, risk assessment, security, environmental security.

1. INTRODUCTION

The current human needs for certain materials and products, in the conditions of a growing market, increasingly require the realization of various technical-technological complex production processes. Such modern business conditions are accompanied by certain security risks, which must be identified, analyzed and assessed in a timely manner [1].
Disaster risk, until the 1970s, was perceived as a direct consequence of natural hazards [2], and then it began to be understood as caused by the intersection of hazards, exposure and vulnerability of influential elements. After several decades of research on various mega-disasters, scientists have introduced the social dimension of disaster risk, with the understanding that disasters are a human construct [3], which requires risk assessment and appropriate handlling [4] through risk management and the integration of risk management and processes [5]. In the multidimensional risk assessment associated with anthropological disasters, different components of risk (hazard, exposure, vulnerability and resilience) are considered, which are observed in the combined natural and socio-economic causation in the disaster risk assessment model.
Various natural and especially anthropogenic disasters, depending on the environment, accompanying processes and conditions of origin and development, are accompanied by different types of risk of consequences for material resources, housing and other objects, human lives and environmental consequences. In parallel with achieving the goals of sustainable development, there is a need to promote sustainability, inclusive and sustainable economic growth, full employment and dignified work [6]. On the other hand, there is a need for development that is more secure for people while promoting a better quality environment. Accordingly, various influential factors, including technical-technological disasters, must not cause harmful consequences for people and the environment [7]; from the point of view of security [8] this is especially covered by environmental

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security. The main goal of this paper is to point out the functional connection that exists between technical-technological disasters, the necessary risk assessment and the realization of the necessary level of environmental security in the living and working environment.

2. TECHNICAL-TECHNOLOGICAL DISASTERS AS A SECURITY PROBLEM

In the third decade of the 21st century, the increasingly numerous human population has become significantly more technical-technological advanced, while facing numerous security risks brought by new technological solutions and applications of new advanced technologies, modern monitoring and surveillance systems. In addition to natural disasters, such as floods, earthquakes, droughts, etc., which affect the economy and the population, in environmental security, the manifestation of security aspects of technical-technological disasters is particularly specific [1]. In the conditions of current social and economic development, environmental and other disasters have become an integral part of the functioning of modern society, with the direct or indirect influence of man on their occurrence and consequences.

The 2009 United Nations International Strategy for Disaster Reduction [9] defines a disaster as a serious disruption in the functioning of a community or society, with widespread human, material, economic and environmental losses and impacts, which exceed the ability of the affected community or society to cope using own resources.

Contemporary socio-economic development, accompanied by an irresponsible attitude towards nature, due to man's desire for an excessive increase in material wealth, has led to a dangerous situation of real and serious anxiety of humanity for its future perspective, quality of life and survival on Earth [10]. On this basis, there has been a development of social awareness about the necessity of rational and moderate exploitation and use of natural resources and of bringing economic development into harmony with the real possibilities of the natural environment, which includes a very important aspect of environmental sustainability.

Man's relationship with the environment, which for decades has been more destructive than constructive [11], has led to a number of different global, regional and local environmental problems. These environmental problems culminated in numerous examples in the emergence of various environmental crises and disasters. Due to the pronounced influence of negative human action on the environment [12], in recent decades there has been an increase in natural and technological disasters in the world.

Various forms of threats to humans and ecosystems dictate the need to improve the conditions of survival and sustainability of current and future generations. Solving this issue requires implications on policies based on activities, which will contribute to sustainable development by investigating the effects of various factors on economic growth [13] and the effects of new technologies on the prevention of technical-technological disasters and their consequences. There exists a kind of paradox between human progress and an increased sense of insecurity [14]. The disaster risk arises when the hazards come into contact with physical, social and environmental threats. According to Vlahos [15], environmental disasters caused by anthropogenic factors include the following: (a) industrial accidents with chemical and radioactive environmental pollution; (b) pollution of river courses; (v) degradation of natural resources; and (g) environmental-political upheavals (eg wars, revolutions, etc.).

Various technologies, especially technologies for processing certain raw materials and creating by-products, have become potentially dangerous for man and his immediate and distant environment, due to the following [1]: (a) inappropriate management of technologies; (b) inadequate choice of location; (v) low-quality technological solutions; and (g) irresponsible behavior of people, society and individuals. As a result, accidents occur, sometimes with catastrophic long-term and unforeseeable consequences for people and environmental security. Contemporary scientific and technological development of society has led to the growth of standards, but also to the increase of security problems and various types of risks in different areas of human activity, including economic, social and environmental aspects of sustainability, accompanying risks and security [1].

3. DISASTER RISK ASSESSMENT

Effective, long-term disaster risk reduction requires taking into account the dynamics of each of the influencing components and the mode of population, economic and climate change, as well as appropriate policies and decisions. It is especially important to apply the appropriate methodology to include these factors within research scenarios designed for smaller losses in disasters. The developed scenarios and their subsequent analysis combine the knowledge and insight of stakeholders and experts as well as the use of simulation modeling in risk assessment and in contributing to strategic risk reduction [16].

The impact of disasters on a global scale is increasing, and existing projections of economic and population growth, together with the impacts of climate change, show that the associated losses will increase in the future [17]. Hence, disaster risk reduction is necessary as an ongoing activity, which includes active efforts to reduce the impact of anthropogenic disasters, but also includes accompanying actions and measures. Planners of disaster risk reduction strategies face difficult decisions regarding resource allocation, scheduling, and planning priorities. Effective disaster risk reduction requires consideration of long-term changes, along with sources of uncertainty for integrated responses to disaster threats.

The disaster risk reduction process inherently exhibits factors of complexity. Designing, testing and implementing risk reduction strategies requires the collection, processing and interpretation of a large amount of data and information from a number of different natural, engineering and social disciplines, among which security is one of the most important. There is a need to incorporate numerous aspects from the local to the international level in the planning and implementation of disaster risk reduction to prevent unwanted outcomes related to various anthropogenic disasters.

Uncertainty in factors affecting disaster risk is also significant, affecting trends in risk components such as economic, population and climate change, urbanization rates, the impact of new technologies and political factors. Disaster risk reduction therefore needs to consider and integrate these uncertainties, especially in risk reduction investment plans and decisions. Determining certain weak points in technical-technological systems in terms of risk should be followed by appropriate improvements in production processes, through redesigning and reengineering processes in order to minimize the perceived risks.

Disaster risk reduction efforts are based on risk assessments and identification of management actions for risk reduction. Such risk assessments in earlier development periods mostly had a static approach taking into account the current risk, which is insufficient to include the mentioned complexities and uncertainties [18]. Their inclusion by risk assessment can be achieved through scenario analysis, with relevant assumptions of tomorrow for a range of stakeholders and expected circumstances, together with the dynamics of disaster risk factors. Therefore, there is a need for an adequate approach in risk assessment, which can include all these elements in risk assessment scenarios [16].

4. RELEVANCE OF ENVIRONMENTAL SECURITY IN CONTEMPORARY CONDITIONS

The contemporary trend of ecology, environmental analyses and environmental problems dictate the inevitable need for a comprehensive perception of environmental security problems. This kind of perception has gained particular importance if the connections and contradictions in the relation between nature, society and the economy are taken into account, which are manifested through environmental security issues [10]. The redefinition of the concept of security begins after the relaxation of the bloc tension of the Eastern and Western bloc countries. In the early 1980s, environmental factors were integrated into the concept of security [19]. In the 1990s, the concept of security was expanded to use the concepts of environmental security, food security, health security, energy security and income security [20].

In the last decade, an increasing number of authors on the international scene use the term environmental security implying the concept of sustainable development, which is at the core of environmental security, while in Serbia the term environmental security is mostly used, which includes the concept of sustainable development, but also the threat to political stability [20]. Environmental security, without which there is no social and economic progress, requires taking the necessary measures to reduce political and ethnic conflicts and prevent the further implementation of environmental crime [21].

The topicality of environmental security stems from the fact that at a time of increasing importance of ecology in all production and social activities, environmental security is becoming part of the security policy of most countries in the world. At the same time, one cannot talk about a complete concept of security [10, 20] if the issues of environmental degradation and protection, scarcity of resources, water and food security, energy, population problems, destruction of ecosystems, migration, natural or human-caused disasters, climate change, environmental crime, environmental terrorism or violence related to environmental degradation are not considered.

The contemporary security approach mandates the obligation to define and assess the risk of technical-technological disasters for the purpose of: (a) preventive action; and (b) ensuring effective action according to the principles of crisis management in the event of an eventual manifestation. A broader analysis of security aspects according to the analytical research carried out in this paper especially includes the relational connections of these disasters with the binding concept of sustainable development and, within that, the particularly significant and current issue of environmental sustainability [1].

5. THE RELATION OF TECHNICAL-TECHNOLOGICAL DISASTERS, RISK ASSESSMENT AND ENVIRONMENTAL SECURITY

The functional consideration of the issue of technical-technological disasters has a wider analytical triangular framework, on the one hand there is the security analysis of potential technical-technological disasters, on the other hand the required level of disaster risk assessment, and on the third hand the achievement of the required level of environmental security, which will be manifested at the local, regional and wider area. In the subject consideration, for the needs of the research-analytical procedure, it is possible to single out dual interconnection relations, which connect pairs of individually separated analytical elements.

The relation of technical-technological disasters - risk assessment is a starting point, because it fits into the concept of risk assessment in a broader sense in the domain of disasters and especially in a narrower sense in the part that refers to technical-technological disasters in various material, energy, economic and other production systems. Undertaking measures aimed at eliminating the causes of occurrence and/or minimizing the effects of a risky event in the case of various technical-technological systems, as well as measures to ensure minimal losses and eliminate the consequences if risky events occur, is, according to the general approach [22], the starting point of risk management of technical-technological disasters.

The relation of technical-technological disasters - environmental security is related to the consequences of security violations due to the occurrence of these types of disasters, especially in the part of the environmental aspects of the impact on the environment, that is, from the point of view of security, it is related to a partial part of environmental security. According to the general approach [22], the field of action of hazard factors of technical-technological disasters does not only include the immediate environment of these production systems, but also often covers a wider territory, including the territories of other countries. In this way, the number of potentially endangered people and material resources, as well as the territory of possible endangerment of the environment, i.e. violation of environmental security, directly increases. Analyzing potential environmental hazards and possible environmental impacts is particularly important in order to achieve the required level of environmental security.

The relation of risk assessment - environmental security is particularly important because of the necessary frameworks, policies, responsibilities and resources for risk management of technical-technological disasters, including the partial environmental aspect. The basic framework for risk management is defined by international standards ISO 31000 [23], which helps organizations to effectively manage risks through processes at various organizational levels. The focus is on environmental aspects, according to which it is necessary to prepare appropriate risk information, derived from the characteristics of technical-technological processes, in order to achieve the required security level of development of the process itself and the security level of people in the process, as well as the security level of the environment.

6. CONCLUSION

The current conditions of the dominant importance of ecology and the environmental trend in economic and human activities of different types and scope, especially in technical-technological complex systems, reflect the special need to expand consideration to various environmental aspects. Among them, the following can be singled out as particularly interesting and functionally significant: technical-technological disasters, risk assessment and environmental security.

The impact of disasters at the global level is increasing, especially in terms of insured losses, that is, various costs of their consequences, and further projections of economic and population growth indicate a trend of their increase in the future. Hence, anthropogenic disaster risk reduction is necessary as a permanent activity, which includes active efforts to reduce the corresponding impacts and hazards, along with technical-technological improvements. The topicality of environmental security in conditions of increasing importance of ecology in production and social activities, conditions the professional obligation of special integrated security analyses according to the comprehensive concept of security.

The functional consideration of the issue of technical-technological disasters has a wider analytical triangular framework, in which through the research-analytical procedure, it is possible to single out dual interconnection relations, which connect pairs of individually separated analytical elements, namely: (i) the relation of technical-technological disasters - risk assessment; (ii) the relation of technical-technological disasters - environmental security; and (iii) the relation of risk assessment - environmental security.

Integrated viewed in a broader environmental and security consideration and approach, the triple relation of technical-technological disasters - risk assessment - environmental security is procedurally, security-wise and functionally very important in the contemporary conditions of the current environmental trend and the need to ensure environmental security for people, objects, material goods and environment media. The same is particularly important in order to achieve integrated risk management, which should be incorporated into the organizational management system with an appropriate level of performance of the production process and managerial, economic and more secure business.

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ECONOMIC CONSIDERATIONS OF THE RELATIONSHIP OF NATIONAL INCOME, MINERAL RESERVES AND ENVIRONMENTAL ACCOUNTING

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Abstract: *In current economic considerations for standards of economic progress, the measurement of economic activity at the country level is particularly important. In that domain, gross national product (GNP) and gross domestic product (GDP) are successfully used as standard measures of economic development. The question of their definition and monitoring relies to a significant extent on the available natural resources, a very significant part of which includes mineral resources and mineral reserves. At the same time, basic mineral production represents the initial production link for many economic branches and many forms of accompanying production, which could not be realized if there were no mineral raw materials produced, that is, if there are no different mineral components. Consideration of the national income and the direction of further economic development policy start from the existing capital funds, namely: (a) produced capital; (b) human capital; and (c) natural capital. Accounting for natural resources and particularly significant mineral resources and mineral reserves occupies a particularly important place in the essential economic analysis. As an integral part of the modern comprehensive analytical approach, environmental aspects are also taken into account, with the inclusion of analytical elements of environmental accounting and the connection with economically significant mineral reserves.*
Key words: economy, national income, mineral reserves, accounting, environment.

1. INTRODUCTION

Both world and national economic trends have a direct and very significant connection with the mineral economy and the mineral sector at the observed level of economic analysis. The developments in question are partly related to the complex market of mineral raw materials, partly to the prices of mineral raw materials, and partly to the contribution of the mineral sector to the national income, that is, to the social and economic development of the country. It is a fact that in the modern conditions of modern material production, certain mineral raw materials are of strategic importance and are considered at the European and world level through the so-called critical mineral raw materials. In countries with developed mineral economies, strategies for securing them are very current, both from the natural point of view of the quantity and quality of mineral reserves, and from the economic point of view of the contribution to the national income and economic development [1].

Contemporary consideration of the conditions and methods of achieving national income is linked to complex analyzes of the realization of newly created value from various economic branches, especially the strategically and economically sensitive mineral sector, but also the analysis of the relevant relationship to the natural resources of the environment, especially mineral resources as basic economic elements of material production. The individual economic development plans of a large number of countries are based precisely on initial analyzes of availability, conditions and ways of using mineral reserves of metallic, non-metallic and energy mineral raw materials. Certain development projections in certain countries show a direct dependence on certain mineral raw

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materials, so that the plans for achieving the national income directly depend on their price, supply and demand, the possibility of placement in terms of quantity and quality, but also on the action of special strategic and non-economic factors [2].
As part of the comprehensive consideration of social development issues, especially the part based on mineral raw materials, especially in domestic conditions in Serbia, it is very important to consider the relationship regarding the environment, issues of ecological economics and environmental accounting. In addition to the issue of securing the required amount of mineral raw materials, the issue of environmental costs of their material production, issues of pollution prevention, costs of environmental protection and costs of elimination of environmental impact is unavoidable. On the other hand, the cost burden of a unit of mineral reserves is analyzed analytically against the question of market price, profit rate and profitability rate, all in accordance with the principles of economic geology and the economics of mineral resources [3].
Consideration of the interrelationship between national income - mineral reserves - environment in the mineral sector is very significant, especially in the part with an overview of the importance in the economy of the company [4, 5, 6], business policy and strategy [7, 8] and management in the company [9]. The main goal of this research and analytical work is to, in accordance with the modern level of the subject matter [10-23], indicate the operational importance of considering mineral reserves according to driving economic activities and direct participation in the national income, but especially according to the ecological aspect and accounting elements of the economy environment.

2. ENVIRONMENTAL CONSIDERATION ITEMS OF NATIONAL INCOME

The realization of the national income is related to various analytical aspects of its acquisition as well as the realization of the final results, in which mineral resources also take part. Initial economic consideration [10] is related to the prior definition of the type of standard measures of gross national product (GNP) or gross domestic product (GDP), which are most often used to measure the level of economic activity and progress in the country's development. Almost all statistics used in macroeconomic analysis are based on these measures, as standards of economic progress.
In practical application, GNP/GDP can give a wrong impression of economic development, due to the existence of inconsistencies, such as failure to account for unpaid work, production for domestic consumption and the value of leisure time. Since GNP/GDP measures only goods exchanged in the market, they leave out labor in the household sector, do not include indicators of health, life expectancy or education level, nor reflect income inequality. Countries with extreme inequality may have higher GDP per capita than countries where income is distributed more equally, even though the average resident in the other country is wealthier. In addition, from the analytical point of view of the issues of this paper, it is particularly important to emphasize that GNP/GDP do not account for environmental degradation and resource depletion. [11]. The subject matter is very important for developing countries, which rely heavily on natural resources, especially mineral resources. If a country clears its forests, digs up mineral reserves, reduces soil fertility and pollutes water sources, it certainly impoverishes the nation. A particular problem is that mineral resources are exhaustible and non-renewable [2]. In such circumstances, the economic policy makers of the development of the economy and the nation can view them quite unrealistically, until the effects of environmental damage become visible, which can sometimes take decades.
Economic growth by itself does not necessarily represent real economic development and can reduce human well-being if it is accompanied by growing inequality and environmental degradation. Therefore, in the analysis of national income, it is very important to take into account the factors of resources, especially mineral resources and the environment. One of the approaches to the revision of the national income budget is to estimate the economic value of depreciation of natural capital and subtract that estimated value from the standard measures of GDP/GNP [10]. In standard national income accounting, the depreciation of anthropological capital, such as buildings and equipment, is subtracted, which is extended to the calculation of the depreciation value of

natural resources, which is also subtracted from GNP/GDP. A comparison of adjusted net domestic product calculations show significant deviations from standard benchmarks.
From an analytical point of view, the modified GDP model with ecological-economic-accounting correction has a particularly pronounced impact on net investments. The standard measure of net investment corrects gross investment by subtracting depreciation of produced capital. Based on the calculation of depreciation of natural capital, a large number of developing countries show much lower or even negative net investment. This significantly affects the development strategy, because investments are the most important economic determinant of long-term growth. By not taking into account the depreciation of resources, including mineral resources, as well as the environment, the real values of investments are systematically overestimated [12].
A very important step in the integration of the analysis of economic policy, environmental policy and social policy was the development of the measure of true savings, which includes depreciation of natural capital and borrowing abroad [13, 14]. That measure tends to determine how much national income is being saved for the future, taking into account both the depletion of natural resources, especially mineral resources as part of them, as well as additions to capital funds. The analysis of true savings, especially suitable for developing countries, indicates that an apparently successful development opportunity may hide a serious depletion of natural capital, which includes especially economically significant mineral resources, and in some cases may even produce a negative amount of net real savings.

3. ASSESSMENT OF ECONOMICLY SUSTAINABLE WELFARE

In the modern conditions of economic analyses, the assessment of depreciation of resources, including mineral resources, through which the ecological component of environmental analysis is viewed, is included in the items of national income. The approach with the so-called defensive costs [10], which are associated with the removal of the consequences of pollution, that is, attempts to repair or compensate for damage to the environment. According to standard accounting, these costs are included in GDP, which is why items of national income can influence the overestimation of national economic success.
As an illustrative example of defensive costs, the expenditures of the US Superfund state fund intended for the cleaning of toxic waste dumps, which are counted as a contribution to GDP [10], can be cited. Medical costs of treating diseases caused by water or air pollution are similarly added to GDP. If homeowners or businesses in a coastal area suffer property damage from an oil spill and file a claim for compensation, legal and cleanup costs are also added to GDP. According to this logic, if the damage from pollution is greater and the costs of removing the consequences of pollution are higher, the country is richer, which is a rather irrational attitude.
To show defense costs and environmental damage, an Index of Sustainable Economic Welfare (ISEW) was proposed for the USA [15]. Later, this concept was partly revised by creating the Genuine Progress Indicator (GPI) for the USA. The GPI adjusts for economic output by starting with a measure of consumption, which is adjusted for income inequality, then adds the value of unpaid labor and subtracts estimates of defense spending. Rather than measuring the total amount spent on consumer durables (eg refrigerators), the GPI measures the services provided by those goods. This favors more efficient and durable capital, which requires less frequent consumption but provides more services. Along with correcting the level of depletion of natural, especially mineral resources and long-term damage to the environment, the GPI shows a much slower economic development compared to the GDP indicator, which is constantly increasing.
Long-term damage to natural, especially mineral resources and the environment, such as the destruction of the ozone layer and the accumulation of gases, which intensify the greenhouse effect, are responsible for a large part of the differences between GDP and GPI [16, 17]. If long-term and cumulative environmental impacts are excluded, the resulting measure is closer to GDP, but still shows a much lower profit e.g. for the USA in the period after 1975. Measures of sustainable economic well-being similar to the GPI, calculated for European countries and Australia, show a

similar pattern. Namely, measures of the GPI type grow more or less parallel to GDP in the period from 1950-1970, but after that they grow at a slower pace or even decline [16].

4. ENVIRONMENTAL SERVICES AND GREEN ACCOUNTING

The third analytical-accounting approach to correcting items of national income for environmental damage includes defining the environment as a production sector, which provides services to the economy, many of which remain unrecorded, because at first glance they are free [18, 19, 20]. Examples include providing clean air and water, removing carbon dioxide from the atmosphere with the help of trees, health and recreational benefits provided by natural areas, etc.

If environmental services are impaired, e.g. by draining wetlands, the estimated costs of replicating those services must be subtracted from national output. Because wetlands perform important functions that include water purification, nutrient recycling, flood control, and providing habitat for wildlife, the estimated values can be very high. According to current standard accounting methods, wetlands do not contribute to output at all, but a shopping center built on a drained wetland would therefore contribute to output, both through the construction of the shopping center itself and through the annual sales of materials, goods and services.

The mentioned approaches of modifying the GNP/GDP items have their advantages, but it is rather difficult to determine a single criterion of modification. Some analyzes reject the single measure of ecological greening of GDP/GNP. Instead, it is proposed to use accompanying items, which in a physical sense measure the funds and functions of the environment, without necessarily attempting to value them [21]. Accompanying items can provide a detailed picture of the natural resource base and environmental condition by measuring variables such as forest cover, mineral resources, water supplies and noting their changes over time. Input/output analysis can show the likely impacts of various economic policies on resource stocks, including economically very important mineral resources. Economic valuation methods can also convert physical measures into monetary measures to estimate adjusted NNP/NDP. The United Nations has published a guide to integrated economic and environmental accounting using the accompanying items approach [22]. In the economic, accounting and environmental practices so far, no system of revision of items of national income for the impact on resources, including mineral resources, as well as the environment has been generally accepted and as a single present in application. In practice, most economic analyzes still rely on standard measures of GDP or NDP. It is obvious that such circumstances require a special correction of economic theories, in order to influence the new measurements of the national product and income. In the current analytical approach, the implications of the environmental accounting or green accounting approach can be specifically explored.

Directing the policy of sustainable development with the evaluation of the national income is economically and accountingly connected with the funds of total fixed assets, which remain the same or increase over time. These capital stocks include manufactured capital, human capital (skills and education) and natural capital. In doing so, different types of natural capital are distinguished, which can be replaced to a certain extent, the so-called. non-critical natural capital, but special attention should be paid to critical natural capital, i.e. resources such as water supplies for which there are no adequate substitutes [10, 22]. The same category can also include economically very important and currently irreplaceable, exhaustible and non-renewable mineral resources.

National income accounting must take into account any changes in the capital categories shown. Investments in capital are an integral part of standard GNP/GDP, and depreciation of produced capital should be subtracted from GDP to obtain NDP (net domestic product). According to existing analytical views, human capital is not amortized, provided that spending on education is adequate. Hence, the main analytical issue in resource and environmental accounting relates to the estimation and subtraction of depreciation of natural capital in order to obtain the adjusted net national product of NNP. The above requires certain specialist and detailed expert analyzes of the depreciation of natural resources, among which the specific issue of mineral resources, considering their characteristics and especially economic, social and development importance.

5. CONCLUSION

Contemporary world and national economic trends have a direct and significant connection with the mineral economy and the mineral sector at the observed level of economic analysis. Consideration of conditions and ways of achieving national income is linked to complex analyzes of the relationship to natural resources, especially mineral resources as basic production elements.

Realization of national income is related to various analytical aspects of acquisition, including starting mineral resources, with expression through standard measures of gross national product or gross domestic product, which are used in macroeconomic analysis and standards of economic progress. In the analysis of national income, it is important to take into account the factors of resources, especially mineral resources and the environment, along with assessing the economic value of depreciation of natural capital and subtracting its value from standard measures of GDP/GNP.

Analytically, the modified GDP model with ecological-economic-accounting correction has a particularly pronounced impact on net investments, which are needed for geological research and exploitation of mineral reserves, as well as the construction of mineral processing capacities. The assessment of depreciation of resources, including mineral resources, through which the ecological component of environmental analysis is viewed, is included in the items of national income and affects investments, so that they are not overestimated.

A special analytical and accounting approach to correcting items of national income for environmental damage includes defining the environment as a production sector, which provides the economy with a number of seemingly free services. In the same way, the direction of the policy of sustainable development with the evaluation of the national income is economically and accountingly connected with the funds of total fixed assets, which increase in development conditions. The main practical and analytical issue in accounting for mineral and other resources and the environment is related to the specific assessment and deduction of depreciation of natural capital. In the mineral sector and the mineral economy of the country, the above requires specialist and detailed expert analyzes of the depreciation of mineral resources, considering their specificities, but also their production and strategic importance in further economic and social development.

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QUALITY OF SWIMMING POOL WATER AND HYGIENE

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Abstract: *Without water there is no life. Today, more than ever, water resources in nature are threatened and it is necessary to preserve them and maintain their quality at a satisfactory level. This primarily applies to drinking water, but water for other purposes such as pool water should not be neglected either. It is pool water that can play a major role in preserving and improving an individual's health, but only if it is safe. In addition to adequate maintenance and disinfection, a prerequisite for safe pool water is the hygienic behavior of the users themselves. Any lack of hygienic behavior can lead to a microbiological risk. Any microbiological contamination carries a risk for users, especially fecal contamination. One of the most basic hygiene measures when using the pool is to shower before entering the pool. Applying this hygiene measure removes all substances that are on the body and can be potential pollutants. Based on the results of numerous studies, it is observed that users neglect hygienic behavior, which can lead to health risks. Research has shown that risky behavior is not related to socio-demographic characteristics and that adequate education is the best way to increase awareness of the importance of hygiene.*
Keywords: Hygienic behavior, Microorganisms, Swimming pool, Water

1. INTRODUCTION

Today, there is a clear need not to endanger the environment, and on the other hand, to satisfy growing human needs. The quality of the environment is the result of the action of various external factors, often negative, which is especially pronounced in the domain of lack of drinking water and often appropriate sanitary conditions. The very decision of the United Nations General Assembly to mark March 22 as World Water Day speaks of the importance of water protection and highlights the fact that every person has the right toa sufficient amount of safe water for drinking, personal hygiene, domestic use, sports, recreation andother needs.

The World Health Organization estimates that about 2 billion people in the world do not have hygienic drinking water in their homes [1], and that almost 50% of the population does not have safe sanitary conditions [2]. Lack of hygienically correct water is one of the main causes of death from infectious diseases, primarily from diarrhea.

Water resources are under great pressure, the number of pollutants is increasing as a consequence and result of industrial and technological development. Water resources are not inexhaustible and it is necessary to preserve them. It is of great importance to maintain water quality at a satisfactory level, above all when talking aboutdrinking water, but also about water for other purposes. It is known that the quality of surface water is threatened by numerous harmful agents, but the quality of water in swimming pools also requires attention.

Using the pool contributes to healthy physical activity and has a stimulating effect on the whole organism. It is recommended for all population groups, and is especially suitable for obese, physically

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inactive,elderly people, as well as for cardiovascular patients. Physical activity contributes to weight control and reduces the risk of cardiovascular diseases, diabetes and other diseases. Swimming is recognizedas one of the most beneficial forms of exercise and is also recognized as a rehabilitation therapy.
Water activity has great potential for health, both preventively and therapeutically.
The safety of pool water is achieved by adequate disinfection and is a prerequisite for improving and preserving health. However, the fact is that adequate disinfection and adequate maintenance of the pool facility will not ensure the safety of the pool water if there is no hygienic behavior of the users themselves.

2. QUALITY OF SWIMMING POOL WATER

Maintenance of all pool facilities as well as regular monitoring of pool water quality is an obligation, but also a task of the responsible persons. Safety, as a goal of public health, implies the reduction of the risk of injuries, the transmission of infectious diseases and the appearance of disinfection byproducts. Most of the challenges that can lead to health risks in the pool can be solved by adequate water treatment, which includes filtration and appropriate disinfection. One of the important moments in maintaining the quality of pool water is the addition of fresh water, in order to dilute substances that cannot be removed from the water by treatment.
Pool water is exposed to pollution risks, primarily microbiological and chemical. Microbiological risk occurs as a result of the presence of microorganisms in the pool water and has the highest probability of occurrence, even in well-maintained pools, especially where the hygienic behavior of the users is absent.

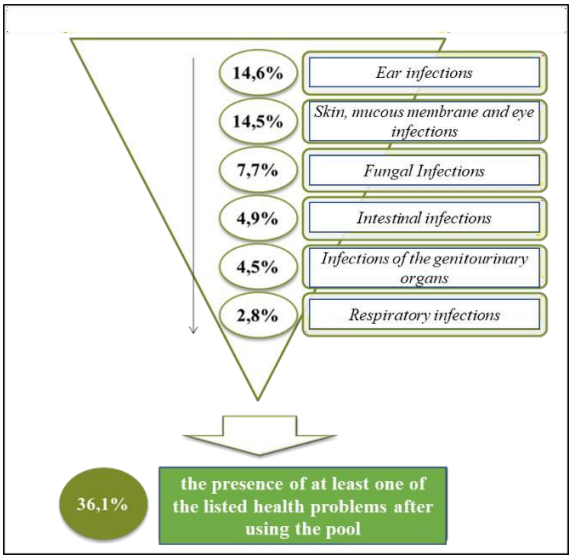

Figure1. The percentage of respondents aged 18 to 25 with the presence of a health problem after using the pool

Source: Krsmanović, S.: Istraživanje i analiza higijenskih navika dece i omladine korisnika bazenskih objekata u Srbiji. Doctoral thesis, The European Center for Peace and Development, University for Peace estalished by UN, (2018).

A large number of microorganisms of non-fecal, as well as fecal, origin can lead to contamination of pool water, and potential sources for this are human body secretions, feces, saliva, urine, sweat or vomited contents. Microbiologically contaminated pool water can lead to the appearance of various types of infections that find their way through natural body openings, as well as present skin damage. As a result of the unhygienic behavior of users of swimming pool facilities, the most common infections that can occur are skin, mucous membrane or eye infections, respiratory infections, ear infections, genitourinary infections, fungal infections and intestinal infections.

The World Health Organization also warns us about the danger of bacterial infections, which has provided a list of 12 bacteria that represent the greatest threat. Among them, Pseudomonas aeruginosa, Enterobacteriaceae and Acinetobacter baumannii stand out.
Looking at the dangers that threaten us from bacteria indicates that the regular application of hygiene measures is a prerequisite for reducing the microbiological risk in pool water. Research has been done on the topic of how much the users are really aware of what the absence of hygienic behavior brings. The results of a study in Italy show that 46.4% of respondents believe thatthey cannot get sick from pool water [3].
The safety of bathers primarily depends on hygienic behavior. The user's hygienic behavior reduces the risk of infections and thus makes all other maintenance techniques easier.

3. HYGIENIC BEHAVIOR

Showering before entering the pool is one of the most basic hygiene measures that can reduce the risk of microbiological contamination of the water. Applying this hygiene measure removes traces of sweat, urine, fecal matter, cosmetics and all other potential water pollutants, but also facilitates disinfection with a reduced amount of disinfectant, which makes the water more pleasant to use.
That hygienic behavior is important, we also notice from the warnings, advice and rules of behavior highlighted within each swimming pool facility. However, the fact is that the rules are not always followed, which is confirmed by numerous studies in the world, as well as in our country.
Based on an Italian study, it can be noted that 41.7% of bathers never read the rules of conduct displayed in swimming pool facilities [3], while another study shows that even 60.9% of respondents are not sufficiently familiar with the house rules of the swimming pool. of the object they use [4]. The data of a study conducted in our country show that less than one third of the respondents (30.2%), who use swimming pool facilities, read the warnings, advice and rules of conduct highlighted within the swimming pool facility, while more than half of them (58.3%) notices, but does not attach importance to them, which is worrying [5].
All substances found on the skin are introduced into the water, which reduces the amount of chlorine in the pool and increases the risk of infection, as well as allergic effects of disinfection byproducts on the respiratory organs and skin [6].
Based on the results of numerous studies over the past ten years, we can conclude that there is a presence of risky behavior on the part of users of swimming pool facilities, both in the past and today. A large Italian study on the behavior of users of swimming pools, which included five cities and more than 4,000 respondents, shows that only two-thirds of respondents always take a shower before entering the pool [7]. In another Italian study, the results showed that 69.2% of users use showers before entering the pool [8]. Bearing in mind the danger of various types of infections that can arise as a result of risky behavior, the percentage of users who regularly shower before entering the pool should be significantly higher.
Research conducted in our country shows that 70.7% of respondents consider that using showers before entering the pool is a very important hygiene measure, but only every other respondent (50.2%) applies this hygiene measure always, i.e. they take a shower regularly before entering the pool [9]. It is concluded that there is a high percentage of respondents who do not attach importance to this hygiene measure, but also a certain percentage of them who have developed hygiene awareness, but do not have developed hygienic behavior. Of interest for future activities, the reasons for this behavior were also important. In addition to hygiene, which is cited as the most common reason for taking a regular shower before entering the pool (86.0%), every tenth respondent also mentions getting used to the temperature of the pool water. Based on this result, it is concluded that there are respondents who have hygienic behavior, but for the wrong reason, which leads to the conclusion about necessary education. On the other hand, respondents who sometimes or never use the showers before entering the pool state that they come to the pool having already showered from home as the most common reason. This reason does not represent adequate hygienic behavior because users ignore the fact that they can be exposed to impurities on the way from home to the pool.

Health culture is part of the general culture of every individual, regardless of gender, age and education. User education on the topic of applying hygiene measures and their importance in reducing health risks is an important segment of public health. Education needs to be carried out continuously in order to achieve the best possible results and to motivate users of swimming pool facilities who have no interest in changing their behavior.
Back in 2010, the Center for Disease Control and Prevention (CDC) created the "Triple A's of Healthy Swimming" program, which encourages hygienic behavior among users of swimming pool facilities through 3 pillars: awareness, action and advocacy [10]. In the framework of awareness, the emphasis is on hygiene, in the framework of action, on the interest of users in water quality, and advocacy means encouraging and educating others on the importance of hygienic behavior and proper maintenance of the swimming pool facility.
The fact is that even in developed countries there are failures in the application of hygiene measures, which is confirmed by the data of a large number of studies, which indicates the comfortable behavior of people, regardless of the standard and living conditions.

4. CONCLUSION

The health risk for users of pool water can occur primarily as a result of inadequate hygienic behavior and insufficiently high awareness of the importance of applying hygiene measures when using pool facilities. The fact is that safe bathing primarily depends on self-discipline and the level of culture. Behavior, as a pattern of actions, can be influenced. Adequate education of all population groups and consideration of risks can point out the importance of hygienic behavior in every domain, which is a safe way to safe use of swimming pools.
Unhygienic behavior, as socially acceptable, represents a public health problem and requires positive changes. It is counterproductive that places that serve for recreation, relaxation and health promotion are actually places that can endanger us. That is more than enough reason to constantly work on strengthening awareness of the importance of hygiene.

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ENVIRONMENT AND SUSTAINABLE DEVELOPMENT. MECHATRONICS. OCCUPATIONAL SAFETY AND HEALTH AND FIRE SAFETY. SMART MANAGEMENT SYSTEMS. GRAPHIC ENGINEERING. DESIGN. TRAFFIC ENGINEERING. BIOTECHNOLOGY AND HEALTHCARE. MECHANICAL ENGINEERING. ECOTOURISM AND RURAL DEVELOPMENT.

ANALYSIS OF HEAVY METAL(LOID)S IN COAL FLY ASH LEACHATE BY INDUCTIVELY COUPLED PLASMA OPTICAL EMISSION SPECTROMETRY

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Abstract: *Fly ash is a by-product of coal combustion in thermal power plants. Heavy metal(loid)s (HMs) are the most recognized among the many dangerous compounds in fly ash. These substances may contaminate the environment and can pose a threat to human health. Various analytical techniques are used to analyze HMs in leachate. To investigate the possibility of contamination of the environment, heavy metals and metalloids (Pb, Zn, Mn, Fe, As, Ba, Be, Cu, Cr, Co, Cd, Sb, Se, and V) were leached from fly ash using a toxicity characteristic leaching procedure (TCLP). The fly ash samples used in this work were obtained from four thermal power plants (Kostolac, Kolubara, Tent B, and Morava). Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES) technique was used to determine the concentration of these elements in the leachate. Accurate elemental analysis was achieved with this technique. Among all analyzed metal(loid)s, Fe, Mn, Zn, and As were the most abundant.*
Keywords: ICP-OES, TCLP, trace elements, power plant, coal combustion

1. INTRODUCTION

Coal combustion in coal-fired boilers produces several different types of ashes, including fly ash, bottom ash, boiler slag, flue gas desulfurization materials, and other fluidized bed combustion ash, cenospheres, and scrubber residues, amongst other things [1]. Coal fly ash and bottom ash are the two main industrial by-products generated during the combustion of coal [2]. Due to the enrichment of heavy metals and metalloids (heavy metal(loid)s, HMs) in the ash particles, the disposal of these solid residues is considered a potential source of soil and groundwater pollution. The concentration of HMs in the ashes depends on several factors, including the type of coal feed, coal source, the occurrence of significant elements and their association with the organic and inorganic components of the coal, combustion conditions, volatilization-condensation mechanisms, and the particle size of the ash [3],[4]. During the transport and disposal of the residues from coal combustion, they are exposed to the leaching effects of rain. It is imperative to predict the leaching behavior of residues to prevent the environmental effects [5],[6].
Inductively Coupled Plasma Optical Emission Spectroscopy (ICP-OES) is a powerful analytical technique widely employed in environmental and materials analysis to determine HMs in various matrices. It has several characteristics, such as the ability to simultaneously analyze multiple HMs, wide dynamic range, high sensitivity, and low interference from matrix effects, which make it an indispensable tool in environmental monitoring, where HMs play a critical role.

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The aim of this study was to develop an ICP-OES method for analyzing HMs in the coal ash leachate and to investigate coal ash leaching behavior in order to analyze the potential for their reuse.

2. MATERIALS AND METHODS

2.1 Chemicals and Reagents

Coal fly ash and bottom ash samples were collected from four thermal power plants in Serbia that combust coal. Leaching of various HMs was carried out by applying batch Extraction Procedure (EP) and toxicity characteristic leaching procedure (TCLP). The TCLP extraction fluid (pH = 2.88) was prepared by diluting glacial acetic acid, while the EP extraction solution was deionized water (18.2 MΩ·cm). Deionized water was prepared using a Simplicity ultrapure water system (Millipore, Bedford, MA, USA). Acetic acid was supplied from Sigma Aldrich (Buchs, Switzerland). Standard solutions were purchased from AccuStandard (New Haven, USA).

2.2 Sample preparation

In a polyethylene bottle, 50 mL of EP or TCLP leaching fluid was mixed with 1.0 g of sample (20÷1 solid-to-liquid ratio), and the mixture was stirred at room temperature for 24 hours. The leachate was centrifuged at 6000 rpm for 10 minutes. The obtained supernatants were used for the analysis of HMs. Triplicate leaching tests were performed using the same weight of the sample and the same volume of the leaching solvent.

2.3 ICP-OES Measurements

The concentrations of HMS were determined by the ICP-OES instruments (Thermo Scientific model iCAP 6500 duo). To control the ICP-OES system, Thermo Scientific™ Qtegra™ software was employed.

3. RESULTS AND DISCUSSION

The first step was to optimize the ICP-OES parameters to enhance the analytical performance and achieve better results in HM analysis in coal fly ash leachate. The simplex method [7] was used to get optimal conditions for this analysis (Table 1).

Table 1. ICP-OES instrumental operating conditions

Parameter	Setting
RF Power	1150 W
Nebulizer gas flow	0.6 L/min
Auxiliary gas flow	0.5 L/min
Cooling gas flow	12 L/min
Exposure time	Axial/Radial
Low (UV)	15 secs
High (Visible)	5 secs
Peristaltic pump speed	50 rpm

Next, the linearity, detection limits (LOD), recoveries, and precision of the method have been investigated. To determine the linearity of the method, a calibration curve was constructed by analyzing a series of standard solutions with known concentrations of the HMs. The response of the instrument is plotted against the concentration of each HM, and the linearity is evaluated by calculating the correlation coefficient (R^2) of the calibration curve. The LOD was estimated by analyzing a series of blank samples and calculating the standard deviation of the blank measurements

and then calculated as three times the standard deviation of the blank measurements. A known amount of HM is spiked into a sample matrix, and the recovery is calculated as the ratio of the measured concentration to the spiked concentration. Finally, the precision of the method was determined by analyzing a series of replicate samples and calculating the relative standard deviation (RSD) of the ICP-OES measurements. Table 2 shows the wavelengths (λ) of the analyzed elements as well as the interferants, LODs, RSDs, and recoveries.

Table 2. Analytical parameters for ICP-OES determination of HMs in fly ash leachate

No.	HM	λ (nm)	Interferant	LOD (ppb)	Spiked conc. (ppm)	Recovery (EP) (%)	Recovery (TCLP) (%)	RSD (%)
1	As	189.042	Al, Co, Fe, V, Ni	2.91	0.3528	103	105	4.1
2	Ba	493.409	None	1.23	0.2601	101	103	3.4
3	Be	313.042	Ce, V	0.97	0.0025	102	102	2.7
4	Cd	228.082 214.438	Ce, Ni, Fe, Ti	0.42	0.0035	98	94	1.9
5	Co	228.616	Ba, Ce, Cd, Cr, Ni, Ti, Mo	0.97	0.0270	104	99	1.8
6	Cr	283.563 267.716	Ni, Mo, Be	1.72	0.0728	103	104	2.0
7	Cu	324.754	Mo, Ti	0.94	0.0447	101	98	1.6
8	Fe	259.940 239.562	None	4.28	3.7163	93	96	4.8
9	Mn	257.610 279.482	Ce	0.87	1.2607	94	97	4.5
10	Sb	206.833	Al, Ce, Cr, Co, Fe, Ni, Ti,	0.54	0.0204	105	96	4.3
11	Se	196.090	Fe	2.33	0.0552	104	98	4.1
12	V	282.402	Ce, Cr, Fe, Ti, Mo	0.91	0.0480	95	92	3.2
13	Zn	202.548	Cu, Fe, Ni	0.18	0.1964	102	97	2.1

The lowest value of the detection limit is 0.18 ppb for Zn, while the highest LOD is 4.28 ppb for Fe. The recovery ranges from 93 to 105%. A good linearity was observed for all HMs (R^2>0.999), and RSD is within ±5%. There are no notable differences between TCLP and EP recoveries.
The chemical constituents of fly ash and bottom ash are very similar, with the main difference being particle shape and size. Bottom ash is larger in size and very irregular, containing pores and cavities [8]. Ground to a suitable fineness, bottom ash can have a similar purpose as fly ash (e.g., production of building materials).

3.1 Leaching of heavy metal(loid)s from fly ash with EP leaching solution

The HM concentrations in the EP leachate are shown in Figure 1. Arsenic is the most prevalent (1.49 ppm) HM in the fly ash sample originating from the Kolubara thermal power plant. Arsenic (As) is markedly toxic and carcinogenic, and it is one of the most important HMs that cause both ecological and human health problems [9]. Concentrations of other HMs do not exceed 0.6 ppm.

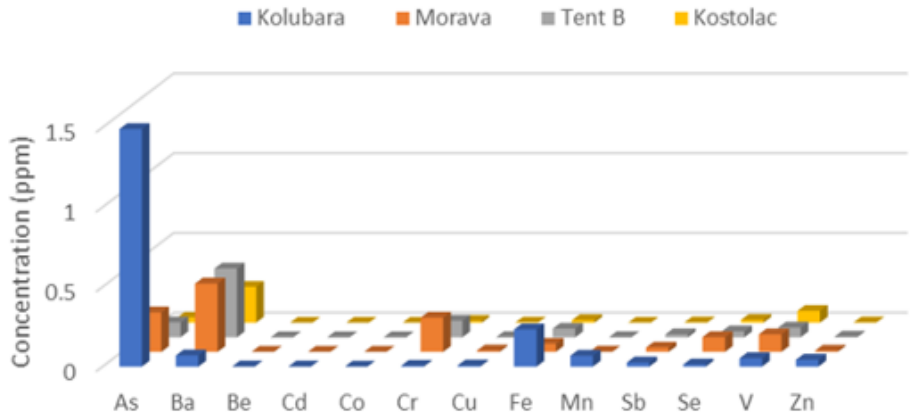

Figure 1. Concentrations of heavy metal(loid)s in fly ash leachate (EP leachate)

3.2 Leaching of heavy metal(loid)s from fly ash with TCLP leaching solution.

Figure 2 shows the results of fly ash leaching using the TCLP leaching solution. Concentrations of HMs are significantly higher in TCLP leachate compared to EP leachate. This is because metal solubility generally decreases with increasing pH. The most abundant HMs in fly ash leachate were As, Fe, and Mn, which were found in the range of 0.03–1.49 ppm, 0.02–0.23 ppm, 0.0005–0.07 ppm and 0.05–1.41 ppm, 1.28–24.38 ppm, 2.24–3.04 ppm, for EP and TCLP leachate, respectively. The ash sample from the Tent B thermal power plant contained the highest concentration of these elements.

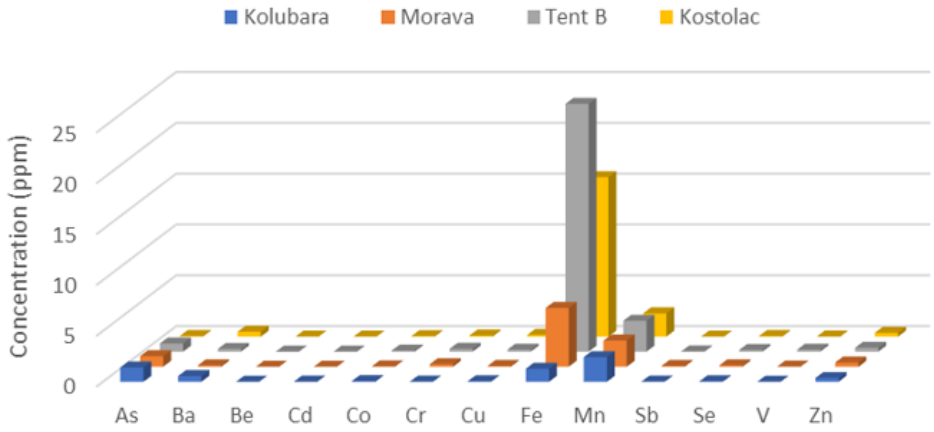

Figure 2. Concentrations of heavy metal(loid)s in fly ash leachate (TCLP leachate)

3.3 Leaching of heavy metal(loids)s from bottom ash with EP leaching solution.

The levels of HMs in the bottom ash leachate are shown in Figure 3. Compared to fly ash samples, less arsenic was leached into deionized water in this instance. Similar to fly ash, the most prevalent metals in this leachate were Fe, Mn, Zn, As, and Ba, though in smaller quantities.

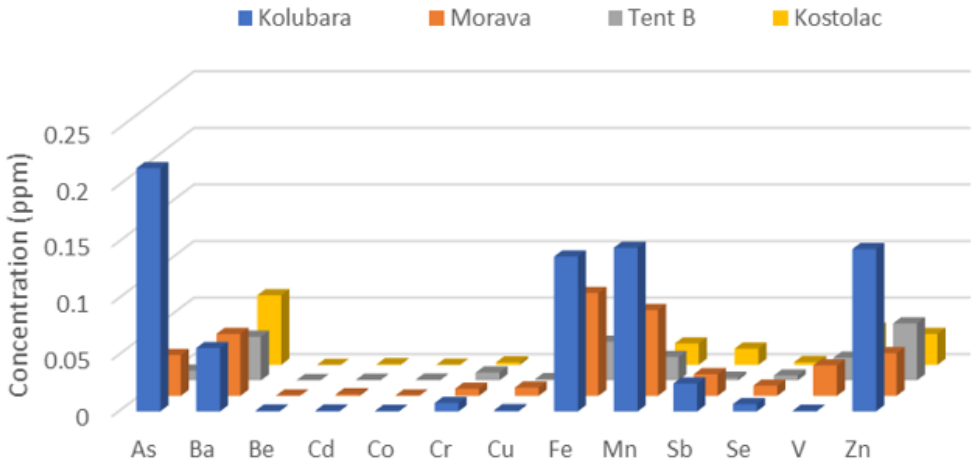

Figure 3. Concentrations of heavy metal(loid)s in bottom ash leachate (EP leachate)

These results can be explained by the similar composition of these two ashes but the different sizes of the particles, which is one of the important factors affecting the amount of leached HMs.

3.4 Leaching of heavy metal(loids)s from bottom ash with EP leaching solution.

The concentrations of the heavy metals(loids) that were leached out with TCLP solvent are shown in Figure 4. Similar to the fly ash samples (Figure 2), the most abundant HMs in the bottom ash TCLP leachate were Fe, Mn, As, and Ba.

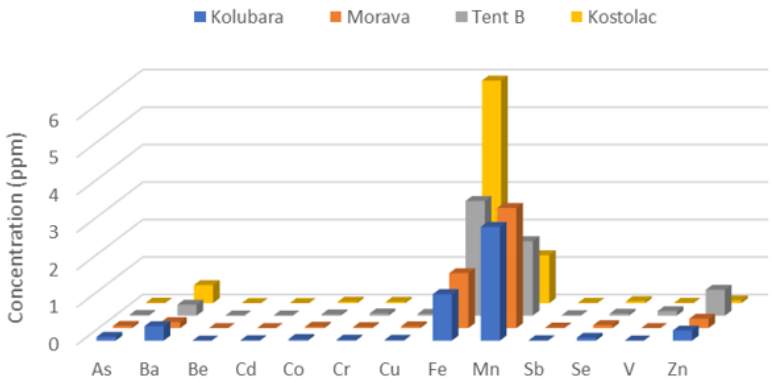

Figure 4. Concentrations of heavy metal(loid)s in bottom ash leachate (TCLP leachate)

4. CONCLUSION

In general, ICP-OES is a reliable and robust technique, offering good linearity, recovery, and precision, making it suitable for analyzing HMs in coal ash leachate. According to the leaching tests, coal fly ash and bottom ash from various locations have similar leaching characteristics. Higher concentrations of heavy metals (loids) were leached during the TCLP leaching test, which can be explained by the lower pH value affecting the mobility of heavy metals. Among all analyzed metal(loid)s, Fe, Mn, Zn, and As were the most abundant in the ash samples.

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ANALYSIS OF CARBON MONOXIDE IN AMBIENT AIR USING PASSIVE SENSORS

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Abstract: *Air quality monitoring is necessary due to various pollutants that can have a harmful effect on human health. Carbon monoxide (CO) is a pollutant of concern because it is very toxic at low concentrations. It is an odorless and colorless gas that is very difficult to detect. In recent years, passive sensors have been widely used to analyze CO in ambient air. The CO sensor for commercial use must be stable during operation and have a linear and reproducible output over a long period. Hence, developing CO gas sensors with high sensitivity, selectivity, and stability is essential. This study compared three types of CO gas sensors: electrochemical, metal-oxide semiconductors, and colorimetric. Each of these sensors is characterized by specific advantages and disadvantages; therefore, their comparative analysis is presented, and their most important characteristics are emphasized.*
Keywords: air quality, electrochemical sensors, metal-oxide semiconductors, colorimetric sensors

1. INTRODUCTION

Rapid industrial development leads to the endangerment of the basic components of the environment: air, water, and soil. This type of pollution has a severe impact on people; therefore, the existence of environmental pollution control is of great importance [1]. Air pollution is a big problem worldwide, especially in cities with developed industries. Harmful substances come directly from anthropogenic or natural activities and can be formed later in the atmosphere through mutual interaction. Gases and particles that pollute the air can be hazardous and associated with various diseases. Air pollutants include CO, NO_2, NO, SO_2, NH_3, and many others [2]. Carbon monoxide (CO) is one of the most poisonous gases and is also called the silent killer because it is very toxic to humans [3]. It is colorless and odorless and can be produced from both natural and anthropogenic sources. This most often includes incomplete combustion of fossil fuels and exhaust gases from vehicles, as well as volcanic activity and wildfires [4]. Depending on the concentration of CO to which people are exposed, the health consequences can be minimal or even fatal [5]. By increasing the concentration of CO in the body, the amount of oxygen decreases because human blood has a much greater affinity for CO than for oxygen [1]. CO binds to hemoglobin in the blood and prevents it from transporting oxygen through the body. Some characteristic symptoms are headache, dizziness, and nausea, which occur at low concentrations of CO. At high concentrations, more serious organ damage occurs, and in fatal cases, even death [4]. Because the content of pollutants in the air directly affects people's health, it is extremely important to monitor air quality. Air monitoring is necessary to determine the source of pollution, assess exposure, and form a plan for air quality management to protect people from the harmful effects of polluting gases [6]. Monitoring the amount of dangerous gases in the air has drawn more attention recently as a way to control the environment, not only in industrial environments but also in workplaces and residences. Most researchers study pollutants such as CO, CO_2, NH_3, VOCs, SO_2, and others [1].

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In the last few decades, various chemical sensors have been developed to detect various types of pollutants in various media [7,8]. Several types of popular sensors are piezoelectric [9], electrochemical [2], metal-oxide semiconductors [1], and colorimetric sensors [10]. For the analysis of pollutants in the air, various types of gas sensors that work on various principles have been developed to obtain fast but high-quality results [11]. Gas sensors are widely used for monitoring air quality in the environment, workplaces, living places, and industries [3]. Recently, gas sensors have been increasingly improved and developed to improve human safety and air quality. The main parameters of the gas sensor are sensor response, selectivity, sensitivity, limit of detection, energy consumption, operating temperature, and, of course, production costs [1]. Various devices are available for measuring CO concentration, but fast, portable, and selective sensors are still being developed [12]. So far, electrochemical sensors, metal-oxide semiconductors, and colorimetric sensors have been widely used [10]. The main goal of this study was to compare three various types of CO gas sensors. In recent years, using these sensors to analyze CO in ambient air has become a real challenge. Therefore, their comparative analysis is presented, and their most important characteristics are singled out.

2. PASSIVE SENSORS

2.1 Electrochemical sensors

Electrochemical sensors work on the principle of converting the concentration or partial pressure of the target gas into an electrical signal. These sensors can differ depending on what type of electrolyte they use: liquid, gel, or solid. However, using electrochemical sensors with a liquid electrolyte is increasingly common in practice. An electrochemical sensor consists of several parts: a working electrode, a counter electrode, a reference electrode, and an electrolyte. Figure 1 shows a schematic diagram of the electrochemical sensor. Electrodes can be made of various materials. The walls of the sensor housing must be made of a hydrophobic membrane that is permeable to gases and impermeable to liquids. This way, the amount of gas reaching the electrodes is controlled [4,13].
Determining CO is based on measuring the potential change when oxidation and reduction processes occur concurrently on the working and counter electrodes. Oxidation occurs when gases collide with the working electrode:

$$CO + H_2O \Rightarrow CO_2 + 2H^+ + 2e^- \quad (1)$$

The process of oxygen reduction takes place on the counter electrode:

$$O_2 + 4H^+ + 4e^- \Rightarrow 2H_2O \quad (2)$$

These two reactions lead to the flow of current. The generated current is related to the number of molecules that have been reduced, i.e., oxidized [4,13].

The measured value of electrochemical sensors can be affected by other substances in the air, and this phenomenon is called the crossing effect. During the crossing effect, the reduction/oxidation potential of undesirable substances is measured, and the result obtained in this way is not accurate. When the measured values are higher than the actual values, it is positive interference, while negative interference occurs when the read values are lower than the actual values. The operation of electrochemical sensors can be affected by the conditions under which the measurements are made [13]. Electrochemical sensors have a relatively fast response, low energy consumption, and are lightweight [11].

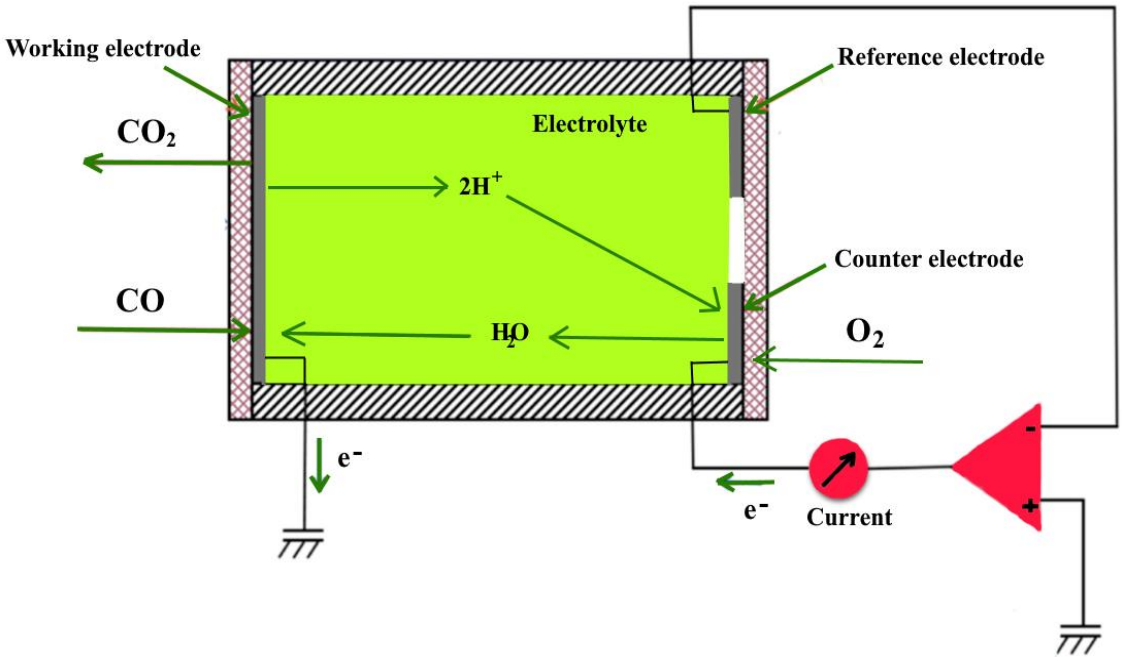

Figure 1. Schematic diagram of the electrochemical sensor

2.2 Metal-oxide semiconductors

When carbon monoxide comes into contact with a metal oxide semiconductor (MOS) gas sensor, a change in electrical conductivity or resistivity occurs. Based on that change, the target gas concentration is determined. Two types of MOS sensors used for CO detection, the n-type and the p-type, are shown in Table 1. Since not all oxides have the same properties, there are differences between semiconductors. Oxides such as SnO_2, ZnO, and TiO_2 are the most widely used because they have a good crystal structure, density, and lattice parameter, and they are the most studied for use in CO detection [1]. In addition to these three n-type conductors, Co_3O_4, the p-type semiconductor, gives good results in the determination of CO because it has a very high catalytic activity towards the oxidation of CO [14]. Metal oxides can be synthesized by various techniques such as hydrothermal, electrospinning, RF and DC sputtering, chemical vapor deposition (CVD), anodization, sol-gel, vapor phase transport, UV lithography, and many others [1].

Table 1. Various types of semiconductors for CO sensing

Metal-oxide	Type of the semiconductor	Reference
TiO_2	n-type	[3]
SnO_2	n-type	[15]
ZnO	n-type	[16]
Fe_2O_3 or Fe_3O_4	n-type	[17]
In_2O_3	n-type	[18]
WO_3	n-type	[19]
CuO	p-type	[1]
Cr_2O_3	p-type	[20]
Co_3O_4	p-type	[14]
NiO	p-type	[21]

MOS sensors detect CO based on the redox reaction between the determined gas and the sensing material. First, oxygen is adsorbed on the surface of metal oxides, creating a surface layer depleted of electrons. Depending on the types of MOS, there will be an electron-depletion layer in the n-type and a hole accumulation layer in the p-type. In the n-type, electrons are charge carriers, and in the p-type, holes are charge carriers. Therefore, due to the adsorption of oxygen molecules, the resistance

in the n-type is high and low in the p-type. Under the influence of the reducing gas, oxygen atoms are removed, and the trapped electron is transferred back to the sensing material, resulting in a decrease in the resistance in the n-type and an increase in the resistance in the p-type. Based on changes in resistance, MOS sensors detect CO gas [1,3]. MOS sensors are characterized by low cost, simplicity, high sensitivity, and low response time. The disadvantages are the high operating temperature, poor selectivity towards gases of the same type, and the fact that they are susceptible to environmental conditions. Currently, SnO_2 is the most efficient MOS material because it has excellent CO detection capabilities, especially at low concentrations [1,4].

2.3 Colorimetric sensors

The colorimetric determination of CO attracts attention due to its high sensitivity, simplicity, and selectivity. The reaction between the tested gas and the sensing probe is crucial when using colorimetric sensors. As a result of this reaction, a color change occurs. These sensing probes are a vital part of the sensor, and the operation of the CO sensor depends on these sensing probes. Chemicals in the probes act as catalysts for the reaction but also cause a color change. There are various types of sensing probes for CO determination. Most current colorimetric CO sensors are based on organic probes such as rhodium, iridium, and ruthenium complexes. Organic complexes of Pd are also used, and one example of a sensing probe contains palladium salts as a catalyst and molybdenum compounds as indicators. Although these probes have a fast response, high specificity, and high sensitivity for CO detection, their synthesis is complex [6,22].
Colorimetric sensors are characterized by their simplicity, rapid response, and low costs. However, their main disadvantage is the impossibility of continuously using a single sensor, especially when the resulting reaction is irreversible [23]. There are various attempts to overcome this shortcoming of colorimetric sensors. Lin et al. (2018) worked on a gradient-based colorimetric sensor, while Mo et al. (2023) developed a repeatable colorimetric system. The system is set to register changes in the colorimetric sensor signal, prevent the sensor from reaching saturation, and allow the sensor to fully regenerate before the subsequent measurement.

3. CONCLUSION

Air pollution from various contaminants is a problem worldwide, particularly in cities and urban areas where industry has grown. There must be enough monitoring to track the amount of contaminants in the air because air quality can significantly impact human health. Due to its unique characteristics and high toxicity, CO differs from other contaminants, making early identification and detection in ambient air crucial. As a result, carbon monoxide sensors aid in preventing excessive CO exposure; therefore, it is crucial to design CO gas sensors with high sensitivity, stability, and selectivity. There are several types of CO gas sensors, but the three most common types are electrochemical, metal-oxide semiconductor, and colorimetric sensors. These sensors have certain advantages regarding CO detection but also several drawbacks. Hence, researchers from all over the world are trying to overcome these disadvantages in order to enhance their performance. By comparing these three sensors, which are frequently used in the analysis of ambient air, their operating principles, advantages, and challenges associated with using them are highlighted. In this way, their comparative analysis was carried out. When synthesizing CO gas sensors, the main interests of researchers are in enhancing sensitivity, response time, selectivity and recovery time. Since the performance of the gas sensor depends on improving these key features, many researchers base their research on this. In addition, modern systems should undoubtedly be quick and affordable for the analysis of the target gas.

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ANALYSIS OF BTEX IN SEDIMENTS BY PURGE-AND-TRAP GAS CHROMATOGRAPHY-MASS SPECTROMETRY

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Abstract: *One of the most BTEX (benzene, toluene, ethyl benzene and a mixture of o-, m- and p-xylenes) compounds are prominent environmental pollutants commonly found in discharges and petroleum products. These volatile aromatic compounds (VOCs) are severely toxic to living organisms if contact is maintained. They originate from incomplete combustion of organic matter, and their major sources to the urban environment include vehicular emissions (mobile source), gasoline evaporation, coal burning and residential heating, and waste incineration (stationary sources). Water sediments are not well known as a source of BTEX. However, it is crucial to consider that they can act as a source, as well as sink, of organic compounds, especially in a water body located in an urban city exposed excessively to the above-mentioned sources of BTEX. In this study, we aimed to identify and quantitatively analyze VOCs compounds in sediment by using purge-and-trap (P&T) gas Chromatography-Mass Spectrometry (GC-MS).*
Keywords: VOCs; sediment analysis; GC-MS; toxicity

1. INTRODUCTION

With the rapid development of urbanization and industrialization during the last two decades, the number of pollutants has increased significantly, which can lead to severe environmental pollution in water bodies. Considering that pollutants, such as BTEX (benzene, toluene, ethyl benzene, o-, m-, p-xylenes), pose a high accumulation property in the body due to heavy exposure, they can cause various adverse health effects. In this regard, BTEX are discharged to aquatic environments from natural or anthropogenic sources and distributed between the aqueous phase and the sediments during their transport. Hence, investigating sediment contamination in terms of ecological and health risks of trace pollutants is crucial in predicting aquatic ecosystem risks [1,2].
BTEX are widely employed as degreasers and intermediates in chemical synthesis, fuels, and fuel additives. The presence of solvents in the environment, especially in water, has become a significant health concern for over three decades due to their potential carcinogenicity [3,4]. It is reported that BTEX in urban environments have harmful effects on the central nervous system, and benzene is classified by the International Agency for Research on Cancer (IARC) as a human carcinogen with pending assessment updates [5]. All the BTEX chemicals can produce neurological impairment, and exposure to benzene can additionally cause hematological effects including aplastic anemia and acute myelogenous leukemia. The critical nature of the neurotoxicity is reflected by the use of neurological

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impairment as the basis for 9 of 13 maximum residue levels (MRL) for BTEX chemicals [5]. The carcinogenic (leukemogenic) potential of benzene is well established, as indicated by its consensus classification as a human carcinogen by the National Toxicology Program (NTP 2001), U.S. Environmental Protection Agency (EPA) (IRIS 2001) [6], and International Agency for Research on Cancer (IARC).

BTEX predominantly originated from a wide array of products such as cleaning supplies, pesticides, building materials, office equipment, and craft materials, including glues and adhesives, photographic solutions, and tires. They are usually included in the composition of paints and lacquers, varnishes, and fuels and serve as precursors for producing other compounds. Aromatic hydrocarbons can be divided into monoaromatic hydrocarbons and polyaromatic hydrocarbons, whereas BTEX belongs to the group of monoaromatics with unique properties due to the delocalized electron density in benzene, including additional stabilization. BTEX are commonly found in crude oil and are used in geochemical investigations as direct indicators of the presence of oil and gas; they are easily volatile and can be degraded by microorganisms, which affect their precise measurement seriously.

Within this work, a procedure of gas chromatography-mass spectrometry (GC-MS), including purge and trap extraction (P&T), is used for the quantification of BTEX compounds in sediment samples [7,8]. The modification of several EPA standard methods for BTEX determination was made. Continuous monitoring of various parameters that may affect the performance of the method is necessary for ensuring an appropriate result quality. This primarily refers to specificity and selectivity, linearity, detection limit, precision, accuracy, and measurement uncertainty. It is emphasized how important it is to reflect the pollution status of BTEX comprehensively and evaluate the potential ecological risk of these analytes for water management in future studies.

2. MATERIAL AND METHODS

2.1 Reagents and laboratory supplies

The QA/QC of the analysis with scientifically acceptable results was ensured using the certified reference material (CRM) (Internal/Surrogate Standard Mix M-8260A-B-IS-SS-10X) for QC of VOCs analyses. CRM and all the reagent blanks were prepared by carrying out the entire analytical procedure and included as quality control samples. Concentrations were obtained as the average of three random measurements, whereas the analytical quality was evaluated by analysis of replicate. Methanol used for sediment sample preparation was of chromatographic grade. The solvent chromatogram showed no BTEX interfering peaks. The stock standard solutions were prepared in the appropriate solvent and stored in vials with Teflon-lined stoppers in the refrigerator. Intermediate mix standard solutions were prepared by diluting the stock standard solutions. Calibration standard solutions were prepared by diluting the intermediate standard solution. Since the exposure to BTEXs was to be minimized, pure standard materials and stock standard solutions were handled in a hood.

Sample containers of 40 ml t screw cap vials were used, each equipped with a Teflon-faced silicone septum. It was essential to wash vials and septa with detergent and rinse with tap and distilled water. The vials and septa were air-dried at room temperature, placed in an oven at 105^{o}C for 1 h, and cooled in a place free from organics.

2.2 Purge-and-Trap Gas Chromatography-Mass Spectrometry

Purge-and-Trap (P&T) Gas Chromatography-Mass Spectrometry (GC-MS) is the most widely used method in BTEX analysis [7]. A purge-and-trap system (Teledyne Tekmar ATOM XYZ) coupled with GC-MS (Agilent GC 7820A with MS 5977B) was used to analyze BTEX in sediment samples. After purging and cooling the trap with ultra-high-purity N_2, the samples were purged, trapped, and then introduced into GC-MS to measure BTEX [8,9].

2.2.1 P&T sampler method conditions

Purge: Prepurge 0.00 min; flow: 0 mL/min, Preheat Mix Speed: slow, sample preheat time: 0 min, Presweep time: 0.25 min, water vol: 10.0 mL, Sweep water time 0.25 min, Sweep water flow: 100 mL/min, Sparge vessel heather: off; Purge mix speed: Medium; purge time: 11.0 min, Purge flow: 40 ml/min, Purge and MCS Purge T = 20 °C; Dry Purge Time: 1.00 min, Dry Purge flow: 100 mL/min; Dry Purge T = 20 °C.
Desorb: Methanol Needle Rinse: Off; (V=0 mL); water Needle Rinse V = 7 mL; Sweep Needle time: 0.25 min; Desorb preheat T = 245 °C; GC Start Signal: Begin Desorb; Desorb time: 2.00 min; Drain flow: 300 mL/min, Desorb T = 250 °C.

2.2.2 GC-MS instrument method conditions

Column: Agilent DB-VRX, 20 m × 0.18 mm, 1 μm film, helium – 1 mL/min; oven profile: 35 °C, 4 min, 15 °C/min to 85 °C, 30 °C/min to 225 °C, 2 min hold, Run 14.0 min; Inlet: 180 °C, 120:1 Split, 19.752 psi; temperature: transfer line 225 °C; Source 230 °C; Quad 150 °C: scan: Range 35 m/z to 260 m/z, solvent delay: 0.5 min, normal scanning; gain: gain factor 10.00, autotune.

2.3 Interferences

Major potential contaminant sources in this kind of analysis are volatile materials in the laboratory and impurities in the inert purging gas and the sorbent trap. Using Teflon tubing, Teflon thread sealants, or flow controllers with rubber components in the purging device is avoided since such materials out-gas organic compounds, which will be concentrated in the trap during the purge operation. Interfering contamination may occur when a sample containing a low concentration of BTEX is analyzed immediately after a sample with high BTEX concentrations. Preventive action of thorough rinsing of the purging apparatus and sample syringes with two water portions was conducted, as well as one or more reagent blanks were analyzed to check for cross-contamination [9]. Another potential source of contamination from traces comes from organic solvents (i.e., the highest purity methanol), which was assessed before the standard preparation in methanol.

3. RESULTS AND DISCUSSION

The specificity and selectivity of the method were determined based on the retention times of peaks and ion characteristics for each analyte (quantifier and qualifier ions).

Table 1. Retention times and selected ions of the target analytes
(Masses for P&T GC-MS VOC and ISTD)

No.	Analyte	RT	Quantifier	Qualifier	Qualifier	Qualifier
1.	Benzene	5.632	78	52	39	77
2.	Toluene	7.827	91	65	39	92
3.	Ethyl benzene	9.003	91	106	65	51
4.	m – xylene**	9.134	91	106	77	51
5.	p – xylene*	9.134	91	106	77	51
6.	o - xylene	9.363	91	106	77	51

** m- and p-xylene (the same RT, as one peak), so the result is given as a total result for m, p-xylene*

Linearity was tested in a range of different concentrations for each analyte individually on a series of standard solutions prepared according to a standard procedure. Linearity is confirmed because the correlation coefficient (R^2) is greater than 0.999.

Table 2. Linearity with and the corresponding values of the coefficient correlation R^2

Analyte	y= Ax+B	R^2
Benzene	y = 212005.8 x + 2802.4	0.9996
Toluene	y = 292823.9 x + 4918.1	0.9994
Ethyl benzene	y = 104198.1 x + 3631.2	0.9992
m,p - xylene	y = 174957.8 x + 6926.3	0.9992
o - xylene	y = 86776.6 x + 3243.8	0.9991

The values of the correlation coefficient R^2 exceed the value of 0.99, so they can be considered sufficiently close to 1.0; therefore, the dependence can be considered linear. The detection limits were determined from seven repetitions of the concentration standard of 1.0 µg/l and based on the equation: MDL = S*t(n-1,1-alpha = 0.99) where: t(n-1,1-alpha = 0.99) – Student's t value for 99% confidence level and n-1 degrees of freedom, S – standard deviation of repeated analysis.

Table 3. Values of standard deviation and limit of detection (t=3.143 for n-1=6)

Analyte	STDEV	MDL
Benzene	0.012	0.04
Toluene	0.010	0.03
Ethyl benzene	0.012	0.04
m,p - xylene	0.013	0.04
o - Xylene	0.010	0.03

Precision and accuracy were determined by running 6 spiked samples at 0.1 µg/kg. Accuracy is determined by calculating the standard deviations and relative standard deviations.

Table 4. Parameters of precision and accuracy at the level of 0.1 µg/kg

Analyte	Mean	STDEV	RSD (%)	Bias	Bias (%)	Recovery (%)
Benzene	1.082	0.0823	7.6	0.082	8.2	108.2
Toluene	0.995	0.0938	9.4	-0.005	-0.5	99.5
Ethyl benzene	0.98	0.0901	9.2	-0.02	-2.0	98.0
m,p - xylene	0.947	0.0641	6.8	-0.053	-5.3	94.7
o - xylene	1.067	0.0963	9.0	0.067	6.7	106.7

The obtained results show that the requirements of the EPA are fulfilled because recoveries were in the range of 80-120%, and the relative standard deviations were less than 20%.

Table 5. Values of measurement uncertainties at the level of 0.1 µg/kg

Analyte	u(Rw), %	u(bias), %	u (%)	U (%)
Benzene	7.6	8.9	11.7	23.4
Toluene	9.4	4.0	10.3	20.5
Ethyl benzene	9.2	4.4	10.2	20.3
m,p - xylene	6.8	6.1	9.1	18.2
o - xylene	9.0	7.8	11.9	23.9

*where *u is the total (combined) measurement uncertainty, while the extended measurement uncertainty is U = u* 2*

There are no specified special EPA requirements for measurement uncertainty, but considering that it is determined based on accuracy and precision that meet the prescribed criteria, it can be considered that the values of measurement uncertainties are also satisfactory.

Table 6. Calibration, Accuracy, and Precision Data

Compound	Calibration			Accuracy and precision (n = 7, 0.1 µg/kg)[1]		
	Linearity RF (%RSD)	MDL (ppb)	Avg. RF	Avg. Conc. (ppb)	Accuracy (%)	Precision (%RSD)
Benzene	5.48	0.12	1.510	0.85	87	4.51
Toluene	3.39	0.13	1.24	0.95	95	4.44
Ethylbenzene	5.48	0.22	1.50	0.88	90	7.91
m-, p-xylene	9.22	0.43	1.15	1.7	89	7.51
o-xylene	6.57	0.20	1.17	0.89	88	7.03

Data from the seven 0.1 µg/kg samples

4. CONCLUSION

This study confirmed the capability of the use of the P&T system for the determination of BTEX concentrations in the sediment samples with a developed method by a GC-MS. The %RSD of the calibration curve passed all method requirements. Furthermore, MDL, precision, and accuracy showed no interference from excessive water. The procedure of method verification showed that the obtained values are satisfactory and that the applied method can be used to analyze BTEX in sediment samples.

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ECONOMIC INSTRUMENTS IN THE FUNCTION OF ENVIRONMENTAL PROTECTION

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Abstract: *Economic instruments influence the trends of those economic activities that present a danger to the environment and are a suitable and efficient way of reducing environmental costs to the expense of companies (polluters). This is called "internalization of externalities", which means that companies that pollute the environment in any way (externally) take on themselves (internally) the payment of that type of costs. The existence of the costs of degradation of the ecological balance is a very strong reason for the establishment of economic instruments through which companies are charged the price of degradation of the ecological balance. There are many economic instruments that serve to protect the environment and in this paper only those that have the greatest application and importance will be listed: environmental taxes; environmental compensations; transferable pollution permits; deposit refund system; subsidies. The basic purpose of introducing various economic instruments is to force polluters to make a choice. The result of this will have ecological, but also economic consequences of rational behaviour. The main reasons or motives for the significant use of economic instruments in environmental policy are: establishment of efficient and economical environmental policy, administration reform, fiscal reform, and gaining of new sources of public revenue.*
Keywords: internalization of externalities, economic instruments, environmental protection, costs, environmental taxes

1. INTRODUCTION

Environmental pollution is a term that was accepted in the time after the sixties of the last century. In the economic sense, it represents a category that the great economist Marshall called "external effects" for producers and consumers. When deciding on alternative levels of production, consumption, investment, etc., economic entities calculate the costs and benefits of each of the different alternatives. Inputs from the environment and/or outputs of economic processes are not specifically included in the costs and benefits borne by the polluter.
In market economy conditions, companies will try in every possible way to ignore elements of social costs of the environment even if they are aware of their existence. Even more if there are no sanctions for such behaviour. The market mechanism will encourage individual economic participants to transfer social costs to other actors or to postpone them for some future time. This, in turn, means that the existence of social costs of the environment is an argument for the formation of social institutions that will take care of the preservation of the environment.

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What are the instruments through which certain institutions approach the realization of this goal? The classic approach of economic theorists is the one that reckons with the "internalization" of these externalities. In some cases, costs related to externalities cannot be expressed because the ownership of goods or services is not precisely defined [1].
In deciding on different alternative levels of production, consumption, investment and the like, economic subjects are forced to take into account the costs and results, only for themselves, of each of the different alternatives they intend to undertake. Ecological inputs and/or outputs of economic processes, and especially their possible social consequences, as a rule, are not included in the costs and results. Hence, they do not have adequate influence on individual economic entities when making business and investment decisions. Under competitive pressure, the market mechanism is powerless to account for the social cost borne by certain participants, especially in the future. In other words, the existence of social costs of the ecological balance disturbance is a very strong reason for the incorporation of social instruments through which economic actors (enterprises) are charged the "price" of the ecological balance disturbance [8].
There are numerous economic instruments that are used to "internalize" these externalities. Their common feature is that, unlike legal and technical instruments, they leave the participants free to respond in the way that suits them best. Economic instruments affect the costs and benefits of those activities that pose a danger to the environment and are an appropriate and efficient way of reducing environmental costs to the burden of companies (polluters). Terminologically, this is called "internalization of externalities", which means that companies that pollute the environment in any way (externally), take upon themselves (internally) the payment of that type of costs, which can be reflected in fees to state or local authorities, taxes, fines and similar [2].

2. CHARACTERISTICS OF ECONOMIC INSTRUMENTS

Before listing and briefly describing the basic economic instruments, it is necessary to get acquainted with their basic characteristics [3]:

- Transparency - The environmental goals of the green tax reform must be realistic, believable and precisely determined, and the interested public must be timely and thoroughly informed.
- Precision - Environmental taxes should be introduced gradually, with an appropriate dose of caution, while taking into account economic, ecological, demographic, bio-regional, ethno-cultural, psycho-social and political trends. Because any ill-measured and ill-advised action with a bad intention can cause very serious problems, ranging from the loss of competitive advantages on the integrated world market and job losses, all the way to the decline of state authority.
- Equality - Environmental taxes must be compensated by tax breaks in other areas, in accordance with the principle of fiscal neutrality, so as not to stifle production. Where environmental taxes act regressively, the application of compensatory measures is necessary. Predictable social injustices can be alleviated by increasing the non-taxable part of income (subsistence minimum) or lowering the rates of already introduced indirect taxes (sales tax, value added tax). In principle, any system of monetary valuation that is not corrected by fiscal redistribution and conflict arbitration works only in favour of the rich.
- Simplicity - Environmental taxes must be easy to understand so that employees in financial services can simply apply them.

- Stability - The possibility of tax evasion (avoidance of paying taxes) is also relevant for the scope of incomes, therefore it should be taken into account that the obligation to pay them cannot be easily avoided.
- Adaptability - An important element of any environmental protection strategy is its adaptability, both to the overall economic dynamics and the pace of environmental changes. One should always strive to achieve the desired directing power with as few adverse consequences as possible, whenever possible.
- Credibility - Determining the optimal level of the environmental tax and the appropriate choice of the taxpayer is a very sensitive issue. The amount of environmental taxes must not be determined arbitrarily or under lobbying pressure. The very assessment of the justification and possibility of introducing environmental taxes, as well as the procedure for determining their optimal level, requires great financial effort (a large number of public officials, a wide circle of experts, representatives of non-governmental organizations, lobbyists of various interest groups are involved).
- Solidarity - Successful green tax reform cannot be done in one country and there must be an appropriate degree of international alignment. Protecting their own environmental well-being, hyper-industrialized countries are introducing an increasing number of standards, regulations and economic instruments for the internalization of environmental costs, and the accelerated transfer of external economies from countries with higher standards of environmental protection and a stronger compulsion to internalize environmental costs to those with a lower degree of regulation feeds the justified fear that ecological progress could (p)remain a monopoly of rich countries. It would be neither fair nor economically justifiable to force developing countries to immediately bear the full costs of adapting to strict international environmental standards at a time when they are faced with the high social costs of the neoliberal transition.
- Expediency - The full benefit from the introduction of environmental taxes will only be realized when the revenues thus obtained are directed to concrete projects of environmental research and development (to make the technology as reliable, safe and high-quality as possible).
- Responsibility - Despite great faith in science, the final decision is still (and almost always) political.

3. ECONOMIC INSTRUMENTS IN THE FUNCTION OF ENVIRONMENTAL PROTECTION

There are many economic instruments that serve to protect the environment (over 150 in the European Union), and only those that have the greatest application and importance will be listed here (5).

3.1. Environmental (ecological) taxes

Establishing tax burdens that take into account the limitation of non-renewable resources means going to meet green tax reforms, with the ultimate clear goal: desirable environmental action should be made economically profitable as well. Green taxes should cover certain emissions (carbon dioxide, sulfur dioxide, nitrogen oxides), municipal waste, nuclear energy, gasoline, fossil fuels (for heating), certain chemicals containing cadmium, mercury, chlorine, soil concreting and others. activities.

Environmental taxes, as a supplementary source of public revenue, are becoming a social reality. In a number of OECD countries, the instruments of the fiscal system are increasingly being used for the realization of environmental goals. The end of the twentieth century, in

most OECD member countries, was marked by the process of the so-called "greening of tax systems", starting with the introduction of individual environmental taxes (on artificial fertilizers, packaging materials, batteries) and ending with comprehensive environmental tax reforms [4].
The key reason for the introduction of environmental tax in the tax system lies in the need to amortize the impact of pollution on the environment. The goal of environmental taxes is to sanction harmful emissions (air pollution, waste water).
Fiscal burdens, which are built into the price of the product, should force the producer or the consumer to take into account the costs of environmental pollution, as well as other external costs (eg increased noise near the airport), when making economic decisions. Both polluters and consumers should be stimulated to produce or use those products that are more ecologically sound, and the producer should reduce pollution to a level where the marginal cost of implementing a measure to prevent pollution is equal to the prescribed tax rate. In all situations, the polluter has a choice: either to pay the full amount of tax, or to introduce new equipment and technology to reduce pollution, thereby reducing his tax liability. There are three basic categories of environmental taxes [5]:

- Tax on energy products - tax on mineral oils and motor fuels, tax on gasoline, diesel, heating oil, kerosene, kerosene, natural gas and electricity consumption;
- Transport tax - tax for the registration and use of motor vehicles, on the import and sale of motor vehicles, on the use of roads and highways, on insurance of luxury yachts and on air passengers;
- Tax on pollution and natural sources - Tax on pesticides and artificial fertilizers, on packaging and packaging of metal, plastic, glass, ceramics, on waste, on air pollution, on batteries, tires, available containers, on waste water, on plastic bags, on water pollution, on ozone pollutants and on nuclear energy.

In the last decade of the 20th century, income taxes were significantly reduced, by around 10%, in order to be able to introduce environmental taxes into the tax system through tax reforms, in which the Scandinavian countries are particularly at the forefront. Finland and Denmark applied a compensatory measure with tax reforms, by reducing income taxes and increasing bills for energy from non-renewable sources. Energy taxes were introduced with the aim of optimizing energy types and preserving non-renewable resource potentials. Energy taxes also fulfil ecological functions, given that tax "impositions" achieve a higher degree of use and the necessary economy in the disposal of resources. Taxes on energy products were introduced into the EU legislation in accordance with several very important legal principles: prohibition of discriminatory application of domestic costs; prohibition of the application of state measures, such as subsidies; banning the application of quantitative import and export restrictions and other measures with the same effects; and the obligation of member states not to temporarily introduce energy taxation.
The green tax reform, in the member states of the European Union, has been implemented with varying success, and the leaders are Denmark, Finland, Germany, the Netherlands, Sweden and Great Britain. A common feature of the tax reforms in these countries is that they implemented a compensatory measure of income/personal income tax cuts, with the aim of increasing employment [6].

3.2. Pollution charges

The basic purpose of pollution fees is to internalize the cost of damage caused by pollution, by determining the price for activities that pollute the environment, according to the "polluter pays" principle. The classic form of internalization of negative externalities is the

determination of fees for products that pollute the environment, in the form of a unit tax (per unit of pollution). The intention of the legislator is to encourage the polluter to internalize externalities, bearing in mind his marginal external costs. This is achieved by imposing a unit tax, which contains an unrealistic assumption that the reduction in pollution will come from a reduction in production. To overcome this difficulty, fees are introduced for actual pollution emissions [7]. In these situations, the polluter considers the damage caused to the environment as his production cost and the company can continue to pay compensation or will invest in new technologies with the aim of reducing pollution emissions to the permitted level.

3.3. Subsidies

Subsidies, as alternative market approaches to reducing environmental damage, are influenced by subsidizing pollution reduction equipment or subsidizing pollution costs. Subsidies for equipment are intended to reduce the costs of technology in the form of donations or loans with favourable conditions (interest, repayment term, write-off of receivables).

3.4. Deposit and refund systems

The economic instrument of the deposit and refund system discourages illegal dumping of pollutants. A deposit is determined for possible damage, which is equal to the difference between the social and private cost of waste disposal, it is mainly applied for packaging waste and a refund guarantee is issued in all cases if no damage is caused. This instrument combines the pollution compensation and the procedure for the supervision of monitoring costs [7].
The deposit has the same function as the pollution fee, but the main difference is that the potential polluter has an incentive to properly dispose of or process the waste, if it is cost-effective considering the quantity, because that is the only way he will be able to return his deposit. The advantage of this economic instrument is that it does not impose additional monitoring and enforcement costs, and that it promotes the recycling/reuse of raw materials.

3.5. Tradable permits/trading system for pollution permits

In the system of exchangeable permits, the state determines the total allowed amount of pollution, and the market determines the price of pollution. When the information is precise and complete, the tradable permit system achieves the same results as the pollution charge, because it starts from a known variable - the socially permissible/permissible level of pollution. There is a type of tradable permit based on credits that a polluter can acquire if its emissions are below the level and "permits" to pollute, which are marketable and available to polluters depending on new technologies. The state determines the trading conditions for exchangeable permits. Polluters whose total emissions are below the limit values enter the market and sell "permits" for pollution, polluters in a certain region, whose emissions are above the target amount, buy them. In this way, the market of "rights to pollute" is developing [7]. The system of exchangeable permits and the trading of permits/quotas is an effective mechanism for monitoring pollution in the region, and individual polluters are beyond its power. The problem is how to establish a balance between different types of pollution, because in one region probably not all polluters emit the same substances, while depending on climatologically, hydrological and other circumstances, for a given area, certain types of pollution may be disproportionately more dangerous than others.

4. CONCLUSION

Linking economic and environmental policies and their effective integration implies the development and more consistent use of economic instruments. In OECD member countries, in the last two decades, around 150 different economic instruments, including subsidies, have been identified, and of that number, more than 80 are various environmental fiscal taxes. Economic instruments are used as a supplement to regulatory instruments, because their application is an effective form of environmental protection. The basic meaning of the introduction of various economic instruments is to force polluters to make a choice, the result of which has ecological and economic consequences of rational behaviour. The tendency to shift the centre of gravity of environmental protection policy from regulatory to economic instruments of environmental protection is motivated by the gradual dominance of the so-called preventive ecology. The modern concept of environmental protection implies a high degree of compatibility between fiscal policy and environmental policy goals. From an economic point of view, the primary goal of environmental policy is to ensure that the external costs of pollution are borne entirely by emitters. The state must intervene to reduce the costs that the polluter creates for other members of society, and it is quite certain that the polluter would not take such costs into account.

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ENVIRONMENT AND SUSTAINABLE DEVELOPMENT. MECHATRONICS. OCCUPATIONAL SAFETY AND HEALTH AND FIRE SAFETY. SMART MANAGEMENT SYSTEMS. GRAPHIC ENGINEERING. DESIGN. TRAFFIC ENGINEERING. BIOTECHNOLOGY AND HEALTHCARE. MECHANICAL ENGINEERING. ECOTOURISM AND RURAL DEVELOPMENT.

OVERVIEW OF AIR POLLUTION IN THE CITY OF BOR DURING THE PERIOD OF 2020–2022

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Abstract: *The annual levels of SO_2, PM_{10}, as well as As, Pb, Cd and Ni in PM_{10} were assessed in the City of Bor, as an environmental hotspot, from 2020 to 2022. The given period included the data when copper smelting activities were not performed due to the enlargement of the production capacities. The data were compared to the air quality in the study area before 2020 and to the current air quality status in the Republic of Serbia and Europe. The defined annual limit values were exceeded for SO_2, PM_{10}, and Pb concentrations in PM_{10}, while the annual target values were exceeded for As and Cd content in PM_{10}. Among the measuring sites, the poorest air quality was observed at the site Jugopetrol, located in the prevailing NW wind direction. The standstill in the copper smelting activities was perceived in the reduction of the annual levels of SO_2, As, Pb, Cd and Ni in PM_{10}. Compared to the current data for the Republic of Serbia and Europe, the air quality in the City of Bor was poor.*
Keywords: air pollution, SO_2, PM_{10}, toxic elements, copper smelter

1. INTRODUCTION

Air pollution originates from natural and anthropogenic emission sources, whereby the latter ones are considered dominant in the areas endangered by different industrial activities. Air pollutants such as: sulphur dioxide (SO_2), particulate matter (PM), ozone (O_3), nitrogen dioxide (NO_2), and carbon monoxide (CO) are recognised by the World Health Organization (WHO) as crucial environmental threats to the human health on the global level [1] based on their association with numerous negative health conditions. Both inhalation and dermal contact with SO_2 could lead to respiratory problems, lung damage, skin burn or irritation etc. PM, as a major component of air pollutants, are classified as carcinogenic [2]. PM exposure is associated with increased rate of hospitalization, lung cancer, as well as respiratory and cardiovascular diseases. It should be emphasised that toxic elements present in PM are associated with carcinogenic and non-carcinogenic health risks [3]. Environmental impacts of air pollutants could be observed through the damages of ecosystems, acid rain, soil acidification, ozone depletion, deforestation, climate change etc. [2,4,5].
Mining and metallurgical activities in the City of Bor have contributed to the significant environmental pollution, whereby extreme air pollution was denoted in previous decades [6,7,8,9]. Thus, modernization of the copper production was performed and pyrometallurgical copper production was replaced with the flash smelting technology (FST) with higher productivity and

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smaller negative environmental impact, as the main advantages. However, the data for the period after the FTS implementation indicated that the City of Bor is still a hotspot concerning air pollution with As and SO_2 [10]. Thus, the continuous monitoring of the air pollution in the City of Bor still represents one of the most important issues in terms of protection of human health and the environment.

This paper summarizes the annual concentrations of SO_2, PM_{10}, as well as As, Pb, Cd and Ni in PM_{10} for the period 2020–2022, aiming at comparing the periods before and after the FST implementation, regarding the current air quality status in the Republic of Serbia and Europe as well. The given 3-year period includes the air pollution data when copper smelting was out of order due to the enlargement of the copper production capacities.

2. METHODOLOGY

Mining in Bor started 120 years ago with the discovery of copper rich ore deposits, which were afterwards exploited and processed. The pyrometallurgical copper production from sulphide ores (chalcopyrite – $CuFeS_2$, chalcosine – Cu_2S, coveline – CuS and arsenopyrite – FeAsS) was the main pollution source of SO_2 and particulate matter, along with the copper mining activities. The outdated technology was replaced with the FST as an advanced and energy-efficient production method, during 2016 [9,10].

Monitoring of the air pollution levels in the City of Bor is performed by Mining and Metallurgy Institute Bor. In the given period (2020–2022), polluting substances (SO_2, PM_{10}, as well as As, Pb, Cd and Ni in PM_{10}) were measured at seven sites (Table 1) which were part of the local and the national Air Quality Monitoring network. The air pollution levels are given in the annual reports by Mining and Metallurgy Institute Bor [11,12,13].

The analysed period also included the data when the smelting was fully stopped, due to the enlargement of the copper production capacities from April 2022 till the end of the year 2022.

Table 1. Description of the measuring sites for monitoring of the air pollutants in the City of Bor
Source: MMI reports [11,12,13]

Measuring sites	Zone	Coordinates	Location*	Measured parameters
Institute (IN)	Urban–industrial	N 44º3’35’’ E 22º6’05’’	2 km S	SO_2
				PM_{10}
Jugopetrol (JP)	Suburban	N 44º3’15’’ E 22º7’46’’	3.3 km SE	SO_2
				PM_{10}
Technical faculty (TF)	Urban–industrial	N 44º4’54’’ E 22º5’43’’	1 km WNW	SO_2
Town Park (TP)	Urban–industrial	N 44º4’33’’ E 22º5’58’’	0.5 km SW	SO_2
				PM_{10}
Krivelj (KR)	Urban–industrial	N 44º7’47’’ E 22º5’42’’	6 km N	PM_{10}
Oštrelj (OŠ)	Suburban–industrial	N 44º4’08’’ E 22º9’36’’	4 km ESE	PM_{10}
Brezonik (BR)	Suburban–industrial	N 44º5’53’’ E 22º5’30’’	3 km NNW	PM_{10}

*in regard to the copper smelter.

Data visualization was done using the R programming language (v 4.1.0, R Core Team) [14] and the R package ggplot2 [15].

3. ANALYSIS OF AIR POLLUTING SUBSTANCES LEVELS

3.1 The levels of SO_2

The annual levels of SO_2 for the study period are given in Figure 1. Annual SO_2 concentrations have exceeded the defined limit value (LV, 50 μg m^{-3}) [16,17] at the sites TF (during 2020 and 2021), TP (2020) and JP (in the period 2020–2022). Considering the 3-year period, it can be seen that SO_2 levels decreased at all the measuring sites, with the highest levels in 2020 and the lowest in 2022. This could be attributed to the fact that smelting activities were not performed since April 2022. Among the measuring sites, the highest levels of SO_2 were observed at the site JP. This site was also characterised by the poorest air quality, regarding SO_2 levels, in the previous years [7,8,9,10]. This can be attributed to the location of this measuring site, which is located in the prevailing NW wind direction.
Although the levels of SO_2 were not as high as in the previous decades [7,8,9,10], in the Serbian Environmental Protection Agency reports [18,19], during 2020 and 2021, the air quality in the study area was of the third category (*i.e.* over-polluted air). The City of Bor was the only agglomeration in this category due to the high SO_2 levels. During 2020 and 2021 the levels of SO_2 were measured in the Republic of Serbia at 44 and 39 stations (excluding stations in Bor), respectively, and the annual limit value was not exceeded at any of these stations [18,19]. The SO_2 annual levels have been decreasing across the European countries from 2009 to 2018, with the highest decrease noted at the stations in suburban, and the lowest at the stations in urban areas [2].

3.2 The levels of PM_{10}

The levels of PM_{10} were above the defined LV (40 μg m^{-3}) [16,17] only at the site JP (2022) (Figure 2). The exceedances of the annual LV were not pronounced as in the period after the implementation of FST [10].
High levels of PM_{10}, along with the levels of SO_2, have contributed to the fact that the air in the City of Bor was overly polluted (III category) during 2021 [19]. During 2020 and 2021, the annual LV was exceeded at 18 and 15 stations, respectively, which makes PM_{10} the dominant polluting substance in the Republic of Serbia [18]. In Europe, during 2018, PM_{10} levels above the annual LV were noted at 6% out of more than 3000 stations [2].

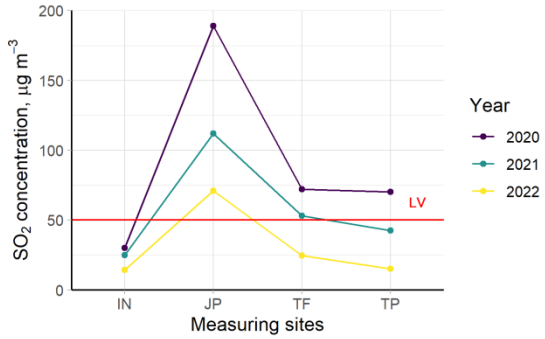

Figure 1. SO_2 concentrations at the measuring sites in the City of Bor (horizontal line represents annual limit value – LV)

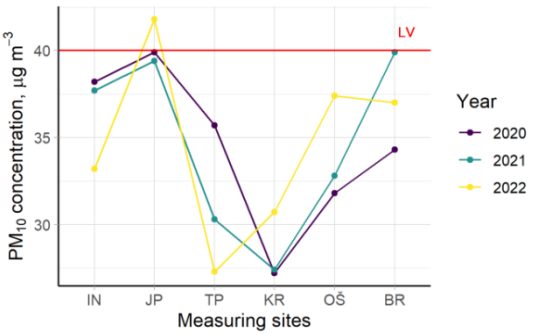

Figure 2. PM_{10} concentrations at the measuring sites in the City of Bor (horizontal line represents annual limit value – LV)

3.3 The levels of As, Pb, Cd and Ni in PM_{10}

Arsenic concentrations have exceeded the annual target value (TV, 6 ng m^{-3}) [16,20] at all the sites, during the analysed period, except at the site KR (2022) (Figure 3a). Compared to the As levels in 2020, during 2021 and 2022, the concentrations were lower, which could be attributed to the standstill in the copper smelting activities. The annual As concentrations were lower compared to the period

after the implementation of FST (2016–2019) [10]. The measuring site with the highest levels of As was the JP, which is located in the prevailing NW winds [10]. The high levels of this toxic element in PM_{10} were also noted during 2022, when smelting was not performed, which indicated that As could also have originated from other anthropogenic activities, such as resuspension of dust from the flotation tailings, as well as handling of the copper concentrates during transportation.
In Serbia, As levels on an annual basis were far below the TV during 2020 and 2021 [18,19]. During 2018, As levels above the annual TV were recorded at 6 out of more than 650 stations in Europe [2].

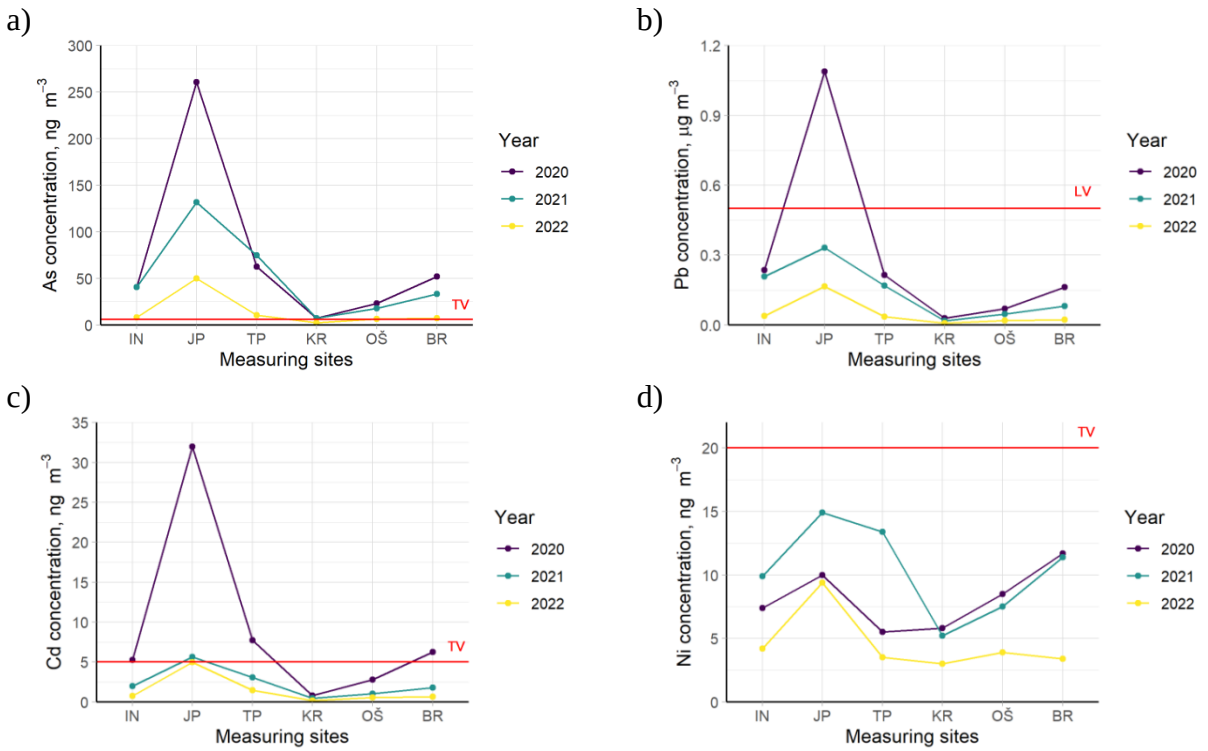

Figure 3. Toxic elements concentrations (a) As, (b) Pb, (c) Cd and (d) Ni in PM_{10} at the measuring sites in the City of Bor (horizontal line represents annual target value – TV for As, Cd and Ni, and limit value – LV for Pb)

Pb levels were above the defined annual LV (0.5 µg m^{-3}) [16,17] at the site JP (2020) (Figure 3b). Compared to the Pb concentrations during 2020, the concentrations of this toxic element were lower during 2021 and the lowest during 2022 when smelting activities were stopped. However, the JP stands out with the highest levels of Pb, due to its location on the prevailing wind directions, resuspension of dust from the flotation tailings, as well as handling of copper concentrates during transportation. The levels of Pb at the site JP frequently exceeded annual LV in the periods before and after implementation of FST [9,10].
In Serbia, during 2020 and 2021, the levels of Pb in PM_{10} did not exceed the LV, both at the stations where fixed and indicative measurements were done [18,19]. The Pb levels above the annual LV were recorded only at one out of nearly 700 stations across Europe during 2018 [2].
From Figure 3c it can be seen that concentrations of Cd were above the defined TV (5 ng m^{-3}) [16,20] at the sites IN (2020), JP (2020 and 2021), TP (2020), and BR (2020). Since 2020, the levels of Cd decreased on an annual basis, with the lowest ones during 2022 when smelting was not performed. The measuring site JP stands out with the highest levels of Cd, due to the dust resuspension from the flotation tailings, as well as copper concentrate handling during transportation. At the site JP the exceedings of the defined TV were observed in the periods before and after the implementation of FST [9,10].
In Serbia, the Cd levels on an annual basis were far below the TV during 2020 and 2021 [18,19]. In Europe, concentrations above the annual TV for Cd were not recorded during 2018 [2].

The Ni levels were below the defined annual TV (20 ng m^{-3}) [16,20] (Figure 3d). Among the measuring sites, the highest levels of Ni were observed at the site JP during 2021 and 2022, and the site BR during 2020. The lowest levels of Ni were noted for all the sites in the period when smelting activities were not performed, which could indicate its dominant anthropogenic origin. The annual levels of Ni did not exceed the defined TV in the period after FST implementation [10].
The levels of Ni on an annual level were below the defined TV during 2020 and 2021 in Serbia [18,19]. The concentrations of Ni were above the annual TV at 3 out of nearly 700 stations in Europe during 2018 [2].

4. CONCLUSION

The aim of this study was to analyse the concentrations of the air pollutants monitored at the measuring sites in the City of Bor, which is recognised as one of the most polluted region in the Republic of Serbia and beyond, due to the copper mining and smelting activities. The annual levels of SO_2, PM_{10}, as well as As, Pb, Cd and Ni in PM_{10} from 2020 to 2022 were compared to the defined limit and target values, as well as the current air quality in the Republic of Serbia and Europe. The data were also compared to the air quality in the study area before the analysed period. The exceedances of the defined annual LVs were observed for SO_2, PM_{10}, and Pb concentrations, and the annual TVs for As and Cd. Regarding the measuring sites, the site Jugopetrol located in the prevailing NW wind direction was characterised by the poorest air quality. The standstill in the smelting activities, due to the reconstruction of the copper smelter, was noted for the lower content of SO_2, As, Pb and Cd during 2022. Considering the air quality in the study area in previous years, the concentrations of the given pollutants were generally lower. However, the air quality in the City of Bor, for the given period, was poor, regarding the air quality in the Republic of Serbia and Europe, as well.

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ENVIRONMENT AND SUSTAINABLE DEVELOPMENT. MECHATRONICS. OCCUPATIONAL SAFETY AND HEALTH AND FIRE SAFETY. SMART MANAGEMENT SYSTEMS. GRAPHIC ENGINEERING. DESIGN. TRAFFIC ENGINEERING. BIOTECHNOLOGY AND HEALTHCARE. MECHANICAL ENGINEERING. ECOTOURISM AND RURAL DEVELOPMENT.

MINING SOLID WASTE AROUND BOR, YESTERDAY, TODAY, TOMORROW

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Abstract: *Intensive exploitation and processing of copper ore in the area of Bor District has led to the degradation of large areas of land and the deposition of large amounts of solid waste (mining overburden and waste dumps, flotation tailings, smelter slag). The characteristic of these wastes is that they contain significant amounts of copper and other elements, but also permanently lead to soil, water and air pollution. The paper shows photos of the evolution of the appearance of mine solid waste landfills and provides data on sanation and recultivation and a plan for further activities. Conceptual solutions for sanation degraded areas created by hundred years of mining in Bor were also given.*
Keywords: Overburden, Flotation Tailings, Environment

1. INTRODUCTION

In the modern practice of producing non-ferrous, rare and precious metals, more and more attention is paid to the possibility of treating raw materials with low metal content, considering that they have disappeared, or the reserves of rich ores are very limited. At the same time, the intensive development of technology in the world leads to a higher consumption of metals, which results in a multiple increase in the price of metals in recent years [1]. The development of technological processes for recov ering the low-percentage copper ore and complex raw materials, demands the massive production, which has got a strong negative effect on the environment, especially when such ore is mined in the open-pit mines. The harmful influence of mining operations has been reflected in the degradation of vast areas of soil (open-pit mines), then, damping large volumes of solid wastes (mining overburden, waste rock dump and flotation tailing) as well as the occurance of acid mining waters. During the metallurgical processes of polymetalic ores and concetrates, besides obtaining the basic metals, there have also been formed middlings (slag, dust, and mud-slurry) [2].
Some research has shown that today there are 3,500 active overburden dumps in the world and that 100 billion tons of mining waste are deposited there annually [3]. In the countries of the European Union, more than 5 billion tons of mining waste are disposed of, most often in Finland, Greece, Ireland, Portugal , Spain, Sweden and Great Britain [1].
In 2020, the equivalent of 4.8 tons of waste was produced per EU resident. This figure includes 3,080 kg of coarse mineral waste and 1,735 kg of waste from other sources. In other words, 64 percent of waste in the EU comes from mining. Figure 1 shows data on waste generation by individual countries in Europe [4].

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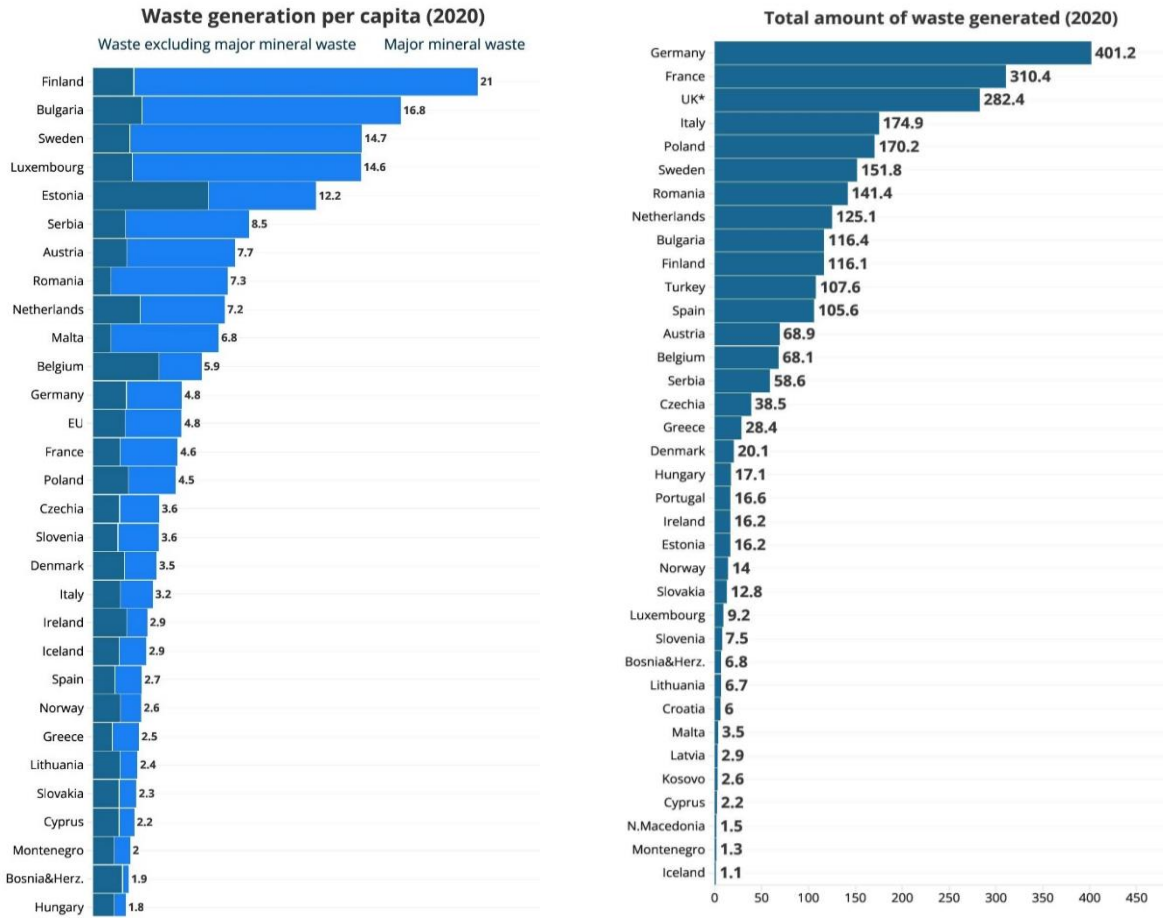


Figure 1. Data on waste generation by individual countries in Europe
Source: https://sn.rs/c9ypb

2. BOR YESTERDAY

Formerly RTB-Bor and today Zijin Copper represents one of the most important mining and metallurgical complexes in the Western Balkans. Mining production in Bor began in 1903, with underground exploitation. Surface mining in Bor began in 1912 and lasted until 1986. The two largest open-pit mines are Veliki Krivelj (opened in 1979) and Cerovo (opened in 1990).

Until 2001, the following were deposited on the territory of the municipality of Bor: 450 Mt of overburden, 207 Mt of flotation tailings and 23 Mt of smelter slag [5,6]. This waste represents a total of 99.95% of the total waste deposited on the territory of the municipality of Bor. Approximate quantities of deposited material in the vicinity of Bor are shown in Figure 2, and a schematic representation in Figure 3.

Mining has degraded 1198 ha of agricultural land, i.e. 0.02 ha per inhabitant. As a result of the discharge of wastewater from flotation and flotation tailings, 2,500 ha of land was destroyed, i.e. 0.4 ha per inhabitant [5,6]. The total area of the RTH tailings pond is 86.4 ha, and the area of the inactive "Visoki planir" mine disposal site is 302 ha with 177 ha of flat areas and 125 ha of sloping areas.

From the creation of the mining waste disposal site until 2019, technical and biological recultivation of degraded areas was carried out on several occasions. For example, in just one action in 1992, 190,000 acacia seedlings were planted on the flotation tailings of Bor and Veliki Krivelj, and 74 ha of degraded soil was filled with humus and grass was sown [7].

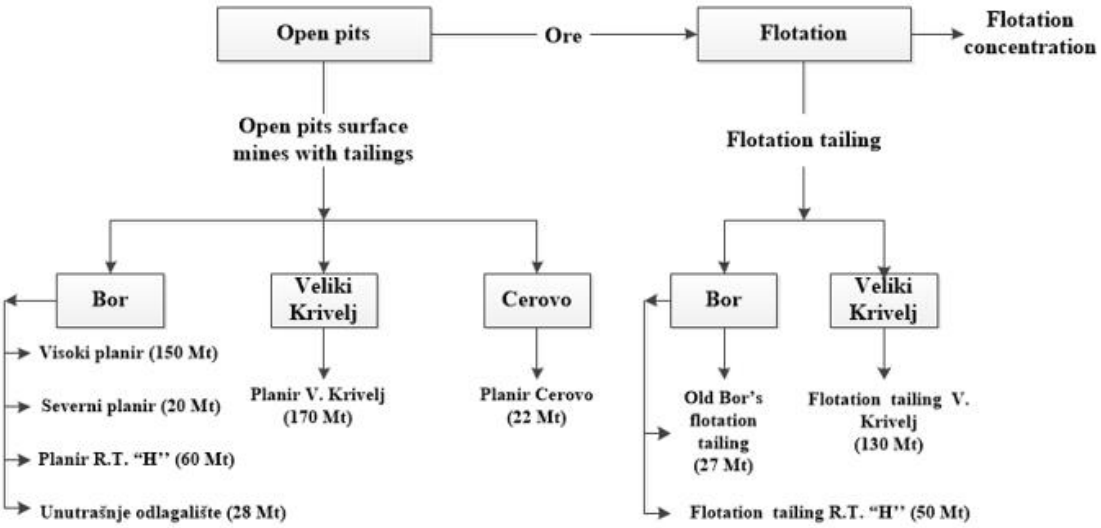
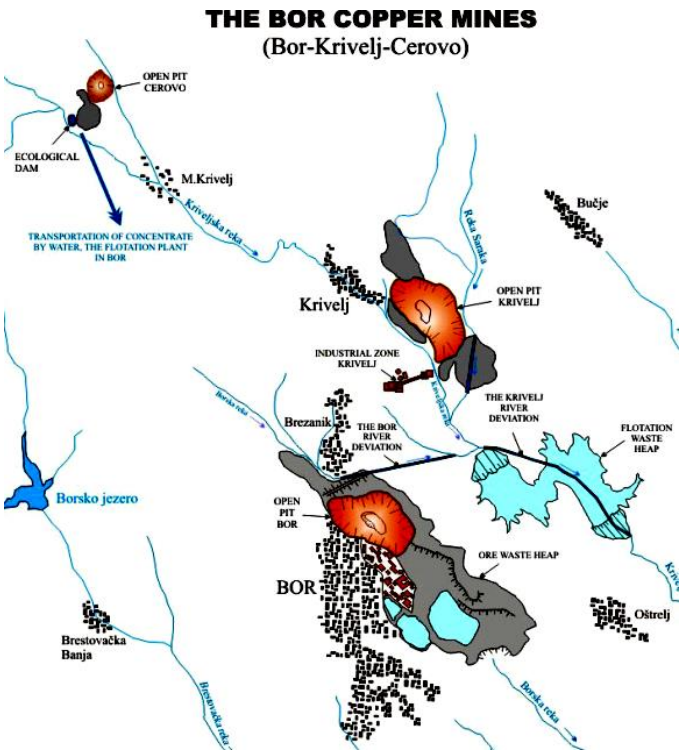


Figure 2. Graphic representation of the amount of waste materials until 2001
Suorce: [5]



Visoki planir and flotation tailing RTH

Lake Robule

Figure 3. Schematic representation of deposited overburden dumps around Bor
Suorce: [8]

3. BOR TODAY

Serbia Zijin Copper DOO is a company operating within the Zijin Mining Group. It was founded on December 18, 2018, on the day when Zijin and the Government of the Republic of Serbia signed the final documents, i.e. the contract on the acquisition of 63 percent of ownership in RTB Bor. Serbia Zijin Copper is committed to reducing the adverse impact on the environment and since taking over RTB Bor has invested considerable funds, among other things, in reculturing degraded areas. Table 1 shows data on recultivated areas and planted seedlings by location [7].

Table 1. The area that has been recultivated and the number of seedlings planted
Suorce: *[7]*

Location	Open-pit mine Veliki Krivelj	Veliki Krivelj Flotation Plant	Flotation tailings VK	Flotation tailings RBM	Flotation tailings RTH	Old Bor dumps	Open-pit mine Cerovo	Cerovo Flotation Plant	Kamenolom	Pit	Zagradje	Open-pit mine RBM	RBM Flotation Plant	TIR	Σ
Recultivated areas, ha	6.72	8.72	50.68	43.99	22.59	14.47	9.24	3.15	0.91	3.65	1.57	16.66	2.31	3.53	188.19
Planted seedlings	11,345	14,750	39,975	36,300	128,865	14,872	6,439	2,546	6,300	18,468	554	33,300	1,829	13,490	329,033

Figure 4 shows an example of two recultivated locations.

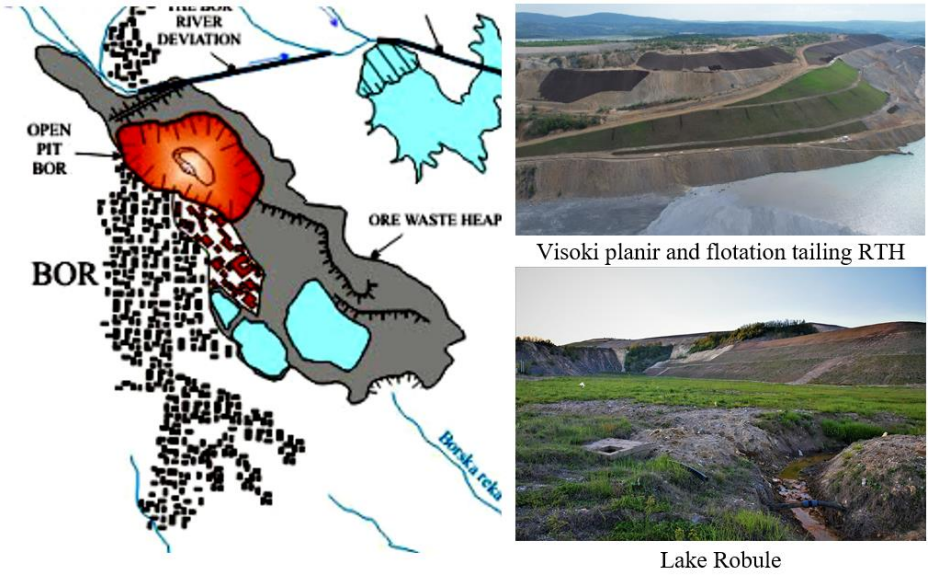


Figure 4. An example of recultivation (Bor today)
Suorce: [8]

4. BOR TOMMOROW

In the future, the company Serbia Zijin Copper DOO plans to continue activities on the recultivation and remediation of degraded areas, as well as the preparation of project documentation and the construction of solar power plants, which would meet part of the electricity needs from renewable sources. The use of renewable energy sources will significantly relieve the electricity grid of Serbia. The construction of solar power plants will be carried out in three phases, over the next 10 years, with the ultimate goal that in 2033 the production of electricity will be around 100 megawatts, while simultaneously reducing carbon emissions by 175,000 tons per year. The plan is that after the implementation of the project, the surroundings of Bor will look like the photos in Figure 5.

Figure 5. Forecasting the appearance of the around Bor in the future
Suorce: [8]

5. CONCLUSION

The constantly increasing development of human society is based on the development of industrial production and energetics imposing thus the necessity for larger exploitation of mining resources, that is, mineral raw materials. A long-term exploitation in Bor and its vicinity had a great influence on the environment through the degradation of large areas of soil (open-pit mines), then, the deposition of huge volumes of solid wastes (overburden and waste rock), next, forming waste waters and air pollution. How it was yesterday, how it is today, and how it will be tomorrow for the citizens of Bor, we leave it to the readers to answer for themselves, and we only give a couple of photos in Figure 6.

Yesterday Today Tomorrow

Figure 6. Past, present, future
Suorce: [8]

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THE SOLUTION FOR REUSING NON-RECYCLABLE PLASTIC-BASED MATERIALS

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Abstract: *In this paper, an innovative technology for recycling materials that cannot be recycled using conventional methods is presented, such as composite plastics, for example. The result is an eco-friendly material with good mechanical properties that can replace wood, metal, and other plastic materials. The production and application of this eco-material are in complete accordance with environmental principles.*
Keywords: Recycling, Innovative Technology, Non-recyclable Materials, Mechanical Properties

1. INTRODUCTION

From the 1950s to the present day, plastic production has been steadily increasing. This is entirely understandable when considering the widespread use of plastic materials in various sectors.The worldwide production of plastics reached a staggering 390.7 million tons in 2021 [1]. The packaging industry undoubtedly takes the lead. Plastic bottles for bottled water and soft drinks, as well as a whole range of other types of packaging in the food and other industries, as well as the automotive, electrical, and construction materials industries, are practically inconceivable without the use of plastic. Only 9% of the mentioned quantity of plastic produced after use is recycled, so it is clear that plastic waste represents a global problem [2].
It is expected that the amount of plastic waste will exceed one billion tons by 2050 [2], which necessitates a serious approach to recycling, as well as innovation in this field and the development of new types of materials.

2. PREVIOUS EXPERIENCES IN PLASTIC RECYCLING

Existing known plastic recycling processes require very careful and detailed sorting of waste materials by type, which is by no means simple and requires prior knowledge to properly separate and sort them after collection. In fact, existing recycling technologies can only process homogeneous plastic materials. Sorting plastic materials, especially when dealing with large quantities, is challenging because plastic materials often appear almost identical at first glance, and the markings for plastic type are sometimes hard to spot.
In practice, it often happens that improper sorting in the primary selection phase, as well as in the primary recycling phase, which involves mechanical shredding of plastic waste, leads to the mixing of various plastics. From contacts with larger plastic recycling centers in the country and the region, we have information that during one business year, between 5-10% of the amount of plastic waste

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processed through primary recycling cannot be further processed with known technology. It is also common for plastic pieces to be sent for recycling that consist of multiple parts made of different types of plastic. The costs of separating such parts far exceed the upper limit of profitability, and they need to be manually separated using various tools. Unfortunately, even such an approach is not a guarantee of achieving complete separation [3, 4]. In such cases, all parts are shredded together and pose a problem for further recycling.

Currently, there is no known technology for recycling, processing, and reusing composite and mixed plastics with glass. Such waste materials are mostly incinerated or deposited in landfills. One of the recycling ideas for composite and mixed plastics is presented in this paper. The result is a new, innovative technology that successfully recycles 80% of previously non-recyclable, non-hazardous composite and mixed plastics and glass, with only 20% consisting of selected plastic materials. The resulting eco-material possesses exceptional properties, as demonstrated in the following chapters of this paper. First, however, we will present the fundamentals of the innovative technology for recycling composite, mixed plastics, and glass.

3. INNOVATIVE RECYCLING TECHNOLOGY AND PRODUCTION OF INNOVATIVE ECO MATERIALS

The innovative recycling technology (Fig. 1), i.e., processing and reusing various types of composite and mixed plastics, which are mostly not recyclable, along with glass, is based on a special process for preparing the initial plastic waste.

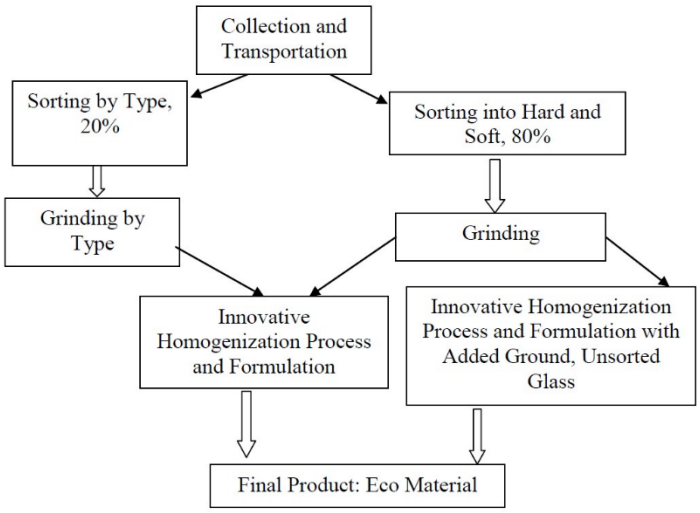

Figure 1. Diagram of Innovative Recycling Technology

The core of innovation is in a specific type of homogenization of the starting material with changes in the sequence of operations in the recycling process. The formulation and recipe design that combine waste materials are also a form of innovation, requiring a significant number of hours for experimentation and trials.

By comparing the processes of conventional recycling and innovative recycling, the innovative technology offers the following solutions:

- Processing, recycling, and reusing various types of waste mixtures, plastic composites, and glass.
- Sorting by type (polypropylene, polyethylene, polyvinyl chloride, etc.) is minimized or can even be eliminated because our formulation includes only 20% of selected plastic, as mentioned earlier. Therefore, there is a clear saving in time, labor, and storage containers.
- The elimination of the need to further process sorted plastic separately and in separate lines (washing, drying, granulation) or to wait for one type to be processed before the next.
- Reducing the number of mechanical processing operations of waste plastic that precedes the production of the finished product.

- A specific process and formulation for mixing waste plastic to homogenize it in a straightforward manner.
- A new process and formulation for mixing waste plastic to obtain a widely applicable material for various finished products.

Through the injection molding and extrusion process from regranulate a new product is obtained with a clear limitation that, depending on the type of initial waste plastic, a recycled product of the same type with known characteristics and limited applications is produced. In our case, the resulting eco-material has entirely new properties, significantly improved compared to the raw materials, and thus a wide range of possibilities for a broad spectrum of finishing products.
The aforementioned observations lead to the conclusion that this innovative technology presents a solution for the reutilization of a significant quantity of mixed waste plastics, composites, and glass. It demonstrates energy efficiency and yields a product with a broad spectrum of applications. It serves as a noteworthy illustration of sustainable development and the circular economy, both of which are global aspirations.
Upon reviewing the literature and closely following developments in this field, it appears that there are seemingly analogous concepts related to recycling composites and mixed plastic waste. However, these concepts are typically confined to specific combinations of plastic and composite mixtures. A notable distinction from our solution lies in the considerably more intricate and extensive mechanical treatment of the initial material they employ. Additionally, these concepts lack in the homogenization process, where high temperatures are utilized, resulting in unavoidably higher energy expenditures and, consequently, escalated recycling costs.

4. A PRODUCT MADE FROM MATERIALS OBTAINED THROUGH NEW TECHNOLOGY

From materials obtained in this way, various products can be made, and the paper examines filled or hollow plastic profiles - eco column, which can serve as a replacement for traditional columns made of wood, concrete, metal, etc.
For this patent, an intellectual property protection certificate number 57664 was obtained in Serbia. In future research, it is necessary to conduct a life cycle assessment of the eco-product using the appropriate methodology [5], as this would further position this eco-material. It is important to note that this innovative technology falls within the recycling sector, which is certainly one of the priority areas for development and investment worldwide, in accordance with the principles of Agenda 2030 [6]. Considering that, until now, there hasn't been a cost-effective and beneficial solution for waste materials such as composite plastics, various plastic mixtures combined with waste glass, etc., the market for this innovative technology, eco-material, and its related products is substantial.

5. THE TYPE OF WASTE PROCESSED USING INNOVATIVE RECYCLING TECHNOLOGY

The formulation of innovative technology involves the following types of waste materials:
- Soft PVC - Index number according to the waste catalog:150201 [7]. After grinding, this mass is homogenized with glass and other non-recyclable plastics, and it is used as a filler for profiles. It is rarely recycled, even though recycling is possible, and is typically subjected to incineration.
- Rigid PVC - Waste index number: 1501002 [7]. It is used as a filler in a certain percentage or for manufacturing profiles.
- Multi-layer HDPE plastic bags with an addition of 10-15% PA or PET are used as a component for filling material. Waste index number: 150102 [7].
- Ground packaging glass, waste index number 150107 [7]. The potential for recycling is significant, but it has almost become inactive in our region. [8].

Manufacturing products from non-hazardous waste plastics that have not been suitable for recycling until now, occurs in several stages.

- The extrusion process for creating elongated hollow profiles from recycled plastic,
- Filling hollow profiles with a composite filler made from non-recyclable plastic-based materials, with the addition of ground glass or fabric. The filled profiles are called eco-columns.

6. MECHANICAL PROPERTIES OF THE ECO-MATERIAL AND THE FINISHED PRODUCT

In order to obtain certain mechanical properties of the eco-columns, tests were conducted on hollow and filled plastic profiles. Prior to that, the properties of the materials for manufacturing the profiles and the filler material were evaluated. The tests were conducted in laboratory at the Faculty of Civil Engineering in Subotica.

6.1 Testing plastic material for profiles

The mechanical characteristics testing of the plastic profile material was conducted on 9 samples. The test specimens were rotationally symmetrical in the cylinder shape with a length of 50 cm, and a diameter of 30 mm. The obtained average values of the results are:

- mass per volume: m = 1.414 g/cm3,
- tensile strength: σ = 33.24 MPa,
- recovery of strain after tensile failure: δ_E = 98.6 %.

6.2 Testing composite filler material

The mechanical characteristics testing of the composite filler material based on hydraulic binder was conducted on 9 samples in the form of a prism with dimensions of 4x4x16 cm. The reported results represent the mean values and pertain to a water-saturated state:

- mass per volume: m = 1.471 g/cm3,
- bending tensile strength: σ = 2.68 MPa,
- compressive strength: σ = 6.22 MPa.

6.3 The compression testing of short columns untill failure

These tests were conducted on samples that were cut out of the columns (hollow and filled) and prepared in a way to avoid slenderness efects during compression testing. The tests were performed on three samples of hollow and three samples of filled columns. The columns had square cross-section dimensions of 75x75mm, an average wall thickness of 7.2 mm, and a composite recycled mixture as the filler, while the height of the samples was 260 mm [9]. Samples during testing are shawn on Figure 2 and obtained diagrams on Figure 3 and Figure 4. The diagrams are interesting because they show the difference in the load-bearing capacity between a hollow and a filled column, and this is in favor of the filled column, as expected. Nonetheless, it's evident what the maximum compressive load capacity is for both column types, hollow and filled.

Figure 2. Samples during testing
Source: [9]

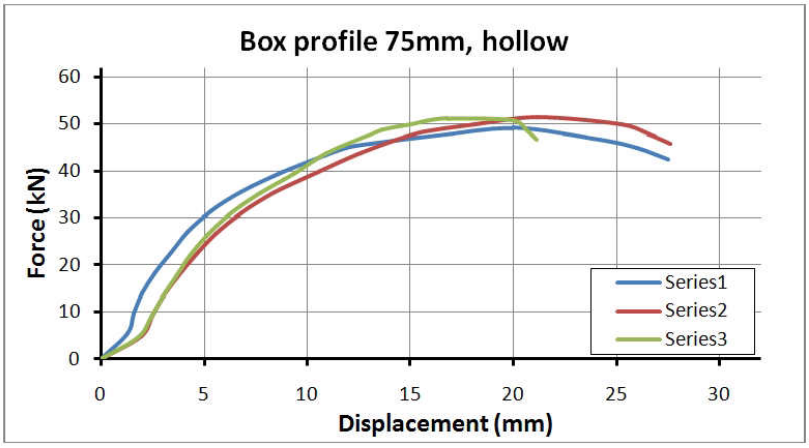

Figure 3. The compression testing untill failure data of hollow profiles
Source: [9]

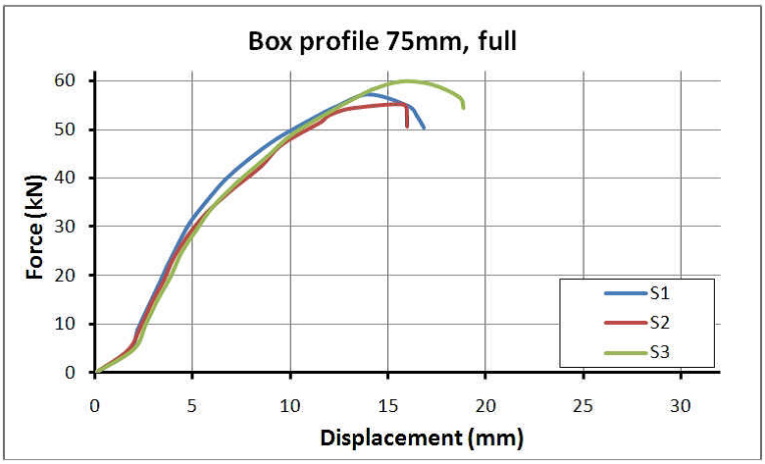

Figure 4. The compression testing untill failure data of filled profiles
Source: [9]

- The maximum achieved compressive force at the point of failure for a filled column: F = 57.87 kN.
- The maximum achieved compressive force at the point of failure for a hollow column: F = 50.89 kN.
- The maximum deformations (shortening) - filled column: Δl = 17.21 mm,
- The maximum deformations (shortening) - hollow column: Δl = 25.42 mm.

7. CONCLUSION

In this paper, the potential of materials resulting from research in the development of innovative technology for recycling composite plastics is presented. This eco-material is functional and comes with numerous advantages, including:

- It can replace traditional materials (metal, concrete, wood, etc.) in the production of widely applicable products in construction, agriculture, transportation, etc.
- It doesn't require additional protection in terms of impregnation or painting.
- Green manufacturing technology.
- Environmental protection,
- Savings and conservation of natural resources - waste materials that were previously incinerated or deposited in landfills are used instead of primary raw materials.
- The products can be recycled again using the same technology.

- The products can be aesthetically attractive, they can be colored during the manufacturing process, and their surface appearance can be customized to mimic the look of wood or any other desired structure.

The points highlighted in this paper undeniably lead to the conclusion that this innovative technology, and we can confidently add the label 'green technology' to it, as a solution for reusing a wide range of waste plastic mixtures, composites, and glass, is energy-efficient and results in a product with a broad range of applications. It can serve as an example of sustainable development and the circular economy that is pursued on a global scale

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ELEMENTAL ANALYSIS OF RARE EARTH ELEMENTS IN COAL FLY ASH FROM THERMAL POWER PLANTS IN THE REPUBLIC OF SERBIA

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Abstract: *Today, coal is widely used as an energy source in thermal power plants, but the process of combustion results in emissions of many air-pollution substances, as well as producing large amounts of bottom ash, fly (electrophilic) ash, and slag. In most cases, these materials are disposed of in landfills where they have a negative impact on the environment and human health. This paper focuses on exploring the possibility of extraction of rare earth elements from fly ash collected from different thermal power plants in the Republic of Serbia (Thermal power plant „Nikola Tesla" TENT A and thermal power plant „Kolubara"), by analyzing the concentrations of those elements in collected samples. Rare earth elements are a group of 17 chemical elements: Sc, Y, La, Ce, Pr, Nd, Pm, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb and Lu. The samples were acid-digested with a mix of concentrated mineral acids (nitric acid, hydrofluoric acid, and boric acid), in order to determine the elements of interest from the sample matrix. Determination of the content of rare earth elements was done by the ICP-MS.*
Keywords: coal fly ash, rare earth elements, microwave digestion, extraction

1. INTRODUCTION

After the process of coal combustion in thermal power plants (TPP), waste materials such as bottom ash, fly (electrophilic) ash, and slag are left behind. In the Republic of Serbia, those waste materials are, in most cases, disposed of in landfills where they have a negative impact on the environment and human health. The reason for this negative effect is due to a high content of various toxic substances, which can pollute different environmental mediums (air, soil, and water) [1]. However, due to the complex composition of fly ash, it is proven that this waste material can be used for various purposes and not disposed of in landfills. It can be used in the construction industry, for producing ceramics, for soil stabilization, in the production of catalysts, as a filler in the tire industry, and its potential use as a sorbent as well as raw material for extraction of useful elements (such are rare earth elements) is widely examined [2]. Because of technological development, increasingly strict regulations in the field of environmental protection as well as economic benefits, interest in fly ash as an alternative raw material for obtaining useful products is higher than ever. In this paper, the possibility of obtaining rare earth elements from fly coal ash was examined.
Rare earth elements (REE) are a group of 17 chemical elements in the periodic table with very similar chemical properties, including scandium, yttrium, and 15 lanthanides (lanthanum, cerium, praseodymium, neodymium, promethium, samarium, europium, gadolinium, terbium, dysprosium, holmium, erbium, thulium, ytterbium and lutetium) [3]. Rare earth elements have been subdivided

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into two groups, i.e., light rare earth elements (LREEs) and heavy rare earth elements (HREEs), according to their atomic weight. LREEs include elements from scandium (atomic weight 44.96), yttrium (atomic weight 88.91), lanthanum (atomic weight 138.91) through europium (atomic weight 151.96) while HREEs include elements from gadolinium (atomic weight 157.25) through lutetium (atomic weight 174.97) [4]. REEs are not found in nature as pure metals, they are extracted from different minerals, which do not often occur in easily exploitable deposits. These elements do not occur individually in nature because of their chemical similarity. There are around 200 rare earth elements containing minerals, but out of those only bastnaesite, monazite, xenotime, and ion-adsorbed clays are mined for commercial REE production [5]. Today, rare earth elements are very used in different industries. Some of them include the high-tech industry and a variety of consumer goods such as computers, cell phones, fluorescent lighting, permanent magnets, medical devices, and advanced defense technology [6]. Catalysts, ceramics and glass, metallurgical use, and alloy manufacturing as well as polishing are the major industries that consume thousands of tons of rare earth elements [4].
In order to extract REEs from coal fly ash samples, nitric, hydrofluoric, and boric acids were used. The main purpose of using those acids is to free the elements of interest from the sample matrix so that the analysis of the content of those elements in collected samples can be done.

2. MATERIALS AND METHODS

Representative samples of electrophilic, and landfill fly ash were collected from the thermal power plants "Nikola Tesla" TENT A and "Kolubara", six samples in total. The first step was to weigh 0.5 g of each sample on an analytical scale and then transfer those to closed tubes specially designed for microwave digestion. The extraction procedure was done in two steps. Firstly, after the samples were weighed, 3 ml of concentrated nitric acid (HNO_3) and 2 ml of concentrated hydrofluoric acid (HF) were added. The microwave digestor was set to work with a power of 800 W and a pressure of 80 psi for the first 10 minutes, and then at a pressure of 120 psi for the next 15 minutes. The second step of the procedure involved the addition of 20 mL of pure distilled water and 10 mL of 5% boric acid (H_3BO_3). Tubes were put back in the microwave digestor and the parameters were set at the pressure of 80 psi for the first 10 minutes, and then at the pressure of 120 psi for the next 10 minutes. After the digestion was done, tubes with samples were put aside to cool. Cooled samples were filtered using syringes and microfilters and preserved. Such samples were further diluted so that the analysis of the content of rare earth elements could be done by ICP-MS. The content of the following elements was determined: Sc, Y, La, Ce, Pr, Nd, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb and Lu. The software program Qtegra was used for analysis of the obtained data.

3. RESULTS AND DISCUSSION

Figure 1 and Table 2 show the obtained results, expressed in unit mg of element per kg of sample. Samples T1 and T2 are samples collected from the TPP "Nikola Tesla" TENT A, and samples K1, and K2 are samples collected from the TPP "Kolubara". Samples T1 and K1 are electrophilic fly ash, and samples T2 and K2 are fly ash collected from landfills.
Analyzing the presented results, it was concluded that the overage content of REE was higher in the samples of fly ash originating from TPP „Kolubara" (samples K1, and K2) compared to the ones from TTP „Nikola Tesla" (samples T1, and T2) (Table 1). The highest content of REE in fly ash from both TPPs was sampled directly from landfills and has a content of 309.65 mg/kg (sample T2) and 434.89 mg/kg (sample K2). This corresponds to the information that the average content of REE on a global scale in fly ash is around 404.00 mg/kg [7]. Taking into consideration that the American Ministry of Energetics proposed that a concentration of REE in fly ash over 300.00 mg/kg is favorable for the extraction process and further metal-recovery application, those fly ashes are estimated to be suitable for this kind of utilization [8].

Regarding the content of critical elements (Nd, Eu, Tb, Dy, Y, Er, expressed in mg/kg), as the most valuable material source, they were measured in all selected samples. The overage content of critical elements was also higher in the K samples – 98.00 mg/kg, compared to the T samples – 83.6 mg/kg, respectively (Table 1).

Table 1. Content of all elements in collected samples

Samples	**T1**	**T2**	**K1**	**K2**
The total content, mg/kg	266.16	309.65	230.19	434.89
Overage content, mg/kg	288.00		332.54	
The total content of critical elements (Nd, Eu, Tb, Dy, Y, Er), mg/kg	76.57	90.63	65.4	130.59
Overage content of critical elements (Nd, Eu, Tb, Dy, Y, Er), mg/kg	83.6		98.00	

In the analyzed samples, the content of cerium (Ce) was the highest of all individual REE (in samples K2, and T2 concentration was 138.63 mg/kg, and 100.12 mg/kg, respectively), which is in accordance with the natural appearance of this element in Earth crust (Figure 1). The descending order of the significant concentration of the elements (in terms of their quantification) was the following: cerium (Ce, in the range of 40.92 – 138.63 mg/kg), scandium (Sc, in the range of 20.09 – 41.05 mg/kg), and lanthanum (La, in the range of 40.92 – 73.99 mg/kg). Respecting the critical elements, only the neodymium (Nd, in the range 34.26 – 62.58 mg/kg), and yttrium (Y, 22.33 – 50.29 mg/kg), have shown significant content in all analyzed samples. The less significant concentrations were measured for the following elements: praseodymium (Pr), samarium (Sm), gadolinium (Gd), and, dysprosium (Dy), in the range of 4.21 – 16.81 mg/kg. The other elements: europium (Eu), terbium (Tb), holmium (Ho), erbium (Er), thulium (Tm), ytterbium (Yb), and lutetium (Lu) have not shown significant values.

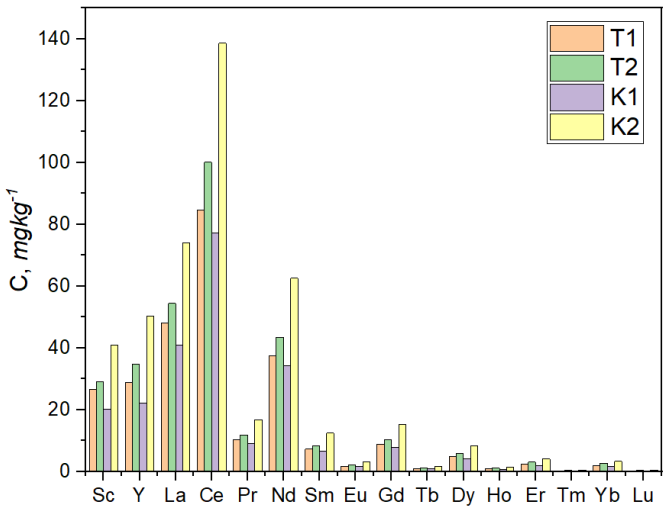

Figure 1. Content of elements in collected samples

Comparing the selected sample sites, it was determined that fly ash collected from landfills has a higher content of REE compared to electrophilic ash (Table 1, Figure 1), which is probably due to the synergetic effects of weather conditions and other (organic/inorganic) compounds present at the landfills. This means that disposal of industrial fly ash is the less acceptable approach, respecting to the waste management hierarchy [9].

The extraction procedure demonstrated in this research (the combination of concentrated mineral acids: HNO_3, HF, and 5% H_3BO_3), has shown an efficient analytical approach for the qualitative and quantitative analyses of REE. The results proved that this method is feasible for the metal-recovery application. Further investigation should be directed toward the environmental impact assessment related to the optimization of three main process parameters: greenness, efficiency, and economy.

3. CONCLUSION

Large amounts of fly ash are being disposed of in landfills which has a negative impact on the environment and human health. Within this work, the content of the REE was examined with the aim of proving that coal fly ash can be used as a material from which those elements could be extracted. The samples were treated with a mix of mineral acids in a microwave digestor. Elements of interest were extracted and their content was analysed using ICP-MS.

Based on the data obtained, the following conclusions were made: (i) The content of REE is higher in the samples of fly ash originating from TPP „Kolubara“ (K1, and K2) than TPP „Nikola Tesla“ (samples T1, and T2); (ii) All four samples of fly ash have the content of all REE that is higher than 200 ppm; (iii) Sample K2 has a content of rare earth elements equal to 434.89 mg/kg which is a bit higher than the global average concentration of those elements in fly ash. Based on that, it can be concluded that fly ash has the potential to be used as a material from which REE could be extracted, but it is necessary to develop appropriate methods for that extraction so the process can also be economically profitable, besides the fact that it would have a less harmful impact on the environment and human health.

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ENVIRONMENT AND SUSTAINABLE DEVELOPMENT. MECHATRONICS. OCCUPATIONAL SAFETY AND HEALTH AND FIRE SAFETY. SMART MANAGEMENT SYSTEMS. GRAPHIC ENGINEERING. DESIGN. TRAFFIC ENGINEERING. BIOTECHNOLOGY AND HEALTHCARE. MECHANICAL ENGINEERING. ECOTOURISM AND RURAL DEVELOPMENT.

SUSTAINABLE PRODUCTION IN CARDBOARD INDUSTRY

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Abstract: *Many aspects of sustainable cardboard industry are not related only to production itself (product quality and its market price, production process, supply of raw materials and its costs), but also to nus products, energy and water consumption, equipment service time, occupational health, and environmental issue. Thus, successful companies in cardboard production are driven by the basic principles of sustainable development and implementation of good manufacturing practice and cleaner production principles. These companies continuously invest in environmental protection – establishing the hierarchy of waste management (waste minimization and waste separation at the source), reduction of raw materials consumption, more efficient fresh water and energy usability, replacement of traditional raw materials with more environmentally friendly (eco – friendly) raw materials where it is possible. Positive effects of these actions are measurable and visible in preserving environment for future generations, by means of minimization of negative impacts on the environment (quantity and quality of wastewater, waste gases, noise and vibrations and solid waste). Implementation of 3R principle (Reduce – Reuse – Recycle) in cardboard industry also brings benefits in its economical aspect. This paper describes one Serbian cardboard mill, with documented certification of the ISO 14001 and successfully implemented principles of cleaner production.*
Keywords: Cardboard industry, sustainability, environment protection, economy, cleaner production

1. SUSTAINABLE PRODUCTION AND ITS IMPORTANCE

One of the most used definitions of sustainable production is the one that defines it as a production of goods and services in a manner that is socially beneficial, economically viable and environmentally benign over whole life cycle [1]. Besides the high quality of final product and its competitiveness at market, the aim of sustainable cardboard production is also to ensure conservation of resources and preserves the regenerative capacity of the environment, as well as to obtain social benefits for employees and associated companies. In practice, sustainable production is based on optimized balance between inputs (raw materials, water, energy, human resources etc.) and production outputs (main products, nus-products and effluents). The environmental aspect of sustainable production presents the implementation of the basic principles of cleaner production in the production process and service activities: automation and digitization of processes, prevention of pollution and minimization of waste generation (e.g. reducing the emission of harmful substances at the point of origin and reducing the amount of generated waste through the 3R principle: Reduce-Reuse-Recycle), then more efficient use of energy, water and resources, application of environmentally friendly products, provision of "green" services and achievement of a more competitive price for the final product [2]. Sustainable production implies the integration of ecological, social, and economic aspects, because it leads the management to think that investment in cleaner production, humanity and effectiveness of resource usage presents a long-term profitable strategy. It results in saving resources, thereby reducing business costs and the price of the final product, with no compromise in its quality. This paper presents one successful cardboard mill in Serbia, as an example of good

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manufacturing practice, especially concerning environmental issue of sustainable cardboard production – minimization of emissions to water, air and soil, economic usage of resources, waste management (Reduce - Reuse - Recycle principle), energy efficiency, and all of them in accordance with legal regulations. The special part in sustainable cardboard production presents the positive impact of described mill on the circular economy principles – recycling cardboard and waste reuse, as well as minimizing generation of solid waste and its characterization if needed. This cardboard mill promotes new and efficient technologies for waste recycling.

2. GOOD MANUFACTURING PRACTICE IN CARDBOARD PRODUCTION

Until the mid-nineties of the last century, the global paper and cardboard industry presented a serious polluter of the environment, especially concerning amounts of spent water and the pollution level of wastewater. Beside such environmental impact, released wastewater contained significant quantities of spent fibers, fillers, and additives. In that way, a certain part of raw materials and additives were permanently lost with released wastewater, instead to be returned to the production process and usefully spent. That problem was partially solved by implementing cleaner production measures (non-obligatory) and obtaining Integrated Pollution Prevention and Control (IPPC) permission (legal instrument in Europe and in Serbia from recently). Beside significant environmental benefits, cleaner production brings economic improvement too – decreased consumption of raw materials, fresh water, and energy, and finally – decrease of production costs. The central idea in the IPPC directive is the application of the best available techniques (BAT) with technically and economically viable measures on pollution prevention, pollution control technologies, efficient resource and energy consumption, prevention of accidents and disturbances, without negative effects on the final product quality [3]. Although there is a wide variety of paper products and production technologies, almost all types of paper- and board-making processes have the following basic units: stock preparation, approach flow system, paper and board machine and additional process units (calendars, coaters, a coating color kitchen…) [3]. This paper presents good manufacturing practice at the example of one successful Serbian cardboard mill, which has implemented the standard for the management in the field of environmental protection (ISO 14000), and has also successfully participated in the UNIDO Cleaner Production Programme (environmental protection and rationalization of resources and energy consumption) [3]. By obtaining IPPC certificate, this mill verified that it has permitted impact on environment, which brings, among all, the direct access to the European Union market.

2.1. About the mill

Described mill is a cardboard factory – recycled cardboard manufacturer near Belgrade, located at the right bank of the Sava River. The mill produces recycled cardboard ("white-lined chipboard") in several quality types (with different layer content and different number of layers) and in different grammage - from 230 g/m^2 up to 450 g/m^2. Total annual production capacity is 160.000 tones/year. With the last reconstruction of the paper machine in 2021, this mill expanded its production portfolio with thinner cardboards - grammage 160 g/m^2, 180 g/m^2 and 210 g/m^2 [4]. During this phase of the investment cycle, with a total value of 30 million euros, significant changes and improvements were made to paper machine, the most significant of which are [4]:

- reconstruction of the former section (installation of the completely new fourdrinier forming section),
- reconstruction of the press section (installation of Jumbo press),
- reconstruction of the coating section (installation of Curtain coater)
- installation of new winder.

Recycled cardboard which is produced in the mill has a wide range of applications in the food and beverage, confectionary, pharmaceutical, chemical, tobacco and spare parts industry, as well as for lamination in the production of transport packaging [4]. Depending on the customer's request, the mill produces cardboard in sheets or reels, and the width of the cardboard machine is 3,2 m. The

reconstruction of drying sections in the mill is successfully completed in September 2023, and expected annual production is 190.000 tons with improvement in product quality [4]. During this phase of the investment cycle, significant improvements were made to the cardboard machine [4]:

- the entire drying section with steam and condensate system was replaced (61 steel cylinder with a diameter of 1.83 m)
- the entire air system with recuperation was reconstructed.

New investments and further modernization of the mill will be continued in next years, with the construction of a new mass preparation line (construction of a new plant and installation of state-of-the-art mass preparation equipment), as well as a new biological wastewater treatment plant [4].

2.2. Environmental issue in cardboard production

Production of cardboard in the described cardboard mill is based completely and only on recycled paper fibers as the main raw material (from year 2005. onwards). Nowadays this mill is the largest recycler of wastepaper in Serbia, with the usage of 120.000 tons of recycled paper per year (for production of 90.000 tons/year of cardboard). In this manner, described mill significantly participate in the green agenda - sustainable development through circular economy, solid waste minimization and toward resource conservation and nature preservation. By recycling paper and cardboard, firstly we save the forests, secondly the energy savings for production is up to 40% and thirdly there is no production of methane. By recycling one ton of wastepaper and cardboard, 17 trees are saved, and 1 ton of office paper as many as 24 trees, thereby saving water, electricity, fuel and not cutting down new trees. Concerning environmental impact connected to paper manufacture, several aspects should be analysed [3]: consumption of raw materials and water, use of additives, energy consumption, wastewater emissions (quantity and quality), solid waste generation (such as waste sludge from effluent treatment plant (ETP) and other types of solid waste), air emissions from paper machines and from energy generation, odour from vapours and from wastewater treatment plant (local) and the noise from paper machines (local). The Reference Document on the Best Available Techniques in the Pulp and Paper Industry commits producers to decrease freshwater consumption, which should be realized by water recirculation and system closure [5]. Paper and cardboard mills in Serbia are faced with more stringent effluent permits, requested by the European norms. Described mill operates in accordance with the postulates of the circular economy, with the application of the principle of reducing resource consumption through the reuse of waste, increasing energy efficiency and, consequently, reducing the emission of gases with the greenhouse effect [7]. Active participation in environmental actions, good cooperation with the local government and relevant ministries, continuous work and investment in the latest equipment and technology in the field of environmental protection using best available techniques (BAT), exchange experience with foreign partners, constant investment in education and training of its staff, this mill builds a safe path towards fulfilling its vision of having good business practice and sustainable production [4].

Prevention of air pollution from the mill is based on special air protection measures which were carried out: partial reconstruction of the boiler facilities and more efficient supply of natural gas. Both measures contribute to the reduction of energy consumption and, therefore, the emission of harmful substances to the air [4].

Protection of water resources (dominantly the nearby Sava River) is based on the existing Wastewater treatment Plant (WWTP) for purifying technological water, which operates in the structure of the described cardboard mill. The WWTP was significantly improved by the realization of investments from 1997/98. in the part of the reconstruction of paper pulp preparation. The next phase of investments foresees investments in the complete closure of the process water flow and investment in the modernization of WWTP, with the recirculation of usable materials from WWTP back to the production process. Only in the first phase of the plant's reconstruction, in 2010, nearly a million EUR have been invested in equipment that enabled an additional reduction in freshwater

consumption, as well as a significantly increased level of wastewater treatment. That was done by the rehabilitation of the existing wastewater treatment system: improvement of the chemical dosing system, waste dewatering presses were installed, a device for additional water purification of the internal water circuit was installed, as well as an additional float unit in internal water cycle. All of this was done with the aim of as much water recirculation as possible, within the production process itself, thus making the wastewater treatment system work as efficiently as possible and decrease the impact on the Sava River. The next phase of the water improvement project toward the highest standards of water protection would be implementation of the biological treatment of wastewater.

Waste management in the mill is based on three main technical measures, respecting the hierarchy of waste management: separation of waste at the point of origin, reduced consumption of raw materials and energy and replacement of raw materials with more environmentally friendly raw materials in the process where possible. All of this results in the minimization of negative impacts on the environment and preservation of the environment for future generations. What significantly distinguishes this cardboard mill from other factories and makes it a friend of the environment is the fact that it uses only wastepaper as the basic raw material to produce European-quality cardboard. For production purposes, about 120,000 tons of wastepaper are collected and processed annually, which would have ended up in municipal landfills.

Operating problems in wastepaper (as raw material) purchasing present significant items in cardboard production across entire country. The first problem relates to individual, non-organized and non-systematic collection of wastepaper, done by persons from vulnerable social groups. That army of people earn money for living by "collecting" certain quantities of wastepaper from the garbage and dump areas near urban sites, sometimes from landfills, and bring it to recycling centers, where they get some refund in cash. The public communal enterprises dealing with solid waste (including wastepaper) cannot employ those people because of the increase of total operating costs, so these people had to work on the streets, as individuals, contributing in unpopular "gray economy." As a result of that non-systematic collection of wastepaper, only small quantities of it can be collected from household waste, so the level of paper recycling is insufficient compared to the paper mills need. Missing recycled fibers are purchased from importing wastepaper from the surrounding countries and region. The second problem in wastepaper purchasing for the mill relates to the quality of collected wastepaper. Very often, wastepaper from household waste is disposed together with other biodegradable waste, especially wet waste. It causes decontamination of wastepaper with other waste, water, and other liquids, predicting processes of decomposition of wastepaper, with occurrence of odor and bacteria, enabling the usage of such a wastepaper as a raw material for producing cardboard for food industry packaging. And the last, but not the least problem in wastepaper purchasing is related to registration of some companies from surround countries to have a status of "recyclers", so the wastepaper generated in Serbia (as a valuable raw material for cardboard mills) is exported to surrounding countries and not used in Serbian paper and cardboard mills. So, it is obvious that all these problems decrease the level of possible usage of wastepaper as raw material.

3. CONCLUSION

According to the presented environmental demands, results, and achievements in sustainable cardboard production, based on described cardboard mill, several conclusions can be made. Firstly, the described mill constantly works and invests in environmental protection, guided by the basic principles of sustainable development and local business guidelines (good manufacturing practice for example). Secondly, this mill uses only wastepaper as the basic raw material to produce European-quality cardboard, what significantly distinguishes this cardboard mill from other factories and makes it a friend of the environment. Thirdly, significant investment in implementing the biological treatment of wastewater is planned in this mill as the next phase of the water improvement project toward the highest standards of water protection. Described mill has the status of "recycler in the field

of wastepaper and cardboard", and all amounts of waste packaging paper and cardboard that are processed in the mill count towards the achievement of national goals in sustainable development and circular economy. By preventing air pollution, protection of water resources and solid waste management, this mill builds a safe path towards fulfilling its vision of having environmentally - friendly and sustainable production.

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SENSORS FOR AMMONIA DETECTION BASED ON CARBON NANOFILLER

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Abstract: *Quartz crystal microbalances (QCM) toxic gas sensors were fabricated using waterborne polymer composites as sensing material. The polymer matrix was reinforced with 1 wt% of graphene/ multiwalled carbon nanotube hybrid (G/MWCNT) prepared in different ratios. The composites were obtained by emulsion mixing. In all composites, the incorporation of G/MWCNT hybrid led to* electrical *conductivity and the Young's modulus. The gas sensing measurements towards different concentrations of ammonia revealed that the sensor reinforced with 1:10 G/MWCNT hybrid had the best response at room temperature compared to the other samples.*
Keywords: Sensors, G/MWCNT, waterborne composites

1. INTRODUCTION

The protection of the living organisms from the harmful influence of the toxic gases is in close connection with their fast detection. Therefore, the development of sensors that can operate ~~at~~ ambient conditions, have simple design, lower production costs and higher efficiency ~~is from~~ great importance.
Quartz crystal microbalances or QCM sensors can detect mass change in nanograms in addition to the good stability [1,2]. The main advantages of these sensors are: the fast response, ability to work at room temperature, chemical inertness of the substrates and low cost. Since the sensor response of the QCM sensors is based on the mass change, the size of this sensor can be changed without compromising the sensitivity [3-5]. Thus, these sensors can be fabricated in smaller dimensions and incorporated into different devices (smartphones, watches, GPS navigation devices, etc.). In this way continuous monitoring of the air and real-time information about the air quality can be achieved. Consequently, this will lead to a rapid reaction of those affected in case of presence of toxic gases [6,7].
Owning to their remarkable chemical, molecular and physical properties, carbon nanomaterials are widely used for fabrication of sensor devices [1-5,8-12]. Disadvantages of carbon nanomaterials are ~~is~~ that the method of their synthesis strongly affects their performance, working with them can be quite complicated [2,3,8,9]. To improve their processability, carbon nanomaterials are incorporated in polymer matrixes. Development of polymer/carbon nanomaterial composites offer additional advantages, such as improved thermal stability, durability and electrical properties [13-17].
In this work polymer composites based on graphene/multiwalled carbon nanotubes hybrid filler were prepared via emulsion mixing. The sensitivity of the obtained composites was investigated towards different concentrations of ammonia gas.

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2. EXPERIMENATL PART

2.1 Materials

For the preparation of the graphene/multiwalled carbon nanotubes hybrid filler graphene nanopowder (G, 8 nm flakes) from Graphene Supermarket (USA) and multiwalled carbon nanotubes (MWCNT, length = 5-15 μm; diameter = 10-30 nm) from Sigma Aldrich were used. For preparing G/MWCNT water dispersions sodium dodecyl sulphate (SDS) with 98% purity from Sigma Aldrich was used. For synthesis of the polymer matrix methyl methacrylate (MMA) with 99% purity from Qumidroga, buthyl acrylate (BA) with 99% purity from Qumidroga and 2-Hydroxyethyl methacrylate (HEMA) with 99% purity from Sigma-Aldrich were used. Dowfax 2A1 45% solution (alkyldiphenyloxidedisulfonate) from Dow chemical company as costabilizer and potassium persulphate (KPS) with 99% purity from Sigma-Aldrich as initiator were used. Throughout the experimental work distillated water was used.

2.2 Methods

The G/MWCNT hybrids were prepared in five different weight ratios, i.e. G:MWCNT = 10:1, 5:1, 1:1, 1:5, and 1:10. The hybrids were prepared by sonicating (UP200Ht, Hielscher Ultrasonics GmbH, Germany) appropriate amounts of G and MWCNT in air medium with constant stirring at 200 rpm in ice bath. The sonication parameters were: amplitude of 70% and 50% duty cycle for 90 min efficient time. Later the hybrids were dispersed in 50g water using SDS surfactant. The ratio SDS:hybrid was 1:1. The dispersion was sonicated for 10 min following the previously mentioned parameters.

The polymer matrix was synthetised by emulsion polymerisation using MMA, BA and HEMA as monomer system. The MMA:BA:HEMA ratio was 49.5:49.5:1. The synthesis started by preparation of seed containing 10 wt% MMA/BA (ratio 1:1). The monomers were dispersed in water using Dowfax 2A1 (2 wt% based on the monomers). The mixture was heated in reactor equipped with nitrogen inlet and it was continuously stirred. When the temperature of the mixture reached 70°C KPS initiator (0.5 wt% based on monomers) was added and the polymerization continued in batch mode for 3h.

The final polymer dispersion was prepared with seeded semicontinuous emulsion polymerization. In a reactor equipped with nitrogen inlet seed (30g) and water (100g) were stirred and heated to 70^{o}C. When this temperature was reached the KPS initiator (0.5 wt% based on monomers) was added and the feeding of the MMA/BA/HEMA monomer system dispersed in water with Dowfax 2A1 (2 wt% based on the monomers) started with rate of 4.2 g/min. The polymerisation was performed in nitrogen atmosphere for 3h in semi-batch and 2h in batch mode. The solid content of the polymer dispersion was 50 wt%.

The nanocomposites were prepared by emulsion mixing. An appropriate amount of G/MWCNT water dispersions were added into appropriate amount of polymer dispersion drop-by-drop during continuous mixture. The concentration of hybrids with respect to the polymer was 1 wt%. In order to obtain free-standing films, the dispersions were casted in silicon moulds and let to dry at 25°C and 55% humidity for five days.

2.3 Characterization

The electrical conductivity of the free-standing samples was measured by Jandel RM3000 four-point probe resistivity instrument.

The tensile tests were performed with SHIMADZU 25T type AGX universal/tensile tester. For this purpose, the free-standing films of the composites and the neat polymer were cut in appropriate tensile test specimens. The length between the grips was 50 mm and the with a constant strain velocity was 20 mm/min. The Young's modulus was calculated with Microsoft Excel functions.

The sensor properties were investigated using Quartz Crystal Microbalance (QCM- 3000 manufactured by MicroVacuum Ltd. of Budapest, Hungary). The composites and the polymer were drop casted onto crystal (Au 5-MHz AT-cut) and let to dry. Before the tests started the thickness of the samples was determined using Biosense software in order to normalize the sensor response. Standard NH_3 and nitrogen gas were used during the measurements. The ammonia gas was diluted with nitrogen by adjusting the flow rates of the gas mixing and regulating system (manufactured by MicroVacuum Ltd. of Budapest, Hungary). The total flow rate of the gas was 50.2 mL/min, and the concentration of ammonia was 100 ppm, 250 ppm, 500 ppm, 750 ppm and 1000 ppm. The measurements were performed ~~at~~ ambient conditions.

3. RESULTS AND DISCUSSION

In this study G/MWCNT/Polymer composites were prepared by emulsion mixing method. The concentration of the G/MWCNT hybrid with respect to the polymer was 1 wt%.
In Table 1 are presented the electrical conductivity values of the samples as average of five measurements. The best electrical conductivity have the samples filled with 1 wt% 10:1 and 5:1 G/MWCNT hybrid. In these samples the electrical conductivity is in the range of 10^{-2} S/m. Slightly lower electrical conductivity in the other samples might be from poorer dispersion of the hybrid throughout the polymer matrix.

Table 1. Electrical conductivity of the G/MWCNT/polymer composites

Sample	Electrical conductivity (S/m)
10:1 G/MWCNT	$1.86*10^{-2}$
5:1 G/MWCNT	$6.03*10^{-2}$
1:1 G/MWCNT	$1.36*10^{-3}$
1:5 G/MWCNT	$1.23*10^{-3}$
1:10 G/MWCNT	$2.89*10^{-5}$

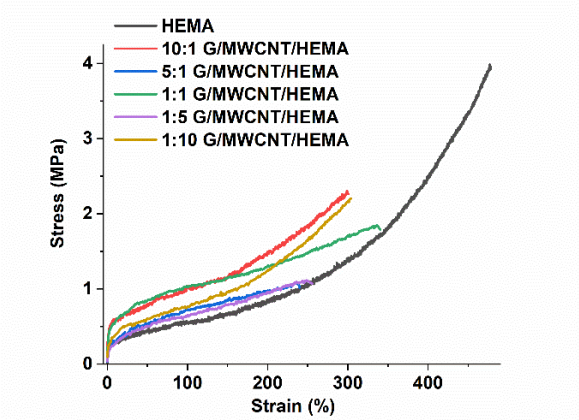

Figure 1. Stress-strain behaviour of the neat polymer (marked as HEMA) and G/MWCNT/polymer composites (marked as: 10:1 G/MWCNT/HEMA, 5:1 G/MWCNT/HEMA, 1:1 G/MWCNT/HEMA, 1:5 G/MWCNT/HEMA and 1:10 G/MWCNT/HEMA)

In Figure 1, the stress-strain curves of the neat polymer (marked as HEMA) and G/MWCNT/polymer composites (marked as: 10:1 G/MWCNT/HEMA, 5:1 G/MWCNT/HEMA, 1:1 G/MWCNT/HEMA, 1:5 G/MWCNT/HEMA and 1:10 G/MWCNT/HEMA) are presented.
In Table 2 are presented the elongation at break, stress at break and the Young's modulus of the samples as average of three measurements. With the incorporation of hybrid filler, the elongation of the nanocomposites decreased and the Young's modulus increased, especially for the 1:10 sample which turned out to have Young's modulus almost 6 times higher than the neat polymer.

Table 2. Elongation at break, stress at break and the Young's modulus of the samples

Samples	Elongation at break (%)	Stress at break (MPa)	Young's modulus (MPa)
HEMA	474	3.46	0.11
10:1 G/MWCNT/HEMA	307	2.16	0.33
5:1 G/MWCNT/HEMA	288	1.28	0.14
1:1 G/MWCNT/HEMA	326	2.27	0.35
1:5G/MWCNT/HEMA	252	0.99	0.11
1:10 G/MWCNT/HEMA	272	1.54	0.63

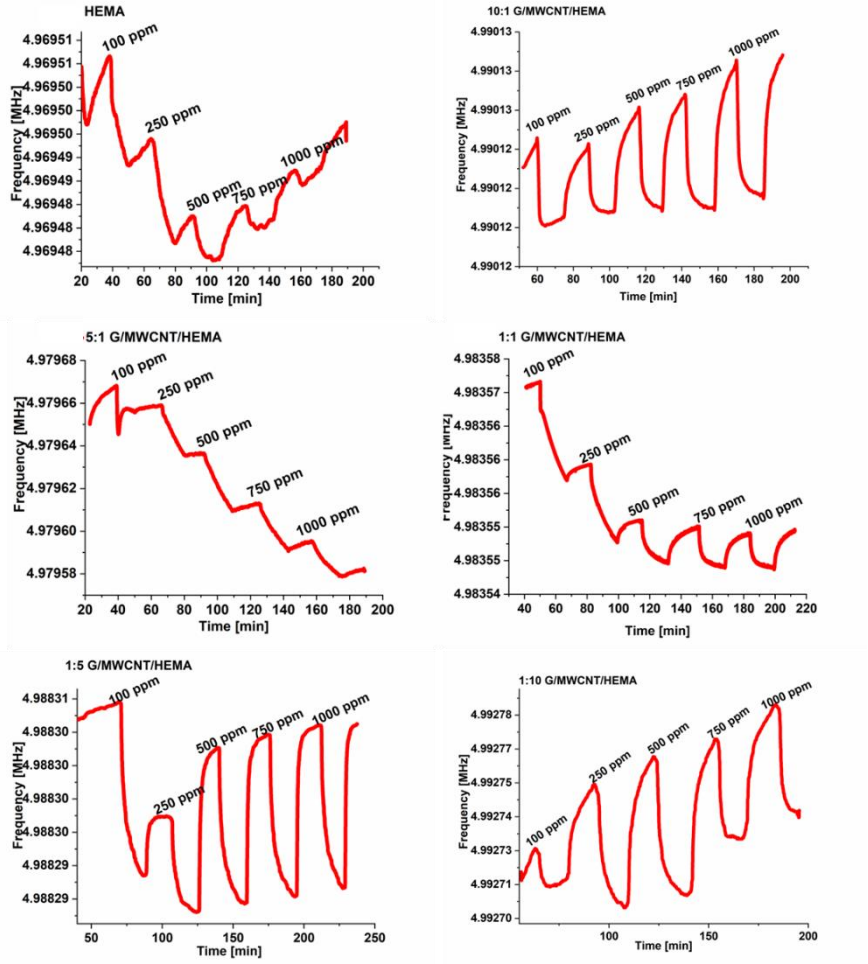

Figure 2. Frequency – time responses of the neat polymer (HEMA) and the composites 10:1 G/MWCNT/HEMA, 5:1 G/MWCNT/HEMA, 1:1 G/MWCNT/HEMA, 1:5 G/MWCNT/HEMA and 1:10 G/MWCNT/HEMA

Figure 2 shows the typical time responses in terms of frequency shift for G/MWCNT/polymer based QCM sensors. The quartz crystals coated with the different composites were employed for detection of different concentration of ammonia gas.

After each exposure to toxic gas, the chamber was evacuated to return the sensor to its initial state. The measurements were carried out at room temperature. In order to evaluate the sensor activity of the material, the frequency change due the mass change as a result from the adsorption of gas molecules on the surface of the material was followed.

In order to compare the obtained results for each sample the frequency change was normalized by dividing the frequency change and the thickness of each sample. In Figure 3 are given the normalized sensor responses.

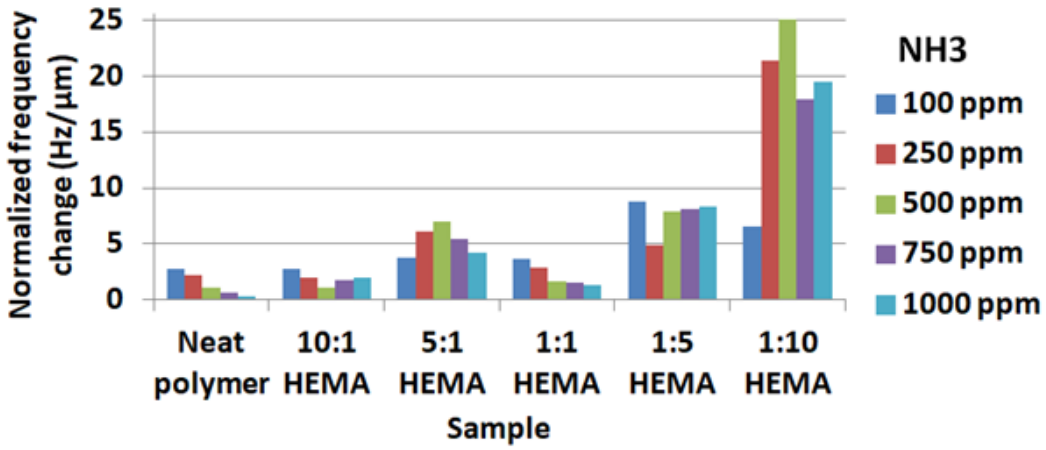

Figure 3. Normalized sensor responses of the neat polymer and composites

From the normalized frequency changes can be observed that the neat polymer, 10:1 G/MWCNT/HEMA and 1:1 G/MWCNT/HEMA composites have sensor responses at the same range, below 5 Hz. The sensor responses of the composites 5:1 G/MWCNT/HEMA and 1:5 G/MWCNT/HEMA are slightly higher, between 5 Hz/μm and 10 Hz/μm. On the other hand, 1:10 G/MWCNT/HEMA presented the best sensor response. The sensor response increased with increment of the gas concentration up to 500 ppm. With further increment of the ammonia concentration the frequency change did not increase, most likely due to saturation of the composite surface with ammonia molecules.

4. CONCLUSION

G/MWCNT/polymer composites were successfully prepared via emulsion mixing method. The incorporation of G/MWCNT lead to electrical conductivity of the composites up to the order of 10^{-2} S/m. The investigation of the mechanical properties showed that the incorporation of hybrid filler led to increase of the Young's modulus of the samples, especially to the 1:10G/MWCNT composite. In addition, this sample presented the best sensing activity towards ammonia which demonstrates its potential to be used as a sensing material.

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ENVIRONMENT AND SUSTAINABLE DEVELOPMENT. MECHATRONICS. OCCUPATIONAL SAFETY AND HEALTH AND FIRE SAFETY. SMART MANAGEMENT SYSTEMS. GRAPHIC ENGINEERING. DESIGN. TRAFFIC ENGINEERING. BIOTECHNOLOGY AND HEALTHCARE. MECHANICAL ENGINEERING. ECOTOURISM AND RURAL DEVELOPMENT.

INVESTIGATION OF THE UV STABILITY OF LIGNIN/POLYMER COMPOSITES

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Abstract: *In the scope of this research polymer/lignin composites were synthesized via in-situ miniemulsion polymerization. The monomer system was containing methyl methacrylate and butyl acrylate in equal amounts. Whether, the concentration of lignin was 1 wt.%, 2 wt.% and 3 wt.% with respect to the monomers. The successful incorporation of lignin within the polymer matrix was confirmed by infrared spectroscopy. The UV and visible light absorptive properties of the composites were investigated using UV-visible spectroscopy. To investigate the UV stability of the polymer/lignin composites, the samples were exposed to UV irradiation (366 nm) for 90 h. The progress of the degradation was followed using infrared spectroscopy. The obtained results indicated that the samples with 2 wt.% and 3 wt.% lignin suffered minor chemical changes after UV irradiation.*
Keywords: Lignin, Waterborne composites, UV stability

1. INTRODUCTION

Lignin is a complex natural polymer that is the building block of plants. This natural polymer has an aromatic structure that can vary depending on the source from which it is isolated [1,2]. Lignin possesses a wide range of properties that contribute to its wide application [3]. Due to its phenolic structure lignin possesses strong antioxidative properties, so with incorporation of lignin into a polymer matrix is expected that the photo-oxidative degradation of the matrix will be supressed [2].
The preparation of lignin-based polymer composites is usually through melt or solution blending [4-11]. The main disadvantages of these methods are the processing of the composites at higher temperatures (160-210°C) [4,5,7,8,11] or the use of toxic organic solvents such as tetrahydrofuran [6], chloroform [12] or dioxane [9]. However, these two methods do not always offer a uniform dispersion of the filler throughout the polymer matrix [13]. This can be an important drawback considering the high tendency of lignin to agglomerate due to its complex chemical structure [10]. The poor dispersion of the filler through the polymer matrix can negatively affect the final properties of the composite. The in-situ synthesis of polymer composites represents a suitable solution to overcome the problems with the dispersion of the filler. During in-situ polymerization the filler is distributed between the polymer chains. In this way, agglomeration of the filler is prevented, which improves its dispersion [14].
In the scope of this research lignin-based polymer composites were synthetised by in-situ miniemulsion polymerization. Emulsion polymerization in which water is used as a polymerization medium is not only an environmentally acceptable method, given that the use of volatile organic components is reduced, but it is also economically viable. The resulting composites were exposed to UV irradiation to investigate their stability towards photo-oxidative degradation.

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2. EXPERIMENATL PART

2.1 Materials

Kraft lignin from Aldrich and sodium dodecyl sulphate (SDS) with 98% purity from Sigma – Aldrich were used for preparation of lignin water dispersion. The neat copolymer and composites were prepared using methyl methacrylate (MMA) with 99% purity and butyl acrylate with 99% purity from Aldrich. Stearyl acrylate (SA) with 97% purity from Aldrich and Dowfax 2A1 45% solution (alkyldiphenyloxide disulfonate) from Dow chemical company were used as costabilizer and surfactant, respectively. Potassium persulphate (KPS) with 99% purity from Sigma – Aldrich was used s initiator. During the experiments distillated water was used.

2.2 Methods

In the first step of the synthesis, lignin water dispersions were prepared. Namely, appropriate amount of SDS surfactant was dissolved in water by stirring with a magnetic stirrer for 30 minutes. Once the SDS was dissolved, an appropriate amount of lignin was added. The lignin:SDS ratio was 1:1. The dispersion was sonicated using a tip sonicator (UP200Ht, Hielscher Ultrasonics GmbH, Germany) the sonication parameters were: 70% amplitude, 50% duty cycle and 10 minutes effective time, while mixing with a magnetic stirrer at 200 rpm.
The composites were synthetised by in-situ miniemulsion. The miniemulsion was prepared by mixing aqueous phase that consisted of lignin water dispersion and Dowfax 2A1 surfactant (2 wt.% based on monomers) and oil phase that consisted of MMA and BA (mass ratio of 50:50) and SA costabilizer (6 wt.% based on the monomers). The intended solid content of the polymer dispersions was 20 wt%. The two phases were sonicated together for 15 minutes effective time following the parameters: 70% amplitude, 50% duty cycle, under continuous mixing at 200 rpm. The miniemulsion was transferred to a 250 mL reactor equipped with a stirrer and a nitrogen inlet. The reactor was heated using a water bath. When the temperature of the mixture in the reactor reached 70°C, KPS initiator (0.5 wt.% based on monomers) dissolved in water was added to it. Then the emulsion was polymerized for 60 minutes at 70°C.The neat copolymer was prepared using the previously described procedure, with the aqueous phase consisting only of water and surfactant.
The monomer conversion was followed gravimetrically, the conversion was 60 %.
To perform the characterization of the samples, the copolymer/composite dispersion was casted in silicon moulds and the free-standing film was obtained by water evaporation under controlled conditions (25°C and 55% humidity) within five days.

2.3 Characterization

The samples were characterized by Fourier transform infrared spectroscopy (FTIR) equipped with an attenuating total reflection (ATR) (Perkin Elmer Spectrum 100) operating at 20 scans. The scanning area was from 4000 to 650 cm^{-1}. The obtained spectra were analysed with OMNIC software.
The effect that the lignin has over the photostability of the polymer matrix was investigated by exposure of the samples to 366 nm UV radiation at ambient conditions (25°C and 55% relative humidity) for 90 hours. The progress of the photodegradation was evaluated by analysing the samples with the FTIR-ATR spectrometer. With the OMNIC software, the surfaces of the spectral bands related to the following functional groups were determined: carbonyl, hydroxyl and ether group. In order to quantitatively monitor the changes, the ratios between the surfaces of the carbonyl and hydroxyl groups and the ether and hydroxyl groups were determined.
To evaluate how the incorporation of lignin into a polymer matrix influenced the absorption in the ultraviolet and visible region, the composites were analysed by ultraviolet-visible spectroscopy

(UV-VIS) (UV-Mini 1240 Shimadzu). The obtained spectra were analysed with UVProbe 2.42 software.

3. RESULTS AND DISCUSSION

Within this research lignin/polymer composites were synthetised via in-situ miniemulsion polymerization. The concentration of the lignin was 1 wt.%, 2 wt.% and 3 wt.% based on the monomers. Figure 1 shows the FTIR spectra of lignin (L), P(MMA/BA) and L/P(MMA/BA) composites.

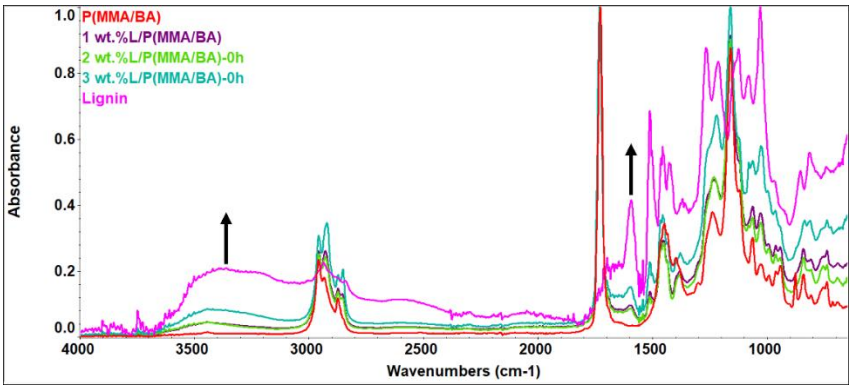

Figure 1. FTIR spectra of lignin (L), P(MMA/BA) and L/P(MMA/BA) composites

The characteristic bands originating from the hydroxyl group (OH – 3700 – 3100 cm^{-1}), the skeletal vibrations of the aromatic C=C bonds (1600 – 1400 cm^{-1}) and the ether group (C – O – C –1300 – 1000 cm^{-1}) can be observed on the spectrum of lignin. Spectral bands characteristic for the carbonyl group (C=O – 1730 cm^{-1}) and the C – O – C from the ester group (1160 cm^{-1}) can be observed in the spectrum of the copolymer. When examining the spectra of the composites, the characteristic bands for the copolymer can be noticed. Moreover, the appearance of the characteristic bands for the hydroxyl group (3700 – 3100 cm^{-1}), as well as bands originating from the skeletal vibrations of the aromatic C=C bonds (1600 – 1400 cm^{-1}) can be seen, which indicates a successful incorporation of lignin into the polymer matrix.

The UV and visible light absorption capability of the samples was investigated using UV-Vis spectroscopy. In Figure 2 are shown the UV-Vis spectra of the samples.

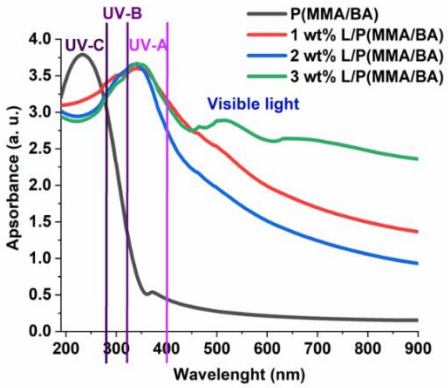

Figure 2. UV-Vis spectra of the copolymer and the composites

Due to its phenolic structure, lignin has a high absorption power in the area of UV-B (280 – 315 nm) and UV-A (315 – 400 nm) light. Therefore, the absorption maximum of the composites is shifted to a higher wavelength compared to the copolymer. It can also be noted that the absorption of visible light is significantly higher for the composites compared to the copolymer. This indicates that the lignin-based composites would be efficient UV blockers and would offer good protection against UV-Vis radiation.

The progress of the UV aging process was followed by infrared spectroscopy. The areas of the characteristic bands that suffered significant change were calculated, i.e.hydroxyl group (OH – 3700 – 3100 cm^{-1}), carbonyl group (C=O – 1730 cm^{-1}) and ether group (C – O – C – 1300 – 1000 cm^{-1}), Figure 3.

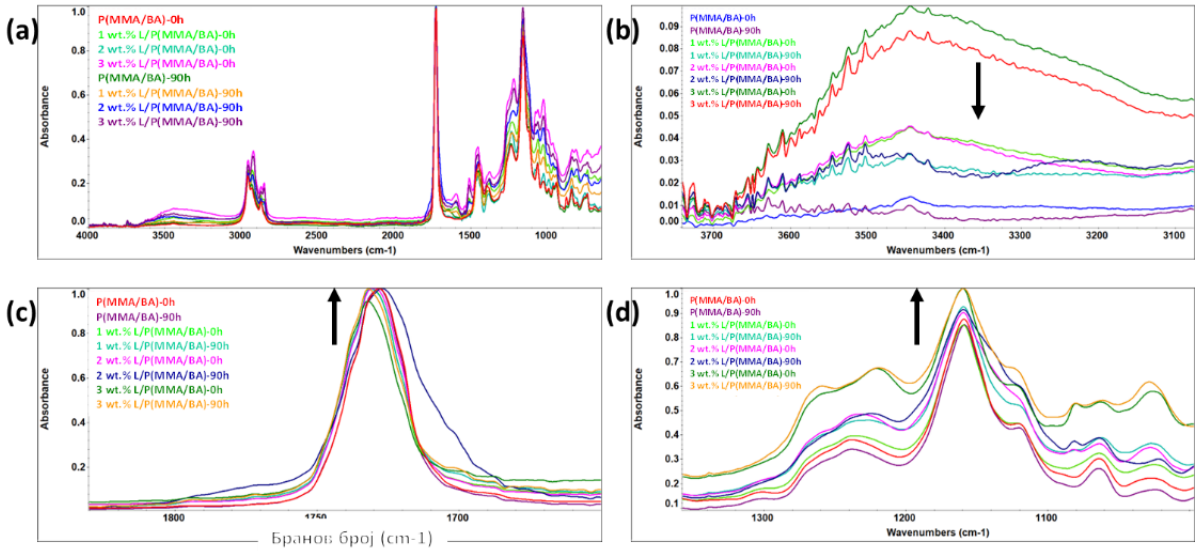

Figure 3. (a) FTIR spectra of the samples after 90 h of UV exposure, zoomed characteristic bands for (b) hydroxyl group (OH – 3700 – 3100 cm^{-1}), (c) carbonyl group (C=O – 1730 cm^{-1}) and (d) ether group (C – O – C – 1300 – 1000 cm^{-1})

To compare the aging progress, the ratios between the carbonyl and hydroxyl group, as well as the ether group and the hydroxyl group before and after irradiation were determined for the composites and the copolymer. These results are given in Figure 4.

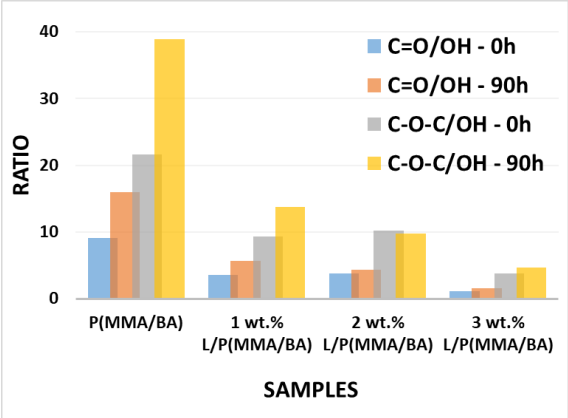

Figure 5. Ratios between the carbonyl and hydroxyl group, as well as the ether group and the hydroxyl group before and after irradiation

From Figure 4 can be observed that the copolymer suffers greatest chemical changes during the UV exposure. While the composites with 2 wt.% and 3 wt.% lignin the differences in the ratios before and after 90 hours of UV irradiation are significantly smaller. Such results indicate that lignin successfully captured and neutralized the free radicals that are formed during degradation, thus slowing down the aging process of the composites.

4. CONCLUSION

Lignin-based polymer composites were synthesized via in-situ miniemulsion polymerization. Lignin was added at a concentration of 1, 2 and 3 wt.% relative to the monomers. Through infrared spectroscopy was determined that the incorporation of lignin into the polymer matrix was

successful. The spectra obtained by UV-Visible spectroscopy indicated that the addition of lignin leads to a shift of the absorption maximum of the composites to a higher wavelengthand increment of the absorption of visible light.
The copolymer and composites were exposed to 366 nm UV radiation at ambient conditions for 90 hours. The aging progress was monitored by infrared spectroscopy. From the obtained results, was concluded that the composites containing 2 and 3 wt.% lignin undergo significantly minor chemical changes after exposure to UV light.

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A COMPREHENSIVE ANALYSIS: OFFSHORE RENEWABLE ENERGY METHODOLOGIES, BENEFITS, AND LIMITATIONS

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Abstract: *In the realm of sustainable energy solutions, significant attention has been drawn to the boundless offshore resources. This paper focuses on the innovative approaches and advancements in offshore renewable energy technologies. The capabilities and advantages of floating photovoltaic solar energy systems have been meticulously analyzed. Additionally, the consistent and reliable energy derived from wave and tidal movements has been examined. Emphasis has been placed on the potential synergies realized from integrating various renewable energy sources, specifically the combination of offshore wind with solar and wave energies. Through this comprehensive exploration, the challenges, present scenarios, and prospects of these promising offshore renewable technologies have been systematically unraveled.*
Keywords: Offshore Technologies, Sustainable Energy, Energy Methodologies, Advantages.

1. INTRODUCTION

In the pursuit of sustainable and environmentally friendly energy solutions, attention has been increasingly directed towards the vast resources available offshore. Energy from the sun, wind, and waves has been recognized for its unparalleled potential in addressing the escalating power needs without exacerbating the planet's ecological challenges. In 2020, the European Commission published an EU Strategy to harness the potential of offshore renewable energy for a climate neutral future. The Offshore Renewable Strategy aims to dramatically increase the EU's production of electricity from offshore renewable energy sources from 12 gigawatts (GW) at the present rate to over 60GW by 2030 and 300GW by 2050 [1]. In this paper, advancements and innovations in offshore renewable energy are explored. The immense potential of floating photovoltaic solar energy systems is discussed, and the consistent power derived from tidal movements is examined. The potential benefits of integrating multiple renewable energy sources, such as the combination of offshore wind and solar farms, are also highlighted. Through this exploration, the current state, challenges, and prospects of these offshore renewable technologies will be revealed.

2. INTEGRATING OFFSHORE ENERGIES: A STUDY OF WIND, SOLAR, AND TIDAL TECHNOLOGIES, THEIR SYNERGIES, BENEFITS, AND CHALLENGES

As the global quest for sustainable energy solutions intensifies, the potential of offshore wind, solar, and tidal sources is increasingly recognized. This chapter delves deep into the individual technologies employed to harness the relentless power of winds, the consistent radiance of the sun, and the rhythmic energies of the tides. Beyond the exploration of individual sources, a significant portion of this chapter is dedicated to understanding the synergies when these technologies are combined. The advantages and challenges of such integrations, as well as the singular benefits and limitations of each energy source, are meticulously scrutinized. By the chapter's conclusion, readers will have been

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granted a comprehensive insight into the current state, potential benefits, challenges, and synergistic possibilities of combining offshore wind, solar, and tidal energy technologies.

2.1 Floating Photovoltaic Systems

Floating Photovoltaic Systems (FPVS) are defined as photovoltaic power plants consisting of modules mounted on floating elements situated on bodies of water, such as lakes, reservoirs, or seas. These systems employ traditional solar panels, which convert sunlight into electrical energy through the photovoltaic effect. Once energy is generated by the panels, it is transformed from direct current to alternating current by inverters, preparing it for grid distribution. These systems are anchored to the seabed, shorelines, or adjacent structures. The floating base, constructed from UV and corrosion-resistant materials, not only allows for the solar panels to safely float but also reduces water evaporation and utilizes otherwise unused water surfaces. Owing to the cooling effect of the water, increased yields have been observed in FPVS compared to conventional ground-mounted systems [2]. While installations with double-digit megawatt capacities can be found in Asia, German installations are limited to a maximum of 750 kW due to financial barriers. As of February 2022, the largest FPVS in Europe is in the Netherlands, boasting a nominal capacity of 27.4 MW [2]. A dynamic growth in FPVS was witnessed in recent years, with over 2.6 GW installed globally by early 2021 [3]. In Germany, potential locations for FPVS include open-pit lakes, former gravel pits, and, in some cases, reservoirs [2]. The first German FPVS, situated in a repurposed quarry near Renningen in Baden, was connected to the grid in late May 2019 and has a capacity of just 750 kW [3]. Beyond lakes, FPVS technology can also be utilized at sea, whether offshore or nearshore. Additional applications include the integration of FPVS on agricultural water reservoir liners or fishponds. For instance, a floating solar film was installed on a water reservoir in Cyprus, reducing both water evaporation and contamination while producing energy for pumping equipment [3]. FPVS implementation over canals is also feasible.

Advantages of Utilizing Floating Photovoltaic Systems (FPVS):

1. FPVS does not occupy terrestrial space, addressing the increasing demand for agricultural and construction lands, and avoiding deforestation and ecosystem disruption [2].
2. Photovoltaic panels, when cooled by water, maintain a higher efficiency under rising temperatures. Experiments in Hyogo, Japan showed an approximate 11% increase in energy production in FPVS compared to land systems.[5]
3. The shadow produced by FPVS can help reduce algal blooms, aiding in preventing water eutrophication, and decreasing water evaporation, thus preserving water resources [5].
4. Maintenance is simpler for FPVS than land-based systems, with reduced dust accumulation and Mibet's FPVS design featuring a maintenance pathway for easier panel cleaning [4].
5. Aesthetically arranged FPVS attracts tourists, offering additional economic benefits [5].
6. The open water surface minimizes shading from trees or mountains, an issue often faced by land-based solar installations.[5]
7. Proximity to settlements, villages, and cities enables efficient local electricity distribution and consumption [4].

Disadvantages of Utilizing FPVS:

1. FPVS have a lifespan exceeding 25 years, highly demanding corrosion-resistant materials with longevity demand and high load-bearing capacities, a challenge with current materials [3].
2. Initial investment costs for FPVS can surpass those of traditional solar panel installations due to setup requirements of specialized equipment and expertise [4].

2.2 Wave and tidal energy

Energy generated from tides is a sustainable energy source that leverages the kinetic and potential energy from ocean tides and currents to produce electricity. As the height difference between high and low tides (tidal range) increases, more energy can be harnessed. Tidal energy harnessing

technologies include tidal barrages, tidal stream generators, and tidal fences, all of which utilize tidal turbines. Despite its potential, tidal power is yet to be widely adopted, with only a handful of significant tidal power stations in operation globally. Some of the most substantial tidal power stations in terms of capacity are:

1. La Rance Tidal Power Plant, France: Located near Saint-Malo in Brittany, this power plant was the world's first large-scale tidal power station and started its operations in 1966. It boasts an installed capacity of 240 MW.
2. Sihwa Lake Tidal Power Station, South Korea: Operational since 2011, this station is currently the world's largest in terms of installed capacity at 254 MW. It was constructed by transforming an existing sea barrage into a tidal power station.
3. Annapolis Royal Generating Station, Canada: Located on the Annapolis River in Nova Scotia, this power station began its operations in 1984. It has a capacity of approximately 20 MW.

Despite the impressive capabilities of these stations, tidal energy faces challenges, such as environmental concerns, high capital costs, and technological hurdles. However, with a global potential estimated at around 2 TW (excluding the area of 30 nautical miles from the polar caps), the opportunities in this sector are vast. As technology evolves and the demand for renewable energy sources increases, it's expected that more countries will explore tidal energy as a viable and sustainable energy source.

Tidal barrages, positioned across tidal inlets, function similarly to traditional hydroelectric dams. Anchored to the seabed, they employ turbines that are activated by both incoming and outgoing tides. These turbines, connected to generators, convert tidal movements into electrical energy. Though efficient, they are costly due to the required concrete infrastructure and pose significant environmental challenges, acting as barriers to marine life.

Tidal fences, blending characteristics of tidal barrages and turbines, utilize vertical rotating structures akin to turnstiles. These structures, moved by tidal currents, are connected to generators, producing electricity. Unlike barrages, tidal fences don't necessitate large concrete constructions and are typically less impactful on ecosystems, being fully submerged and allowing more marine mobility.
Advantages of Tidal and Wave Energy [7]:

1. It's a renewable energy source.
2. No greenhouse gas emissions during electricity generation.
3. Highly predictable energy production.
4. Can produce large amounts of electricity due to water's density.

Disadvantages of Tidal and Wave Energy [7]:

1. Specific location requirements, predominantly coastal areas with significant tidal differences.
2. High initial investment costs.
3. Potential environmental impacts on marine life and local ecosystems.
4. Inconsistent energy output despite its predictability.

2.3 Offshore wind energy

Offshore wind energy harnesses the power of ocean winds, converting it into electricity and delivering it to the onshore electrical grid. Wind turbines transform the kinetic energy of the wind into electrical energy. As wind blows, it moves the turbine blades, which are attached to a rotor. This rotor rotation produces mechanical energy. The rotor is connected to the main shaft, driving a generator. Inside the generator, the shaft's rotation causes relative motion between a magnetic field and a conductive wire, creating electrical energy through electromagnetic induction. Wind turbines can be standalone, supplying power to a single or very few users, or they can be clustered to form a wind farm. Each turbine comprises of a set of blades, a nacelle, and a shaft. Wind turbines tend to be either white or very pale gray – the idea being to make them visually unobtrusive. The world's first wind farm was

inaugurated in New Hampshire, USA, in 1980 [8]. With a capacity of 1.2 GW, Hornsea One is one of the largest offshore wind farms globally. It is situated 120 km off the Yorkshire coast in the North Sea [12].

Advantages of Offshore Wind Farms:

1. Provide renewable energy without consuming water, emitting pollutants, or greenhouse gases [8].
2. Reduced noise and environmental impact due to distance from population centers [8].
3. Potential creation of 60,000 jobs in the USA with increased capacity by 2022 [9].
4. Offshore winds are stronger and more stable, leading to higher energy production [9].
5. Can meet the high energy needs of densely populated coastal regions [9].

Disadvantages of Offshore Wind Farms:

1. Concerns about habitat loss, disturbances, and collisions due to climate changes [8].
2. Challenges in constructing in deep waters (beyond 60m) [9].
3. Risk of damage from intense storms or hurricanes [9].
4. High costs for underwater energy cable installation [9].
5. Unclear effects on marine life and birds.
6. Potential aesthetic concerns impacting tourism and property values near coasts [9].

2.4 Combined offshore wind and solar energy systems

Pérez-Collazo et al. [10] explored the potential of floating wind turbines and solar panels near the Asturias coast, emphasizing their combined benefits. Using meteorological data, the total available renewable energy in the region was estimated. The expected energy output from both solar panels and wind generators was calculated, both individually and when combined, based on current commercial technology. Both technologies were compared in terms of their nominal power, sea space usage, and production variability. Results suggest that marine-based combined wind-solar parks possess a production synergy worth considering in future marine renewable energy projects [10].

Advantages of Combined Systems [10]:

1. Higher Energy Output: Combined wind and solar farms can achieve a density of 57.5 MW/km² and a specific yield of 61.2 GWh/(km²·year).
2. Stable Energy Production: Combining both systems reduces output variability by 68% compared to standalone wind farms, ensuring a more predictable energy flow.
3. Optimal Sea Space Usage: Hybrid farms maximize output per unit of sea area.
4. Reduced Temporal Variability: Combining both systems improves power output consistency.
5. Superior Wind Farm Performance: Using a commercial 6.2 MW wind turbine, energy production and capacity factor are significantly higher than solar farms.
6. Better Sea Surface Usage: Solar farms don't require deep waters for optimal energy production, unlike wind farms.

Disadvantages of Combined Systems [10]:

1. Need for Floating Technology: The studied area's depth requires floating structures, except in the narrow coastal zone.
2. Variable Wind Resources: Wind resources decrease towards the coast, possibly affecting closer regions' yields.
3. Need for Further Research: Being the first of its kind, this study suggests that more in-depth research is needed to fully understand combining these two systems.

Combining wind and solar energy can efficiently harness marine resources for renewable energy production, but more research is needed to determine all aspects and potential challenges.

2.5 Combined offshore wind and wave energy systems

Combined wind and wave systems represent an innovative approach to harnessing renewable energy sources for electricity generation. These systems rely on the integration of wind turbines and wave

energy capturing devices, creating a unique platform that simultaneously exploits both wind and ocean wave energy. Such a configuration allows for a continuous and stable production of electricity. Even when the wind isn't blowing, ocean waves can generate energy and vice versa. This integrated approach not only increases the system's efficiency but also reduces the need for energy storage and ensures a more consistent supply to the electrical grid. Combined wind and wave systems can be categorized based on technology, water depth (shallow, transitional, or deep water), or location relative to the coast. Pérez-Collazo et al. [11] proposes a new classification based on the degree of connectivity between the wind turbines and wave energy converters, defined as co-location systems, hybrid systems, and island systems.

Co-location Systems: The simplest option in the current development phase is the co-location system. These systems combine a wind farm with a series of wave converters but share the same maritime area, grid connection, etc. They can be independent or combined [11].

Independent Arrays: These are systems where the wind farm and wave park are based in separate maritime areas but are close enough to share the same grid and other services [11].

Combined Arrays: In contrast to independent arrays, combined arrays share the same maritime area. They can be further classified into three categories: Peripherally Distributed, Uniformly Distributed, and Non-uniformly Distributed systems [11].

Hybrid Systems: Hybrid systems combine a wind turbine and a wave energy converter on the same structure. They are part of a broader category of multi-purpose platforms that integrate various marine applications [10].

Fixed Hybrids: Fixed wind and wave hybrids represent innovative systems emerging from the evolution of current substructures employed by the offshore wind industry, adapted to accommodate a wave energy converter. Alternatively, integration of the converter into an existing wind turbine can be considered, but both alternatives require further research [11]. Concepts within this category include Wave Star, proposed by a Danish company; Wave Treader, by Green Ocean Energy from Scotland; and WEGA, developed by the Portuguese company Sea For Life [11].

Floating Hybrids: Floating hybrids are a novel concept that has begun to be explored given the development of floating wind turbine prototypes. Interest in this concept stems from the greater wave energy reserves in deep waters and the absence of continental shelves in some countries with high wave energy potential, such as Spain or Portugal [11]. Some examples of floating hybrids include: W2 Power by Pelagic Power AS; OWWE by the Norwegian company Ocean Wave and Wind Energy Ltd.; Poseidon Floating Power by Floating Power Plant AS from the Netherlands; WindWaveFloat by the American company Principal Power; and Offshore Ocean Energy System by Float Inc.
Highlighted are the following advantages and disadvantages of combined hybrid systems [11]:
Advantages:

1. Technology Synergy: Combining wind generators with wave energy exploitation devices can lead to a more efficient energy production as some regions may experience strong winds when waves are not powerful, and vice versa.
2. Space Optimization: By combining both systems, the same maritime space is used for energy production from two sources, which can be advantageous in areas where maritime space is limited.
3. Resource Sharing: Combined systems can share resources such as grid connection infrastructure, maintenance and management equipment, and personnel.
4. Production Stabilization: Multiple energy sources can reduce the variability of total energy produced, meaning that energy can be produced more steadily over different time periods.
5. Design Flexibility: There are multiple ways these systems can be configured (e.g., PDA, UDA, NDA) to optimize energy production and minimize potential environmental impacts.

Disadvantages:

1. Design Complexity: Combining two different technologies can lead to technical challenges, especially when integrating with existing systems or adapting substructures.
2. System Interaction: Further research is needed to understand the interaction between the wind generator and wave energy exploitation device and how this interaction can affect overall performance.
3. Costs: Initial development, installation, and maintenance costs for combined systems might be higher compared to deploying individual systems.
4. Lack of Mature Technologies: Since some of these concepts are relatively new, there may be technological risks and unknowns that need to be addressed before commercial deployment.
5. Ecological Impact: Combining two systems might result in a larger ecological footprint, especially if potential negative impacts on the marine ecosystem are not considered.

3. CONCLUSION

In conclusion, the integration of wind and wave energy systems presents a promising avenue for enhancing renewable energy production from maritime resources. The combination of these technologies offers several advantages, including increased energy output, optimized use of space, resource sharing, production stability, and design flexibility. However, this innovative approach also comes with challenges, such as design complexity, the need for further research into system interactions, higher initial costs, the development of mature technologies, and potential ecological impacts. As these combined hybrid systems continue to evolve and mature, they hold significant potential for contributing to a more sustainable and diversified energy landscape in the future. Further research and development efforts will be crucial in addressing these challenges and unlocking the full potential of integrated wind and wave energy systems.

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WIND COMFORT DESIGN BASED ON BUILDING POSITION

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Abstract: *Considering wind as a load and its impact on buildings and their environment is gaining importance due to increasingly pronounced climate changes and the occurrence of strong winds. Increasingly intensive residential construction and transformation of existing settlements, justified or unjustified construction of new buildings, leads to changes in the wind comfort of entire residential blocks. The subject of research is residential towers characteristic of multi-family housing in the 70s and 80s of the 20th century in former socialist countries. The focus is on the analysis of changes in wind comfort caused by the construction/addition of a new building - individually and by multiplying it around a typical residential tower. The effect of the wind was analyzed in a modern way using numerical fluid dynamics, CFD.*
Keywords: Wind, Wind comfort, Computational fluid dynamics, Atmosferic boundary layer.

1. INTRODUCTION

Residential construction in the seventies and eighties of the 20th century on the territory of former socialist countries, among others, is characterized by large housing estates and the appearance of high-rise buildings - residential towers with organized free inter-block space for various purposes. A few decades later, there were frequent cases of that space being occupied by the construction of new residential buildings with slightly lower height compared to the existing towers. This intervention changes the air flow around buildings, which affects the change in wind comfort in the entire environment. Wind as a natural phenomenon [1] characterized by stochastic behavior has always been a challenge for people. The aspiration of ordinary people to understand the behavior of the wind and to provide shelter from its destructive effect in the past, leads to modern research approaches where the wind is viewed not only theoretically [2] and through standards [3] but also with an experimental approach through wind tunnels, and using modern numerical simulations.
The paper analyzed the behavior of the wind around the residential tower as an isolated object, and at the level of the entire residential block when there are lower buildings in the vicinity of the tower with a different position compared to the primary object (residential tower). The wind is considered in a complex way in accordance with its nature, using computational fluid dynamics (CFD).

2. METHODOLOGY

The conducted research included four models (M0, M1, M2, and M3) (Fig. 1). The initial model M0, represents an isolated residential tower (Gnd + 10 lvl.) with dimensions of base 16x22 m and height

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40 m. The wind acts perpendicularly to the longer side of the facade. To the initial model (M0) were added lower residential buildings (Gnd + 4 lvl.) with a height of 15 m and with base dimensions of 16x16 m, as individual ones: in front (model M1) and on the side (model M2) of the tower, and also all grouped together (model M4) representing one characteristic residential block. The relative position of the buildings, their base dimensions and distances are shown in Figure 1. The wind speed for all models is assumed to be 50 m/s, with its direction as shown in Figure 1.

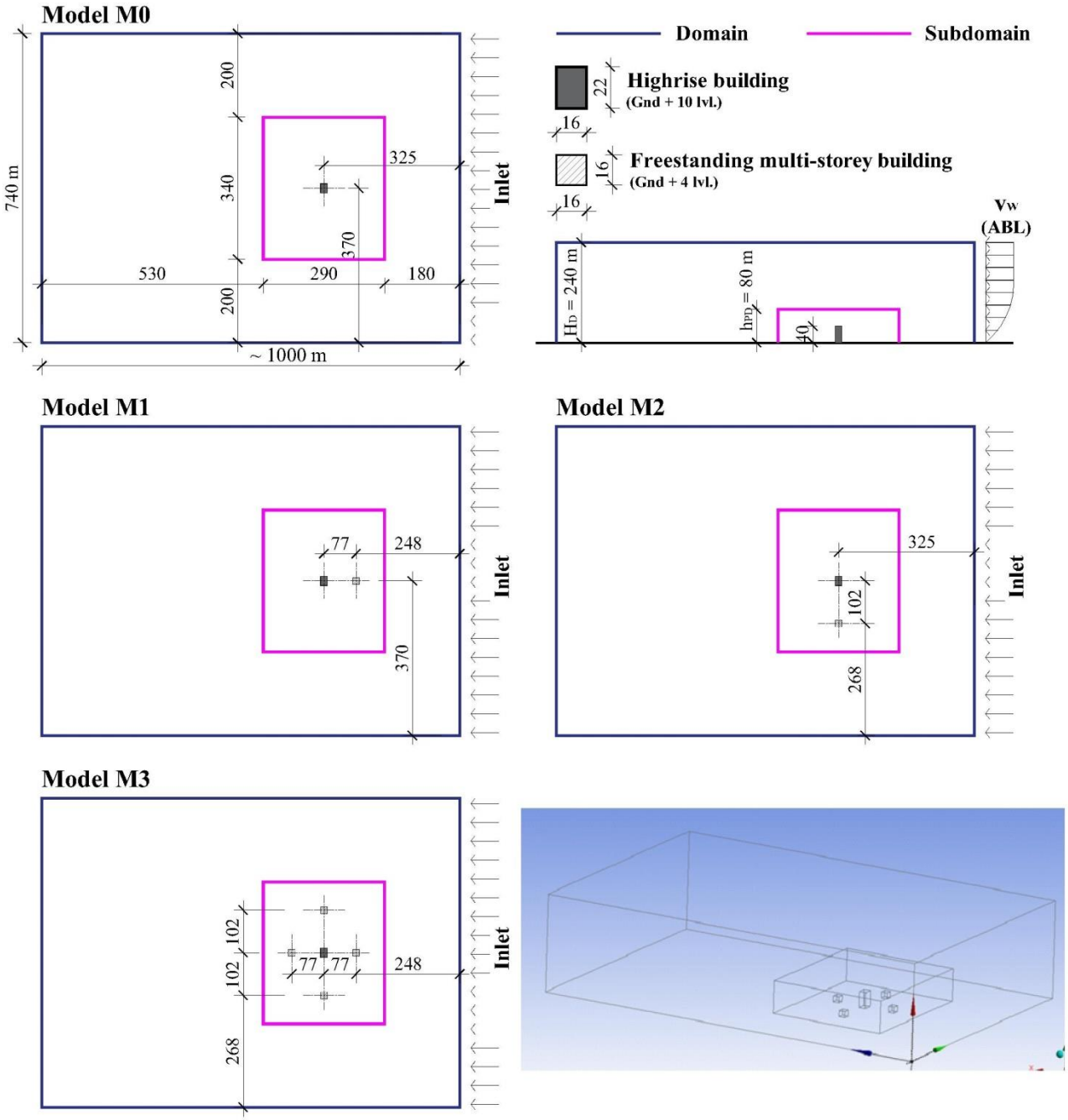

Figure 1. Model formulation
Source: Authors

For all models, a single computational domain was adopted (Fig. 1) according to the current recommendations of Franke 2004 [4] and Franke 2007 [5] for this type of analysis, and according to the recommendations of Ferziger & Perić [6], the mesh quality of finite volumes was adopted.

2.1 Theoretical framework

The influence of the wind was analyzed for each model in ANSYS Workbench 19.0 (CFX) software [7, 8] using numerical fluid dynamics CFD. The wind velocity varies with height by defining the Atmospheric Boundary Layer, ABL. The air flow in the ABL belongs to turbulent flows, and the numerical solution of any fluid mechanics problem requires the solution of the continuity equation (1) and the Navier-Stokes equations (2).

$$\frac{\partial \rho}{\partial t} + \frac{\partial (\rho u_j)}{\partial x_j} = 0 \tag{1}$$

$$\frac{\partial (\rho u_j)}{\partial t} + \frac{\partial (\rho u_i u_j)}{\partial x_j} = -\frac{\partial P}{\partial x_i} + \nu \frac{\partial}{\partial x_j}\left(\frac{\partial u_i}{\partial x_j} + \frac{\partial u_j}{\partial x_i}\right) \tag{2}$$

$$P = \frac{p}{\rho} \tag{3}$$

$$\nu = \frac{\nu_t}{\rho} \tag{4}$$

In equations (1) to (4), the following symbols were used: u_j represents the components of wind flow velocity [m/s], x_i is the spatial coordinates of the rectangular coordinate system, p is the static pressure [Pa], ρ is the air density [kg/m3], ν - kinematic viscosity [m^2/s] and ν_t - turbulent (dynamic) viscosity [kg/(s*m)].

When studying the effect of wind on structures, the Reynolds averaged Navier-Stokes equations (RANS) are most often used to calculate turbulent flows [9]. The continuity equation (equation of conservation) (1) and the moment equation (Navier-Stokes equations) (2) together with initial and boundary conditions, are considered sufficient to describe turbulent flows. Nowadays, there are many different turbulent models that describe the flow, and for the purposes of this research, the two-equation Re-normalization group, RNG k-ε model [10] are used, which involves solving two additional transport equations to determine the Reynolds stress tensor [11]. The Reynolds stresses have a linear dependence with the turbulence kinetic energy, k (5) and the mean velocity gradients (6).

$$k = \frac{1}{2}(\overline{u_i' u_i'}) \tag{5}$$

$$\overline{u_i' u_j'} = \frac{2}{3} k \delta_{ij} - \nu_t \left(\frac{\partial \overline{u}_i}{\partial x_j} + \frac{\partial \overline{u}_j}{\partial x_i}\right) \tag{6}$$

$$\delta_{ij} = \begin{cases} 1, & j = i \\ 0, & j \neq i \end{cases} \tag{7}$$

$$\nu_t = C_\mu \frac{k^2}{\varepsilon} \tag{8}$$

In equations (5) to (8), k is the kinetic energy of turbulence, δ_{ij} – Kronecker's delta operator, C_μ is the empirical constant of the turbulent model, and ε is the dissipation rate.

3. DISCUSSION

The numerical simulation results of wind effects are shown in Figure 2 (a-d) through a horizontal and vertical section of the computational domain for all models (M0, M1, M2 and M3). Wind flow streamlines are shown in the pictures. Considering M0 model, it is noticeable that the wind flow is predominantly uniform in front of the tower, while its speed increases at the sides because a separation of the flow appears. The vortex trail behind the residential tower (model M0) shows vortices but of lower velocities than in front of the building (Fig. 2a). By adding an object in front of the tower (model M1) a vortex is formed between the buildings, but the sides of the tower are now in a calmer

flow and lower velocities (Fig. 2b). In the M3 model, which includes the tower and four buildings added on each side, is noticed that the side buildings do not significantly affect the comfort due to the effect of the wind, while the buildings located directly in front of the windward and behind the leeward side of the tower, have an impact (Fig. 2d). The vortex zone covers a larger area, but the velocities are lower. The most pronounced flow with the most intense velocities occurs on the sides of the tower because so-called "wind canyons" are formed (Fig. 2d).

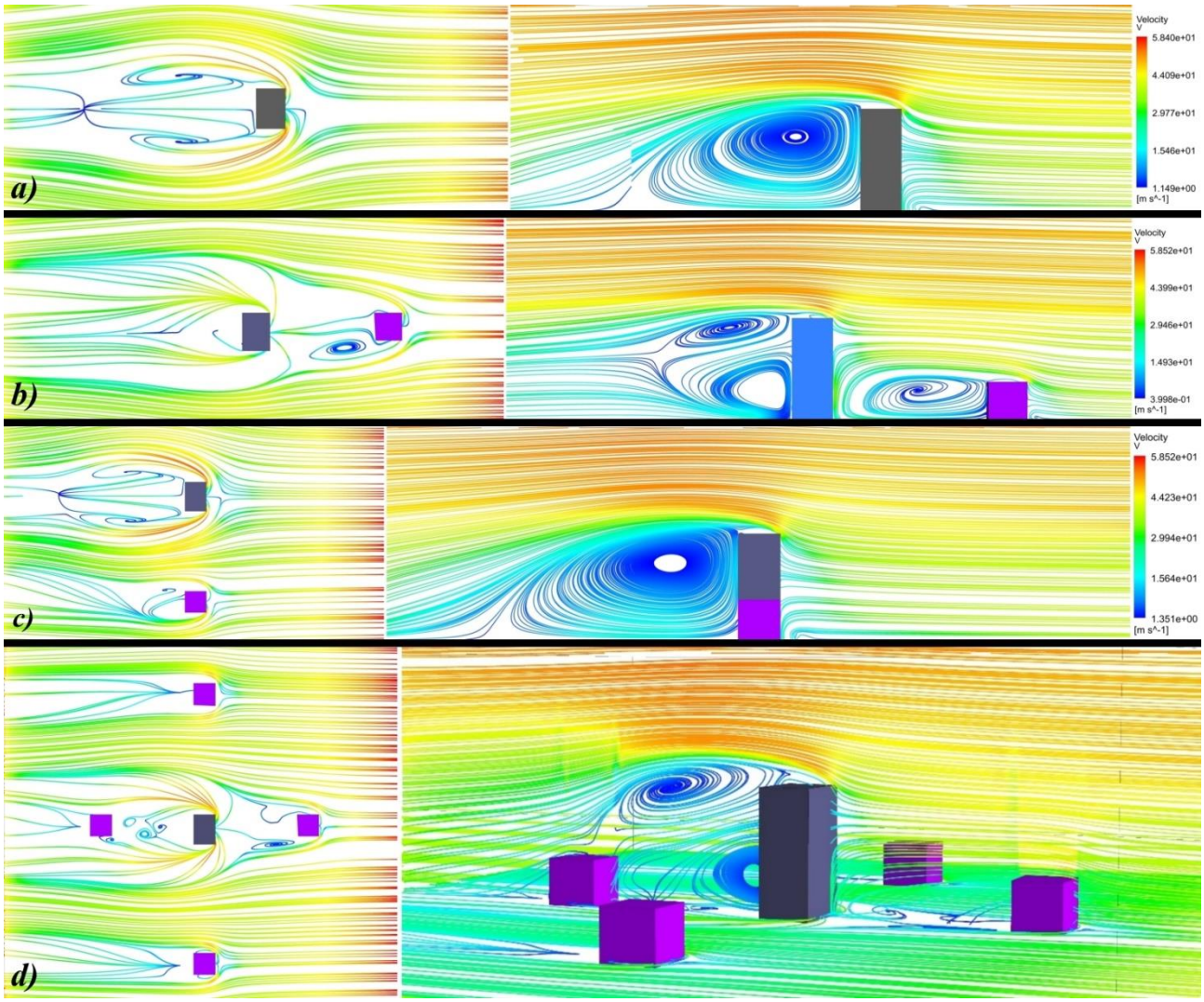

Figure 2. The results of numerical simulations
Source: Authors

4. CONCLUSION

In the last decades, the development of awareness about the possible consequences of climate change actualizes wind as a complex load, and because of that, it has become the subject of numerous researches. At the same time, modern achievements in computer technology significantly improve and speed up numerical procedures and lead to the realization of advanced numerical simulations of the wind effect on buildings and their environment. Increasingly, free space around residential towers has been usurped by new buildings that change the microclimate and air flow around the existing towers. Although it seems that additional buildings would reduce wind speeds around the building, this is not always the case and depends on numerous factors. Vortex zones are created that are sometimes independent and sometimes overlap with the existing ones, while on the sides there is an increase in wind speeds, usually due to the formation of a "wind-canyon". All this implies that the

wind analysis must be carried out in detail using available advanced methods, so that the space around the buildings receives an adequate purpose in the best possible way.

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INNOVATIVE SYSTEM FOR ELECTROCHEMICAL ACTIVE CHLORINE PRODUCTION IN COAXIAL AND CABINET-TYPE REACTORS

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Abstract: *Drinking water, whether previously purified or not, even if entirely clear, can often be contaminated with bacteria, viruses, or harmful microbes, necessitating disinfection. Disinfection serves as the final and sometimes the sole process in preparing drinking water. This paper presents a solution for the on-demand production of active chlorine (sodium hypochlorite) without the need for storage, aiming to prevent its degradation and ensure the safety of workers during handling.*
Keywords: Drinking water, sodium hypochlorite, chlorine

1. INTRODUCTION

Disinfection of water is most commonly performed using gaseous chlorine and chlorine compounds, during which oxidation reactions predominantly take place. Chlorine readily oxidizes alcohols, aldehydes, amino acids, various inorganic substances, and substances causing water discoloration, among others. Disinfection is carried out by precisely dosing chlorine compounds into the water using a dosing device (such as a dosing pump, dropper, or ejector). These quantities typically range from 0.3 to 0.5 g/m3 and depend on the quality of the filtered water, specifically on the content of substances susceptible to oxidation. These amounts are adjusted so that the disinfected water contains residual chlorine levels of 0.3 to 0.4 mg/l immediately before use. This free chlorine serves as a convenient indicator that an adequate amount of disinfectant has been used, while also preserving the bacteriological safety of the water for a certain period. Chlorination of water serves as both primary and secondary disinfection. This means that chlorine is used for both the primary inactivation of microorganisms in the water and to provide protection to the distribution system through residual action. The residual chlorine aims to maintain biological stability and protect against secondary contamination. Maintaining the biological stability of the system involves keeping the water in a state that does not promote the growth of microorganisms in the distribution system. For small-capacity facilities, disinfection is commonly carried out using sodium hypochlorite, NaOCl. The active chlorine content in the solution is about 15%. Gaseous chlorine is primarily used in high-capacity waterworks but is being phased out from water treatment processes due to the risks associated with handling and storing chlorine gas cylinders. Water solutions of sodium hypochlorite, produced in large petrochemical complexes or on-site generation units, are increasingly being used. In both cases, the water solution of the raw material (chloride salts) and the finished product (sodium hypochlorite) are stored in tanks exposed to atmospheric temperature and, potentially, sunlight radiation. Storage under such conditions triggers a thermochemical reaction in which sodium chlorate is formed from sodium hypochlorite, which is three times less effective in the water disinfection process. This

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problem is particularly pronounced during the hot summer months when the air temperature exceeds 30 degrees Celsius. To prevent the degradation of sodium hypochlorite, climate-controlled storage spaces and containers that do not allow UV radiation must be provided. In addition to hypochlorite degradation caused by heat and UV radiation, there is also spontaneous degradation defined by a half-life of approximately one and a half months. Since the solutions are alkaline, contact with carbon dioxide from the air leads to a reaction with sodium hydroxide, forming sodium carbonate, further complicating the operation of dosing systems by clogging nozzles, pump suction baskets, droppers, and injection valves.

2. BACKGROUND

In recent years, several companies worldwide have developed on-site sodium hypochlorite production devices, but they have mainly presented two design solutions: devices with flow and batch-type reactors, both involving the storage of the resulting sodium hypochlorite solution. These solutions have demonstrated various advantages over gas chlorination technology in practice. However, they tend to be large in size, considerably expensive, and susceptible to the degradation of sodium hypochlorite, particularly when left in the receiving tank for extended periods. When situated in air-conditioned environments, operational costs escalate significantly, which poses a substantial financial burden, especially for devices with smaller capacities. On the other hand, for non-air-conditioned settings, the installation of heat exchangers becomes imperative, both in the reactor itself and in the tank containing active chlorine. To ensure the reliability of the disinfection process, sizable storage tanks are implemented, containing significant amounts of sodium hypochlorite.

This precaution safeguards the continuity of the disinfection process in the event of device malfunctions. The intricate nature of the construction [1-3] justifies the need for product storage, guaranteeing the uninterrupted flow of the dosing process during any necessary device repairs. Similar challenges persist across the operation of batch, flow, and recirculation reactors. The initial prototype of one such device emerged in the USA under 'Capital Controls,' featuring a flow reactor, table salt reservoirs, an active chlorine tank, a water chemical preparation system (for softening), and an active chlorine dosing system. Fully automated, the device operates with minimal human supervision. Similarly structured devices were later developed in our country during the early 1990s, with the first model crafted by 'Fabrika vagona' in Kraljevo and commercially produced by 'Sigma' in Kula. By the late 1990s, various European manufacturers introduced new iterations of these devices, including 'Wallace Tiernen,' 'Fisher Porter,' 'Dinotec,' 'ProMinent,' 'Siemens Plc' OSEC-NXT with a membrane electrolyzer, and 'Water Engineers Ltd.' The designs, though diverse, predominantly rely on flow reactors and the accumulation of active chlorine. Notably, some devices utilize seawater in the electrolysis process to generate active chlorine, such as those from 'EU-CHLOR Ltd' in England and 'Prima Atec' in Korea, employing 'NC' cell types for the conversion of seawater. More recent entrants into the global market, including 'Titanium Tantalum Products Ltd' from India, have introduced electrochemical cells with carbon steel cathodes and titanium anodes activated with RuO_2, polarized monopolarly. Asian manufacturers, such as 'IEC Fabchem Limited' in India, 'Water Engineers' in Singapore, 'WestWater Enterprises Pty Ltd.' in Australia, 'Prima Atec Inc.' in Korea, 'Kalf Engineering' in Singapore, and 'Nagpur Aquatech Ltd.' in India, have also developed devices for on-site active chlorine production. These systems are constructed with flow reactors and active chlorine storage, catering to both seawater and table salt solutions for electrolysis.

Cleaning of the electrolyzer is accomplished by ceasing the process, filling the electrochemical cell with an acid solution to eliminate potential limescale buildup, expelling the acid, and resuming electrolysis using kitchen or sea salt. Most of these automated solutions are tailored for large-scale systems generating over 50 grams of active chlorine per hour. This paper introduces a novel device designed to address the limitations observed in previously described systems, primarily focusing on rectifying the issue of sodium hypochlorite degradation. The storage of sodium hypochlorite in tanks exposed to atmospheric temperature and potential solar radiation triggers a thermochemical reaction, converting it into chlorate, significantly diminishing its effectiveness in water disinfection, up to three

times less effective. This problem is particularly acute during the sweltering summer months when temperatures exceed 30 degrees Celsius. To counteract the degradation of sodium hypochlorite, the provision of air-conditioned storage facilities and the use of UV-resistant materials for containers become imperative. Apart from causing water contamination with chlorate, which possesses lesser disinfectant properties than sodium hypochlorite, prolonged storage elevates the cost of utilizing this disinfectant solution.

3. PROBLEM STATEMENT AND SOLUTION

To address the noted deficiencies in existing solutions, we have developed a device for active chlorine production featuring a coaxial reactor design. This innovative system generates sodium hypochlorite in quantities precisely matching the demand for water disinfection, eliminating the need for its storage. In our novel coaxial and cabinet reactor solution, the water undergoing chlorination circulates around the reactor housing, ensuring that the electrolyte temperature remains in close proximity to the cooling tap water temperature.

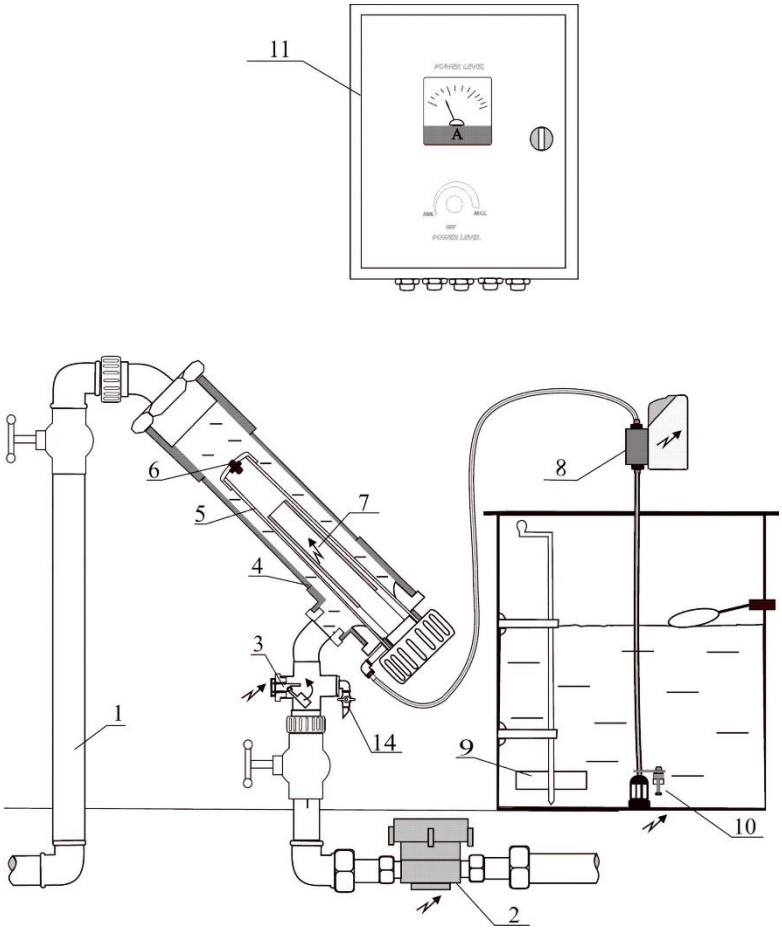

Figure 1. Device for the electrochemical production of active chlorine from dilute chloride solutions with a coaxial reactor mounted on a pipeline

Consequently, the sodium hypochlorite solution produced at the reactor outlet remains below 30°C, considering that tap water typically ranges between 10°C and 20°C. Essentially, the water undergoing chlorination doubles as a cooling agent. This design maintains the outlet temperature below 28°C, minimizing the risk of thermochemical degradation of hypochlorite to chlorate.

Our design circumvents the necessity for a thermoregulator and heat exchanger, only requiring a water flow sensor in the pipeline, leading to substantial simplification and material, electrical component, and automation savings. The device's proper operation is ensured through the installation of two sensors, one for monitoring the water flow to indicate the operational status of the pumping

pump and another for the minimum chloride solution to prevent the dosing pump from running dry. The electrolyzer activates only when there is a flow through the pipeline and the chloride solution exceeds the minimum threshold.

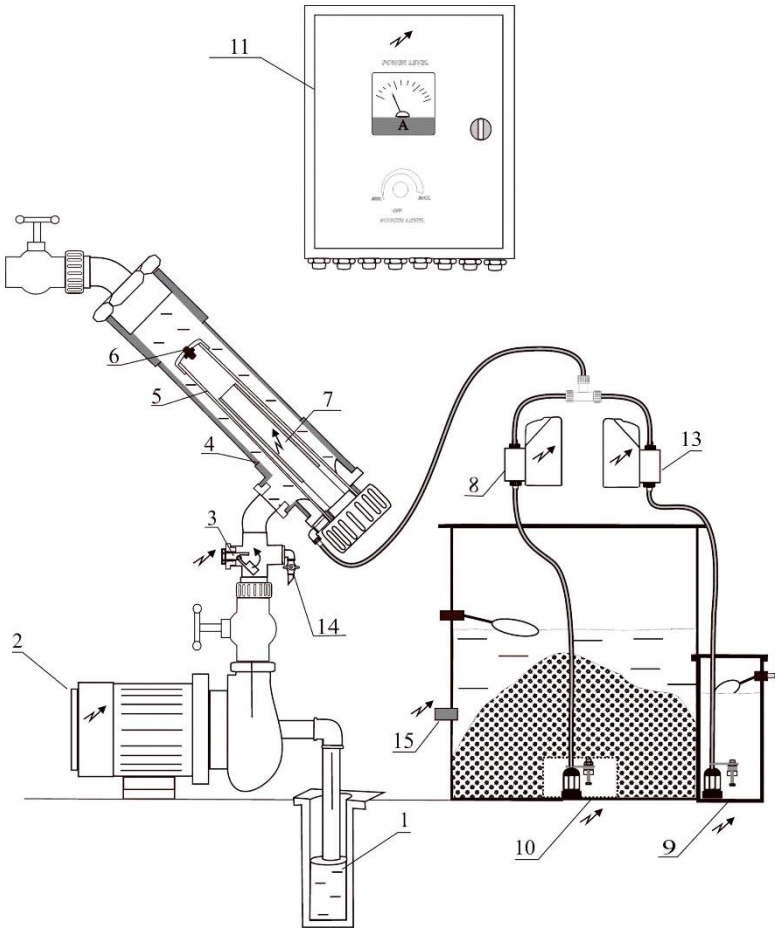

Figure 2. Device for the electrochemical production and dosing of active chlorine from a concentrated chloride solution with a coaxial reactor mounted on the pressure of the pumping pump

Our innovative solution, with its water-cooled coaxial and cabinet reactor, obviates the need for temperature sensors, thermoregulators, and their corresponding automation. Furthermore, the design eliminates the requirement for hydrogen separation and venting, as all reaction byproducts are introduced into the raw water along with the active chlorine. The dosage of active chlorine and hydrogen into the treated water remains below 1 mg, ensuring environmental friendliness. During operation, the dosing pump draws in a diluted chloride solution (3%) (refer to Figure 1). Alternatively, two dosing pumps may be employed, one drawing clean water and the other a concentrated table salt solution, mixed just before entering the reactor to produce a diluted chloride solution (3%) (refer to Figure 2). The frequency of diluting the sodium chloride solution depends on the monitoring intensity, with the option to refill the diluted solution container more frequently (every ten days) in more closely monitored settings. For locations with less frequent monitoring (distant sites), two dosing pumps are used, necessitating a higher input of concentrated salt solution into the container, achieving a 3% solution ratio upon mixing at the reactor inlet.

Within the tubular reactor, chlorides undergo electrochemical conversion to hypochlorite, with the resulting solution passing through a non-return valve before entering the water treatment process. The dosing pump flow, reactor current strength, water flow, and pipeline pressure are regulated based on the water flow and pressure. The minimum pressure requirement in the pipeline is 0.1 bar, with a flow rate of 0.1 liters per second. This device can be conveniently installed on the pump's discharge or suction line (as depicted in Figure 1) or anywhere along the pipeline, necessitating the installation of a flow meter instead of a flow sensor to signal the reactor's activation and operational intensity.

With its straightforward design, modular reactor system, and user-friendly servicing, our system ensures dependable operation and maintenance efficiency.
The device comprises an electric block, a sodium chloride tank, and a hydraulic assembly. The hydraulic assembly is composed of dosing pumps, an inlet valve, a flow sensor, a coaxial reactor or reactor cabinet, and an outlet valve. The sodium chloride solution, sourced from the tank (either 3% or 30% NaCl), is conveyed through the pipeline via dosing pumps. It is then mixed with clean water and subsequently introduced into the coaxial or cabinet reactor through a non-return valve.
Upon entering the reactor, chlorides undergo an electrochemical transformation, with active chlorine being generated at the anode and hydrogen released at the cathode. The resultant reaction products are directed through the upper non-return valve into the water circulating around the reactor housing, simultaneously undergoing chlorination.
Inside the reactor housing, a dosing pump maintains a pressure higher than that in the pipeline, ensuring the continued hydraulic transportation of the reacted solution. Subsequently, the solution is injected back into the pipeline through another non-return valve. This process guarantees that the chloride solution, or the active chlorine solution within the reactor housing, remains at the temperature of the well water (typically ranging between 7°C and 19°C). These optimal conditions facilitate the electrochemical synthesis of active chlorine.

4. CONCLUSION

This paper introduces a cutting-edge device for on-demand sodium hypochlorite production, eliminating the need for storage to prevent degradation and safeguarding workers during handling. The device ensures enhanced reliability in dosing system operations by generating a slightly alkaline solution with a pH of around 8 through the electrolysis of diluted solutions, thereby reducing the impact of CO2 reactions. Notably, this solution prioritizes user and environmental safety and represents a significant innovation compared to preceding methodologies.

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ANALYSIS OF ENERGY-SAVING MEASURES IN RESIDENTIAL BUILDINGS CONNECTED TO DISTRICT HEATING SYSTEMS USING INFORMATION TECHNOLOGY

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Abstract: *The thermophysical properties of the building materials and elements from which the buildings are constructed determine the heat losses of the building structures. When looking at the percentage share, the energy consumption in buildings in the USA and the EU is higher than that in industry and transportation. To achieve minimal energy standards, rules have been put into place, such as the European Union Directive on energy efficiency in buildings. The implementation of energy efficiency measures heavily relies on the improvement of building quality and suitable component selection. Energy efficiency measures are still important to implement in buildings built before the present standards and directives were adopted, as well as in newly constructed buildings. The research is based on buildings aged 30, 40, and more years, insulated, covered by the Energy Retrofitting of Buildings project in Šabac, implemented by the Distict Heating Company (DHC) "Toplana-Šabac" in collaboration with the European Bank for Reconstruction and Development (EBRD). The aim of the study is to track real-time heat energy consumption using Supervisory Control and Data Acquisition (SCADA) information systems over the past six years, or six heating seasons, before and after the energy retrofitting. The ultimate goals of the energy-saving measures are to reduce greenhouse gas emissions and decrease the operational costs of the facilities.*

Keywords: information technology, district heating systems, energy efficiency, residential buildings, reduction of CO_2

1. INTRODUCTION

The modern world is confronted with large challenges in the field of energy. The primary issue is the shortage of energy and its unreliable supply, while the secondary encompasses environmental pollution and the consequences of climate change, resulting from irresponsible energy consumption. The production, distribution, and utilization of energy play a pivotal role in all aspects of human activities, deeply influencing the societal and economic development of every country.

Questions of sustainable energy consumption have long been neglected, but today, they are in focus and recognized as an urgent problem requiring immediate solutions. But, despite the heightened attention to the social, environmental, economic, and security aspects of energy use, the existing uncontrolled model of energy consumption has proven to be unsustainable. Thus, the priority should be achieving sustainable energy consumption through a strategic approach to energy consumption itself and the implementation of energy-efficient measures in all segments of the energy systems of each country.

Buildings constitute the largest individual consumers of energy, exhibiting a growing trend in tandem with rising standards of living. In Europe, around 40% of the total energy is used in the construction sector, followed by transportation at 32%, and industry ranking third with 28% energy consumption [1–2]. Moreover, buildings serve as significant sources of environmental pollution,

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contributing to increased energy consumption and carbon dioxide emissions. This underscores the crucial potential for energy reduction within the realm of energy efficiency in the construction sector. Achieving the fundamental aim of energy efficiency in construction involves adopting measures and mechanisms for a sustained reduction in energy consumption in new buildings, utilising novel design methods and materials, and through the judicious reconstruction of existing buildings [3]. The implementation of regulations, adoption of directives, and formulation of guidelines on energy efficiency in buildings are planned to result in a substantial reduction in energy consumption for both new and existing structures [4].

In Serbia, a significant part of energy is dedicated to space heating, a factor contingent on the heating system type, heat distribution, and thermal characteristics of the building envelope, as well as the size, geometry, and orientation of the structure itself. When the energy efficiency of the building envelope is insufficient, considerable amounts of energy are required to achieve the desired temperature [5]. The building envelope assumes a critical role as the interface between the interior space of the building and the external environment, with components such as external walls, windows, roofs, ceilings, floors, and doors exerting a large impact on the energy consumption needed for heating and cooling.

The efficiency of a building envelope depends on various factors, including the type of building, climatic conditions, construction methods, geographical location, and the age of the structure. The significance of a quality building envelope is evident in the fact that heating and cooling buildings constitute a large part of the energy consumption globally, ranging from 30% to over 50%, depending on climatic conditions. In the residential sector, this consumption can exceed 60% of the total energy consumption [6]. According to the 2022 population census in Serbia, there are a total of 2.6 million residences, indicating significant potential for energy savings in buildings. The majority of constructed structures exhibit energy consumption for heating in the range of 150 to 200 kWh/m^2, highlighting inefficient energy use in these constructions [7, 8].

From the perspective of energy consumption, the construction period is crucial. Between 1950 and 1980, many residential and non-residential-constructed structures were erected, which now represent significant energy consumers, with average energy consumption for heating exceeding 200 kWh/m^2. In 1980, new requirements of thermal protection of buildings were introduced, reducing the allowable heat transfer coefficients by approximately 30%. The standards issued in 1987 were in effect in Serbia until September 30, 2012, when the implementation of the Regulation on the Energy Efficiency of Buildings and the Regulation on the Conditions, Content, and Procedure for Issuing Energy Performance Certificates in Construction began [9]. In this regard, the focus should be on the reconstruction of buildings constructed before 1987.

2. MATERIAL AND METHODS

2.1 Research description

The aim of this work is to enable benchmarking of energy efficiency indicators by comparing buildings that have implemented project activities with those that have not undergone such a program. The energy consumption for heating buildings should fall within the limits specified by the Regulation on the Energy Efficiency of Buildings, corresponding to the energy class "C." The anticipated reduction in energy consumption after implementing energy efficiency measures (building insulation) while preserving comfort and heating quality leads to a decrease in fossil fuel consumption, so resulting in lower emissions of suspended particles.

The analysis covers six residential buildings, two of which are connected to the "Trkalište" Heating Plant, and four to the "Benske Bare" Heating Plant. The capacity of the first plant is 66 MW, while the second is 24 MW. All buildings are connected to the SCADA system, through which all significant parameters are monitored. The buildings are selected so that each one is on a separate substation and does not share heat capacity with any other building. Heat sources are also managed through the SCADA system.

One of the parameters taken into consideration is that for each analysed building, there are preserved measurement results on heat energy consumption for at least two years before and two years after insulation, ensuring the reliability of the conclusions drawn. All the analysed buildings are located in the city centre, and they all share the commonality of being older than 30 years. The oldest building was constructed in the 1960s, while the youngest among them was built in the early 1990s. The study includes the following heating seasons (the period when the building uses heat energy from the district heating system, from October 15th to April 15th of the following year): the seasons 2017/2018, 2018/2019, 2019/2020, 2020/2021, 2021/2022, and 2022/2023. A list of objects with ID numbers of measuring points, heat capacity, year of construction, and the period in which energy retrofitting of the object was performed is given in Table No. 1.

Table 1. List of buildings
Source: *DHC „Toplana Sabac"*

Serial No.	Address:	Year of Construction:	Heat Capacity :	Energy efficiency measures :	District heating plant:
1.	Tsar Dusan st. 44	1993.	365kW	Season 2021/2022.	"Benske Bare" Heating Plant
2.	Queen Marija st. 1	1989.	83kW	Season 2021/2022.	"Benske Bare" Heating Plant"
3.	Sremska st. 1,3,5	1962.	128kW	Season 2021/2022.	"Trkalište" Heating Plant
4.	King Peter I st. 10	1974.	474kW	Season 2021/2022.	"Benske Bare" Heating Plant
5.	Student Battalion Square st. 15	1960.	328kW	Season 2021/2022.	"Trkalište" Heating Plant
6.	Knyaz Lazar st. 2	1977.	625kW	Season 2021/2022.	"Benske Bare" Heating Plant

2.2 Results

Due to varying average temperatures from season to season, all buildings are normalized to the same average temperature using the coefficient of the outside temperature. Temperatures are also obtained from the SCADA system and averaged for the entire season (Ta,avg). The specific heat consumption (SHC) is calculated according to formula (1). The coefficient of the outside temperature (*k*) is calculated according to formula (2).

$$\mathrm{SHC} = \frac{\text{Energy consumption for the heating season}}{\text{Heated area}} \left[\frac{\mathrm{kWh}}{\mathrm{m}^2}\right] \tag{1}$$

$$\text{The coefficient of the outside temperature} = \frac{20 - \mathrm{Ta,avg}}{20 - (-15)} \tag{2}$$

Where it is -15°C, the external projected temperature is for the city of Sremska Mitrovica [4]. The same temperature is used for the city of Šabac. A temperature of 20 °C is the design temperature of the room.
The specific heat consumption whit k (SHC*k*), taking into account the coefficient of the annual outside temperature *k*, is calculated according to formula (3) [11].

$$\mathrm{SHC}k = \frac{\text{Specific heat consumption} \times |k_{season\ i+1}|}{k_{season\ i}} \left[\frac{\mathrm{kWh}}{\mathrm{m}^2}\right] \tag{3}$$

For each building, a season is selected as a reference for analysis. Based on the values for the non-insulated season, the percentage savings for insulated seasons are obtained. The percentage savings (PS) are calculated using the formula (4).

$$\mathrm{PS} = \frac{\mathrm{SHC}k_{season\ N} \times \ \mathrm{SHC}k_{season\ N+1}}{\mathrm{SHC}k_{season\ N} \times 100}\ [\%] \tag{4}$$

The research results are presented in Figure 1. Percentage savings compared to the year without energy saving measures (Benchmark year) are shown in Figure 2.

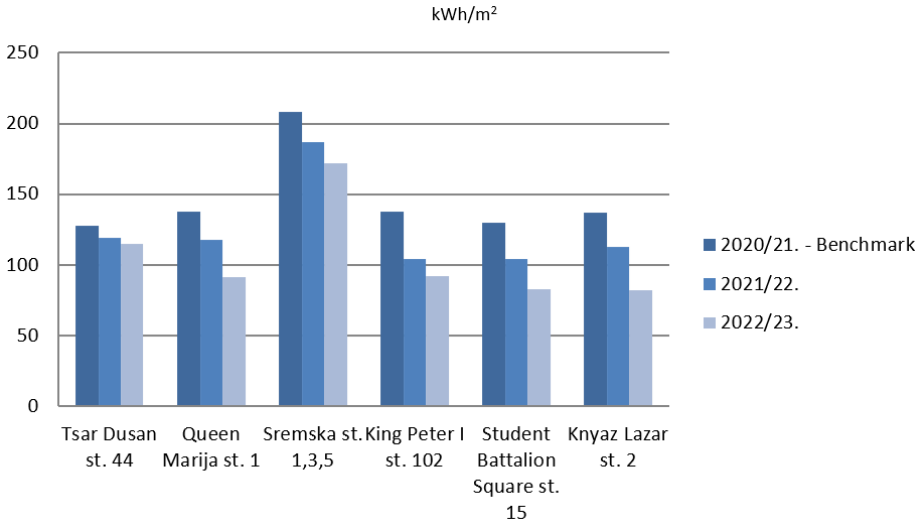

Figure 1. Specific Heat Consumption whit coefficient *k*
Source: DHC „Toplana Šabac“

Based on the obtained results, it is evident that the energy efficiency package has yielded results in reducing thermal energy consumption. The percentage of savings varies from 8% to even 40%. Various factors influence the percentage of savings, such as windows and doors in buildings not covered by this project, the building's position, construction period, quality, and age of installations, as well as the maintenance level of installations. The behaviour of end-users and their use of thermostat valves also play a crucial role. The energy efficiency package has delivered significant results and serves as a good practice example. The average savings based on the analysis of the energy efficiency package in these six buildings range from 15% to 28%.

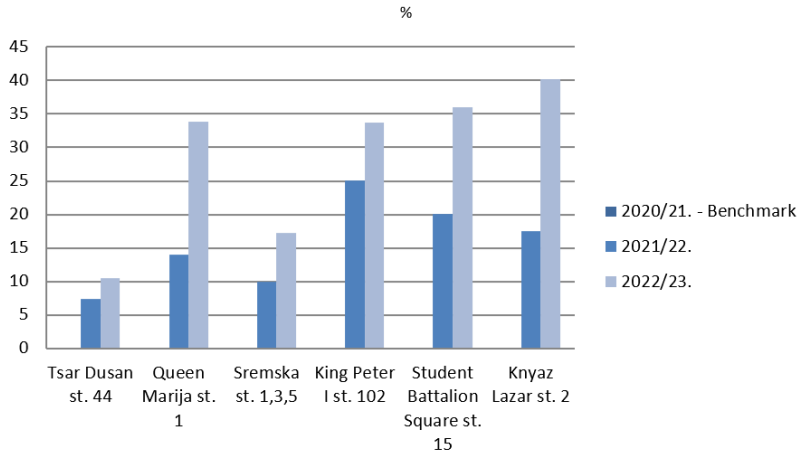

Figure 2. The percentage savings compared to the year without energy savings measures
Source: DHC „Toplana Šabac“

3. CONCLUSION

The energy policy of a local community (LC) that relies on energy management in the public sector, as well as strengthening the capacities of residential building managers to prepare and implement energy efficiency measures, would contribute to reducing the consumption of thermal energy for heating and cooling in public, commercial, and private residential buildings (single-family and multi-family). Informed decision-making on the implementation of energy efficiency measures, as well as the financial and technical sustainability of these measures, leads to the successful implementation of individual projects and the achievement of planned goals defined in strategic documents, programs, and action plans.

Examples of good practices motivate citizens and decision-makers to plan and implement activities over an extended period, ensuring that the local community remains resilient to rising fuel and energy prices, maintains energy supply security, works on environmental preservation, and improves the quality of life. It also aims to protect vulnerable and marginalised groups from the emergence and consequences of energy poverty and actively support the decarbonisation process and the development of a "green" economy.

In this context, it is crucial to analyse the thermal energy consumption in buildings, as well as the effects of applied energy efficiency measures, and publish the results and gained experiences through various communication channels to stakeholders. It is necessary to explore financing models and, based on conducted surveys, propose improvements to existing financing models and all other support mechanisms, as well as suggest innovative solutions that could be sustainable and accepted by all actors and direct and indirect participants in projects, especially decision-makers.

Maximising the contribution to a successful energy transition involves increasing the share of renewable energy with the aim of completely abandoning local energy based on fossil fuels in a pre-defined period. The specificities of local communities and the application of different solutions that are based on efficient "green" technologies should also be taken into account. For this reason, it is necessary to explore the level of technical knowledge and awareness, primarily of building managers, about the possibilities of applying renewable energy technologies and the attitudes of citizens and their needs to raise awareness about the way of implementing and financing renewable energy projects.

The research process begins with compiling a list of stakeholders, such as decision-makers, energy managers, citizens, including the media, representatives of the civil sector, as well as educational institutions and experts in local energy, energy efficiency, and renewable energy sources. Without good information, the participation of experts, and effective support mechanisms, the goals defined in energy policies, strategic documents, and energy efficiency programmes will not be achieved. Users of research results are often members of local communities who have no experience with similar projects, emphasising the importance of collaboration between local communities in transferring information, knowledge, and best practices.The results of the analysis conducted based on the research will be of great importance to other local communities that have not yet started implementing projects to improve the thermal properties of buildings, both the optimal implementation of energy efficiency measures (insulation of existing buildings) and choosing a finncing model.

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ENVIRONMENTAL ACCOUNTING EDUCATION FOR SUSTAINABLE DEVELOPMENT: A COMPREHENSIVE OVERVIEW

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Abstract: *Reporting on an organization's financial performance is no longer the only emphasis in corporate reports, as investors and other relevant addressees increasingly require companies to also provide information on their impact on the environment and society as a whole. Therefore, environmental accounting and reporting are becoming increasingly important for stakeholders and profit-oriented organizations, since the environmental and social performance of the organization has a significant impact on the status of the organization's financial health. The purpose of this research is to review the current situation in this area and make certain recommendations.*
Keywords: environmental accounting, sustainable, reporting, education

1. INTRODUCTION

Accounting is a discipline that, in its practical application, can, among other things, include environmental aspects, especially when it is used to monitor and disclose information about the impact of companies' operating activities on the environment. Green accounting is a branch of accounting science that companies accept in order to contribute to environmental protection. The primary focus is on promoting sustainability and the company's role in the environmental context. It is crucial to emphasize these principles throughout the organization and to ensure that they are recognized by all stakeholders. Green accounting is also called "environmental accounting", "environmental protection accounting", "ecological accounting" and is related to ecological services and goods. Moreover, it is recommended that academic circles use the term "environmental accounting" uniformly. The implementation of green accounting in companies has caused debate, and the results of previous research suggest that there is no universally accepted standard model for its implementation to improve performance (Astawa et al., 2018).
Environmental accounting was generally viewed as a subset of social accounting until the late 1980s, whereas today it is viewed as a "predominantly new" area of accounting consideration. Environmental accounting in the modern environment plays a key role in understanding the role that businesses play in economic security and general well-being, especially in the context of environmental security. Green accounting is an approach that emphasizes the long-term efficient use of resources in the company's production processes, in order to achieve synergy between corporate growth and environmental responsibility, which ultimately contributes to social benefit (Indriastuti & Mutamimah, 2023).This accounting provides information that highlights the contribution of business enterprises to economic development, on the one hand, but also information on costs initiated through pollution or resource degradation, on the other hand. Due to the increasing needs of financial statements users related to the disclosure of green information, on

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the one hand, and the increasingly pronounced tendency to deal with the shortcomings of traditional disclosure, it has given rise to the need to develop an accounting standard that would include consideration of green or environmental disclosure (Maama & Appiah, 2109).
Green accounting has a dual purpose. The first purpose is to improve the financial environmental performance of the business, while the second purpose is to analyse the impact of the organization's business on the environmental system. The implementation of green accounting within the organization's management system has a key role in achieving progress, both in environmental and economic performance of the organization.
This paper is structured as follows. First, the background to environmental accounting is outlined. The second part deals with the methodology, the third part presents the results of the research and the accompanying discussion. Finally, some concluding remarks are made.

2. LITERATURE REVIEW

Environmental protection is an extremely important issue, among other things, also in a normative sense (Owen et al., 1997; Knežević, 2011; Knežević, et al., 2013; Thornton, 2013; Stanković &Mitrović, 2021; Mitrović et al., 2022).).In its full capacity, "green accounting" should refer to the actual accounting of an organization's environmental impact (Cho & Patten, 2013). However, the question arises as to how likely it is that the effects of companies' environmental actions will be included in their financial statements. Additionally, it raises the question of whether companies will continue to provide information about these initiatives. Understanding corporate disclosure and its impact remains as relevant today as it was two decades ago, which is of particular importance to the accounting academic community.
When applying "green accounting", it is crucial to identify and numerically express the impact of the investment project on the environmental aspect, as well as the costs resulting from reducing this impact, such as land restoration, water purification and other measures to restore the environment. In addition, we must not forget to take into account the irreparable damage to the environment and human health. Without such analyses, investment managers can make decisions that can be extremely "expensive" for future generations (Stanojević et al., 2010).
"The literature on green accounting in distorted economies remains comparatively small" (Vincent, 2000, p. 18). Awareness of environmental constraints has led to a proliferation of accounting methodologies designed to measure the impact of human activity on Earth's ecological systems and resources. Current practice usually focuses attention on parallel reporting, while financial accounting still remains dominant. Green accounting remains largely voluntary and unaudited.
Companies can become leaders in promoting green initiatives by integrating them into their operations, thereby also motivating other organizations to do the same. When green accounting is incorporated at all levels of the organization, a greater level of environmental responsibility can be achieved (Agarwal & Kalpaja, 2018, p. 207). Introducing the concept of green accounting into the organization's management system plays a key role in improving the organization's environmental and economic performance. However, we are facing challenges when it comes to the implementation of this type of accounting in Serbia due to the lack of information that would be available to interested parties regarding the additional costs and effects brought by the implementation. Most companies are not sufficiently familiar with the potential results and therefore may be hesitant to implement this tool.

3. METHODOLOGY

This research study was conducted in Belgrade in 2023.The sample consists of 159 respondents, who are students and people from the economy, who are classified into three groups - employees, lawyers and businessmen. For the purposes of the research, a questionnaire was structured in accordance with the objective of the research, which was distributed to respondents via e-mail, thus collecting primary data. A Likert scale of 1 (strongly disagree) to 5 (strongly agree) was used.The

collected data were classified and tabulated for analysis in accordance with the objectives of the study.

4. RESULTS AND DISCUSSIONS

Using Google Forms, we collected primary data through questionnaires and analysed them to obtain the final results. In the first phase of the analysis, we applied a percentage analysis to explore the general profile of the respondents (Table 1).

Table 1. Analysis of the respondents' general profile
Source: *Primary Data*

	Classification	No.of respondents	Percentage
Gender	Male	91	57.2
	Female	68	42.8
	Total	**159**	**100**
AgeGroup	18-30yrs.	38	23.5
	31-40yrs.	43	27
	41 - 50 yrs.	59	37.1
	51 - 60 yrs.	12	7.5
	61 and above	6	11.11
	Total	**159**	**100**
Occupation	Employees	55	34.6
	Student	26	16.4
	Lawyer	12	7.5
	Businessmen	66	41.5
	Total	**159**	**100**

The primary data was collected with the help of 159 respondents. Table 1 shows that out of 159 respondents, 91 (57.2%) respondents were men, and 68 (42.8%) were women. There were 38 (23.5%) respondents in the 18-30 age group, 43 (27%) in the 31-40 age group, 59 (37.1%) respondents were under 41-50 years of age, 12 (7.5%) were in the age group of 51-60 years, and 6 (11.11%) belonged to another age group except the above-mentioned age groups. Of these, 55 (34.6%) respondents were employees, 26 (16.4%) were students, 12 (7.5%) were lawyers, and 66 (41.5%) were businessmen.

Considering the defined goal (according to: Agarwal& Kalpaja, 2018), the paper provides answers to three research questions – Figures 1-3.

When 159 respondents were asked whether environmental accounting must be included in all companies (Figure 1), only 28.3% of the respondents strongly agreed, 24.5% were neutral, 23.9% agreed that environmental accounting should be incorporated in all companies, and 7.5% said they disagreed with it. The results of the survey on this matter indicate that slightly more than 50% of the respondents are aware of the importance of including environmental accounting in all companies, considering the benefits related to the fact that companies can monitor two things: what is taken from the environment and what is received in return.

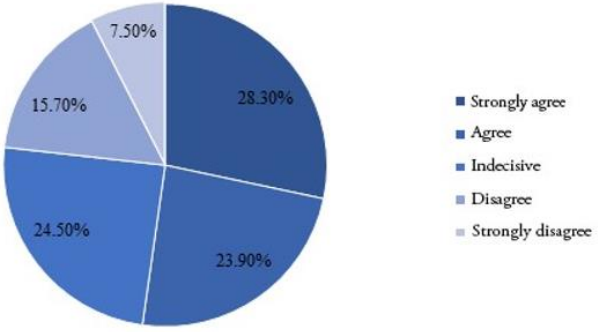

Figure1. Integration of environmental accounting in all companies
Source: Authors

Then, the respondents were asked whether it is useful to increase awareness of environmental accounting. The following answers were obtained: as shown in Figure 2, it can be seen that 34.6% of the respondents strongly agree with the statement, 31.4% of the respondents agree, while the rest of the respondents are either not very sure about the contribution of environmental accounting to profit-oriented organizations or are they strongly disagree.

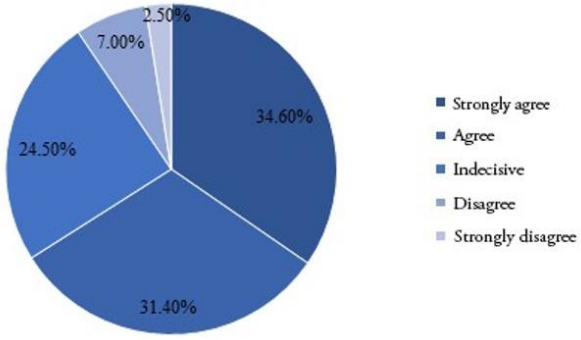

Figure 2. Increasing awareness of environmental accounting
Source: Authors

Furthermore, when the respondents were asked whether the government must take strict action if environmental reporting is not followed (Figure 3), 9% of them strongly disagree and 6% disagree. More than half of the respondents are of the opinion that the government must take strict measures if environmental reporting is not respected (agree or strongly agree).Furthermore, 23.9% of them were neutral on this issue. Governments should encourage activities and performance measures in the sphere of environmental impact to a greater extent.

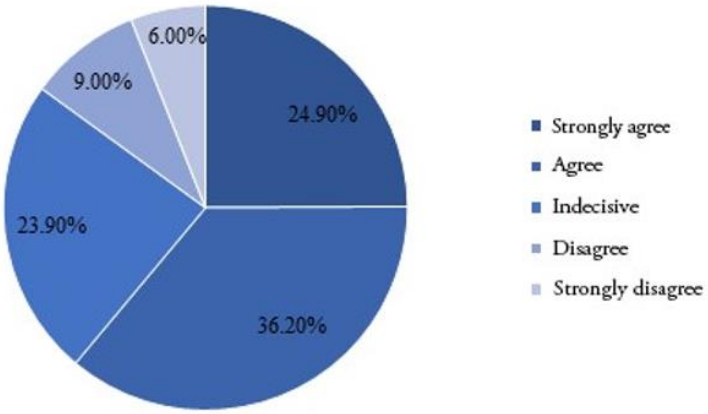

Figure 3. Government influence on environmental reporting
Source: Authors

Based on the above brief review and analysis of Serbia's achievements in environmental accounting research in the last two decades, we believe that in order to improve theoretical research and practical application of environmental accounting in Serbia, it is necessary to make significant efforts in various fields.First, it is necessary to integrate environmental accounting research and systematically build a theory, which would design an engineering system for the establishment of environmental accounting.Second, it is necessary to encourage larger number of empirical research and as an example the research can be cited related to identifying the differences between the share prices of companies that disclose environmental information and companies that do not disclose information.Third, it is necessary to attract the attention of companies to focus more on environmental factors in making management decisions, where the introduction of the concept concerning the development of environmental management as an internal driving force would help.In order to achieve all three goals, it is necessary to increase education, both formal, at business and other faculties, as well as informal education through various types of training from this practice.

5. CONCLUSION

Viewed from the content of current research on environmental accounting, most scientists pay more attention to theoretical research on environmental accounting theories, such as the goal of environmental accounting, subject matter, basic assumptions, etc., but conducting specific research is necessary on how technical methods are borrowed and used from of other disciplines and as such are called upon to be applied to operational problems in the practice of environmental accounting. Research on the application of environmental protection in the segment of accounting recognition and measurement methods in practice should also be strengthened.

Achievements of theoretical research should be applied in the practice of environmental accounting of companies. The theory should be checked and corrected through practices in order to improve its practicality. The academic community can play a major role in this. Starting from the fact that environmental accounting is a comprehensive tool for introducing environmental considerations into business decisions, it is necessary to investigate more deeply the issue of depletion of natural resources. The study also highlights the significant importance of environmental accounting education as a core course within universities. It is necessary to incorporate environmental considerations into the practices of financial and management accounting, which would best support the making of eco-responsible business decisions.

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VALIDATION OF THE ICP-OES METHOD FOR DETERMINING THE ELEMENTAL COMPOSITION OF WATER

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Abstract: *Every research or analytical method requires validation to ensure the accuracy, reliability, and precision of the results. Validation is a critical component of research, especially in areas such as water analysis or any field where the presence of elements or chemical compounds is measured and analyzed. In this study, we investigated the validation of the Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES) method for determining the elemental composition of water, along with the application of analysis of variance (ANOVA). The validation of the analytical method and the use of ANOVA analysis play a crucial role in ensuring the reliability and precision of results, as well as in exploring the variability among different samples. This paper emphasizes the significance of analytical method validation and the application of variance analysis in securing accurate and reliable results in water analysis, contributing to better water quality control and environmental protection.*
Kaywords: validation, LOD, precision, accuracy, linearity.

1. INTRODUCTION

Validation of an analytical method is a documented process that confirms the suitability of the applied procedure for obtaining useful data and thereby fulfills its intended purpose [1]. Validation begins immediately after the development of a specific method and is a prerequisite for its application. If feasible, a standard method published by international, regional, or national organizations should be selected. Such a method has already been validated - it has been determined that the testing method is suitable for its intended use. However, to use such a standard method for testing, it is necessary to confirm its feasibility in the working conditions of a specific laboratory, using its own resources such as equipment and personnel, and this process is called verification. In cases where a laboratory wishes to use a method developed in-house, a non-standard method, or a modified standard method (in-house), there is an obligation for it to be properly verified and validated before implementation [2,3].
From the initiation of an analytical problem to the laboratory's decision on whether the request can be executed using the identified method, a series of steps are followed (Figure 1). The validation process concludes with a determination and statement of whether the analytical requirement has

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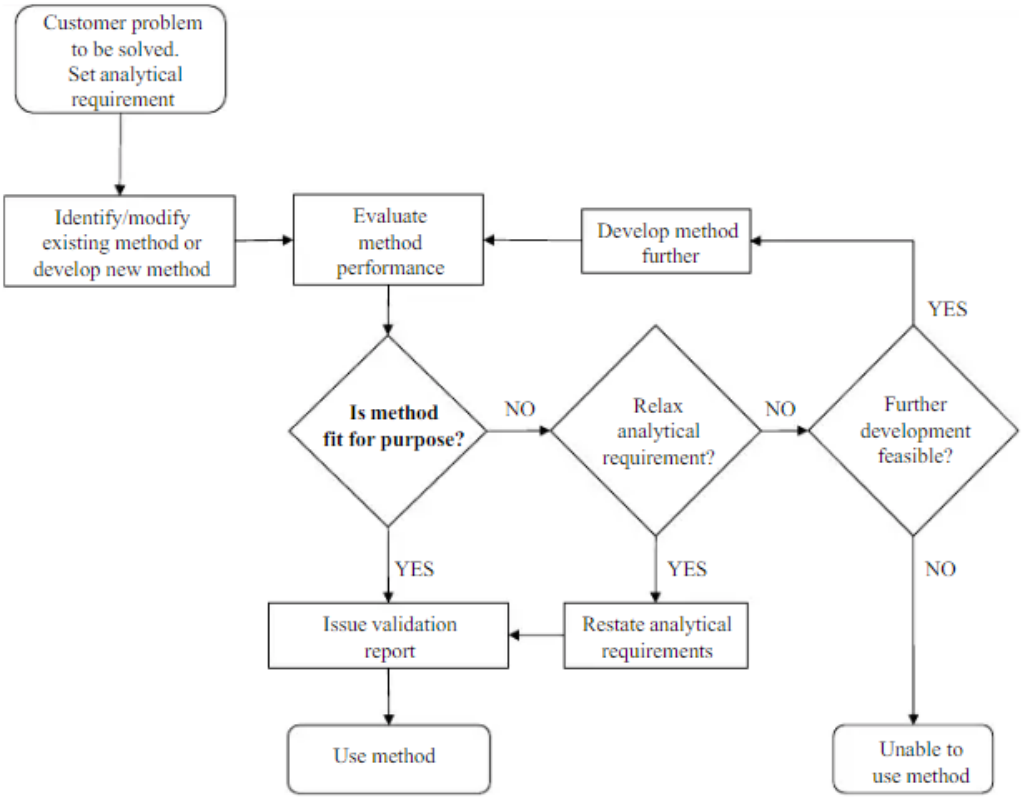
been met or not. The results of the validation work are reported in a documented form that confirms the successful completion of all steps.
This paper presents the procedure and content of validation for the application of Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES) to determine the elemental composition, specifically the content of Ba, Fe, and Pb in wastewater. The method is in accordance with the EPA 200.7:1994 standard, and measurements were conducted using the ICP-OES 9820 SHIMATZU spectrometer.



Picture 1*:* Diagram of the method validation process
Source*:* [4]

2. EXPERIMENTAL SECTION

Before aliquoting for the direct determination of elements, the pH of the water samples was measured to confirm proper preservation (pH < 2). To determine dissolved elements, the sample must be filtered through a membrane with a pore size of 0.45 μm before analysis. A blank sample is prepared and analyzed alongside the actual samples. The experimental plan is shown in Table 1 in accordance with the specified data quality requirements. The sample types and concentrations to be analyzed are presented in Table 2.

Table 1: Experimental plan with specified data quality requirements

Validation Parameter	Sample Type	Description	Number of Repetition Tests
LOD, LOQ	Blank	Blank sample	10
Linearity	Calibration Solutions	Calibration solutions at 7 concentration levels	Duplicate measurements
Precision	Real Samples	Real wastewater samples	6 series in duplicate
Тачност	CRM	Synthetic samples with nominal concentrations	6 series in duplicate
	Spike Sample	Spiked samples at 3 concentration levels	6 series in duplicate

Table 2: Method Validation Samples

	Description
Sample A	Blank - DI water
Sample B	Wastewater from Henkel
Sample C	A + 0,2 mg/L mix metals
Sample D	A + 0,45 mg/L mix metals
Sample E	A + 0,75 mg/L mix metals

2.1 Calibration and standardization

For calibration and standardization, the following solutions are used:

a) Calibration Mix

The calibration curve is formed by diluting the calibration mix solution in a concentration range from 0.005 to 1.00 mg/l at 7 points (As, Se, Cd, Fe, Co, Pb, Cr, Ni, Cu, Mn, Ag, Sr, Ti, V, Al, Ba, Be, Mo, Sb, Na, K, Mg, Ca, Zn, Sn).

b) Blank (Blank Sample)

For the analysis, two types of blanks need to be prepared: calibration blank and reagent blank. The calibration blank is prepared by adding an acid to water in the same concentration as that used in making standard solutions. The reagent blank is prepared for each type of material according to the sample dissolution instructions but without adding the sample, only the chemicals used in its dissolution.

c) Initial Calibration Verification Standard (ICV)

These solutions are prepared from the same basic standard solutions used for calibration standards. They serve for periodic verification of instrument performance during the analysis.

d) Control Calibration Verification Standard (CCV)

These solutions are used for the initial and periodic verification of calibration standards to check instrument performance. They must be prepared independently of the solutions used for calibration.

2.2 Measurement

The instrument is configured with the appropriate operational parameters. After selecting the appropriate program from the ICPsolution package, the instrument is re-profiled by scanning argon lines while distilled water is dispersed into the plasma. The instrument is ready for measurement, and wavelengths are selected from the provided list of lines on which measurements will be performed. Prepared solutions are then introduced into the plasma.

The linearity of the calibration curve is verified by measuring calibration points in duplicate at concentrations that cover the entire range (0.005; 0.01; 0.05; 0.1; 0.25, 0.5; 1 mg/L). First, the calibration blank is measured, followed by standards from the lowest to the highest concentration. Distilled water is dispersed after each solution to rinse the system and prevent contamination. The choice of wavelengths (λ) for measurement depends on the type of material being tested, specifically the composition of the sample matrix and the potential interference of the measured line with the matrix lines. Lower concentrations are recorded in axial mode, while higher concentrations are recorded in radial mode. Determining the limits of detection (LOD) and limits of quantification (LOQ) involves tenfold repeated measurements of the blank at the λ used for element detection. The limit of detection for each element is determined by multiplying the standard deviation of the measurement results by 3. The limit of quantification for each element is determined by multiplying the standard deviation of the measurement results by 10 [4,5].

2.3 Pre-work verification

The measurement procedure on the instrument involves comparing the emission intensities of the test samples with synthetic standards, which means that recalibration is performed with each measurement. Quality control of measurements is carried out in each measurement series as follows: during each series of measurements of real samples, the calibration curves are checked by verifying the values for the calibration blank and one calibration solution, the initial calibration verification standard (ICV), which is recorded as an unknown sample. This verification is mandatory at the beginning and end of the measurement series. The calibration blank solution, prepared from the reagents used for dissolution, serves as a check for possible contamination. Along with the samples being analyzed, a control standard, the control calibration verification standard (CCV), is also measured, which is prepared independently of the solutions used for calibration. This type of control is conducted in each measurement series in parallel with the real measured samples. This measurement method checks the calibration curves and the instrument's stability over an extended time period, especially in cases of series with a large number of samples.

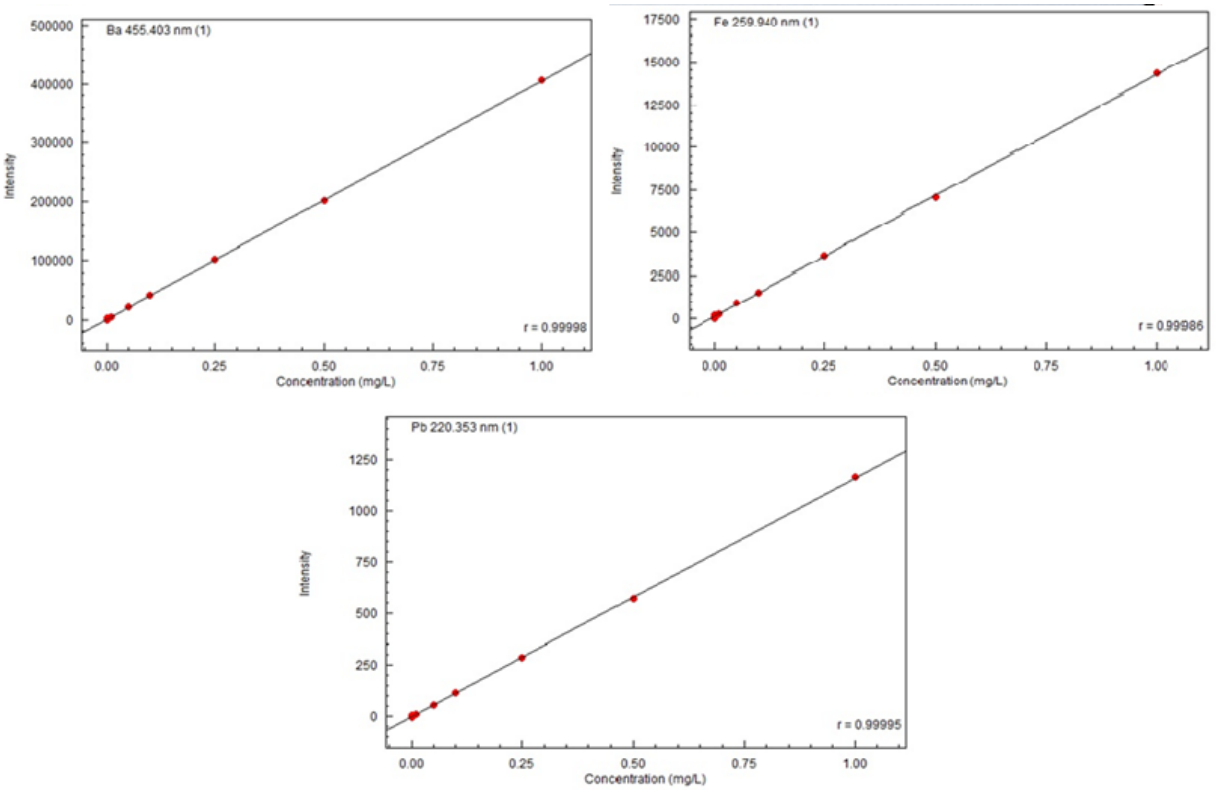
3. RESULTS AND DISCUSSION

The ICP spectrometer is connected to a computer, and data acquisition and processing are carried out using the ICPsolution software. This software automatically calculates the calibration curve from the signal intensities of the calibration standards and the blank sample while correcting the measured signals for the background. It then calculates the concentration of the test element from the resulting curve. Negative results are those where the presence of the test element is not detected, while positive results are those above the Limit of Detection (LOD) and quantitatively above the Limit of Quantification (LOQ).
The method for determining elements in aqueous solutions using ICP-OES is expected to meet the conditions presented in Table 3 [6]. These values represent the expected performance and quality control standards for the method. The relative standard deviation indicates the precision of the method, accuracy ensures that the results are within an acceptable range, and the minimum correlation coefficient value demonstrates the linearity of the calibration curve. These criteria help assess the reliability and robustness of the analytical method.

Table 3*:* Characteristic values of the method
Source: *[6]*

Relative standard deviation	≤ 10 %
Accuracy	85-115%
Minimum value for the correlation coefficient	0,990

From the calibration plots, it can be observed that the calculated correlation coefficient (R) is above 0.999 (0.99998 for Ba, 0.99986 for Fe, and 0.99995 for Pb) for all metals (Figures 2-4). This high correlation coefficient indicates a strong linear relationship between the concentration of the analyte and the signal intensity, demonstrating the linearity and reliability of the calibration curves for these elements.
Accuracy and precision have been determined by spiking the sample matrix at three levels of interest (20%, 45%, and 75%). The data collected for the assessment of precision and accuracy have been processed using the Anova: Single Factor method from the MS-Excel package, which is one-way analysis of variance (ANOVA). The obtained results are presented in Table 4.



Picture 2: Calibration curve for Barium (Ba, Fe, Pb)

Table 4: The determination of precision and accuracy using a single-factor ANOVA approach

Analite	Concentration		Ricavery %	No.	Precision		
	Expected (mg/l)	Determined (mg/l)			Reproducibility	Repeatability	Overall Precision:
					S_b (mg/L) CV_b (%)	S_w (mg/L) CV_w (%)	S_{tot} (mg/L) CV_{tot} (%)
B – Wastewater							
Ba	/	0.216	/	2	0.00417 (1.93)	0.005115 (2.37)	0.00660 (3.05)
Fe	/	1.183	/	2	0.00500 (0.42)	0.019579 (1.65)	0.02021 (1.71)
Pb	/	0.033	/	2	0.00033 (1.01)	0.000698 (2.11)	0.00077 (2.34)
C (A+0,20 mg/l)							
Ba	0.20	0.206	96.15 – 98.04	2	0.00072 (0.36)	0.00112 (0.56)	0.00133 (0.66)
Fe	0.20	0.197	97.56 – 111.73	2	0.00538 (2.69)	0.00612 (3.08)	0.00819 (4.09)
Pb	0.20	0.202	96.62 – 101.01	2	0.00398 (1.99)	0.00100 (0.50)	0.00410 (2.05)
D (A+0,45 mg/l)							
Ba	0.45	0.463	95.74 – 98.47	2	0.002149 (0.48)	0.00450 (1.00))	0.00499 (1.11)
Fe	0.45	0.455	94.74 – 102.51	2	0,006568 (1.46)	0.01052 (2.34)	0.012409 (2.76)
Pb	0.45	0.464	94.14 – 100.22	2	0.005968 (1.33)	0.00505 (1.12)	0.007812 (1.74)
E (A+0,75 mg/l)							
Ba	0.75	0.759	95.54 – 103.45	2	0.01782 (2.38)	0.00488 (0.65)	0.01848 (2.46)
Fe	0.75	0,761	97.28 – 99.73	2	0.00356 (0.48)	0.00632 (0.84)	0.00726 (0.97)
Pb	0.75	0.771	94.57 – 99.47	2	0.01233 (1.64)	0.00735 (0.98)	0.01435 (1.91)

The determination of the limit of detection (LOD) and the practical limit of quantification (LOQ) involves a computational analysis. The results obtained from this analysis are presented in Table 5. Afterward, the obtained limit of detection is verified by measuring a diluted Standard Reference Material (SRM) at a level of interest.

Table 5: The determination of the LOD and LOQ

	Ba (mg/L)	Fe (mg/L)	Pb (mg/L)
LOD	9.49E-05	0.000645	0.001273
LOQ	0.000316	0.002150	0.004244

It appears that the method has demonstrated excellent performance in various aspects of analytical validation. Here are some key points from the provided information: The method exhibits excellent linearity with correlation coefficients above 0.999 for all metals, indicating a highly linear response over a wide range of concentrations.The method shows satisfactory repeatability with coefficients of variation (CV_w) ranging from 0.50% to 3.08%. This indicates that the method can produce consistent results when the same sample is analyzed multiple times under the same conditions. The method demonstrates satisfactory reproducibility with coefficients of variation (CV_b) in the range of 0.36% to 2.69%. This suggests that the method can produce consistent results when applied by different operators or in different laboratories. The total precision of the method, expressed as CV_{tot}, falls within the range of 0.66% to 4.09%, which aligns with the specifications for data quality outlined in EPA method 200.7. The recoveries of the analyzed samples range from 94.14% to 111.73%, meeting the accuracy requirements of the method (85-115%). The method's LODs for validated metals are significantly lower than the LODs specified in EPA method 200.7, which indicates high sensitivity. The LODs are reported as 9.49E-05 mg/L for Barium (Ba), 0.000645 mg/L for Iron (Fe), and 0.001273 mg/L for Lead (Pb).

4. CONCLUSION

Based on the conducted validation of the ICP-OES method for measuring concentrations of Ba, Fe, and Pb, it can be concluded that the method has been successfully adapted, validated, and documented according to the standard EPA method 200.7, using the ICP-OES 9820 SHIMATZU spectrometer. Taking all the mentioned factors into account, it is evident that the ICP-OES method meets the requirements for precision, accuracy, sensitivity, and linearity. This is crucial for reliable measurements of Ba, Fe, and Pb concentrations in wastewater and can be used in routine work within the defined scope of application in the Polichem laboratory. The application of ANOVA analysis has proven to be an important step in our research, allowing us to analyze differences between samples and method parameters more efficiently, resulting in more reliable results in the analysis of the elemental composition of water.

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PROFICIENCY TESTING AS A TOOL FOR QUALITY CONTROL OF LABORATORY TEST RESULTS IN ENVIRONMENTAL POLLUTION ANALYSIS

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Abstract: *Proficiency testing (PT) is a valuable tool for quality control and assurance in various industries, including manufacturing, healthcare, environmental monitoring, and more. It plays a crucial role in ensuring the accuracy and reliability of test results, measurements, and processes. Within the SRPS ISO/IEC 17025:2017 standard, there is a requirement related to ensuring confidence in the quality of test and calibration results. According to this requirement, a laboratory must have quality management procedures in place to monitor the validity of performed testing and calibration. This monitoring must be planned and reviewed, and one of the steps involves participation in inter-laboratory comparison programs or proficiency testing programs. In order to maintain its competence, the Polihem laboratory, which is part of the Academy of Applied Technical Studies Belgrade, conducts internal and external quality control. In this paper, inter-laboratory comparisons will be presented as a form of external quality control in which the Polihem laboratory has participated.*
Kaywords: Proficiency testing, laboratory, quality control

1. INTRODUCTION

According to the definition from ISO/IEC Guide 43-1, inter-laboratory comparison (ILC) is the organization, execution, and evaluation of test results for the same or similar test items or samples by two or more laboratories under predetermined conditions. Proficiency testing, often referred to as PT or interlaboratory comparison, is a formalized process in which a sample of known properties is distributed to multiple laboratories or testing facilities for analysis. The participating laboratories are unaware of the sample's true properties, and their test results are compared to a reference or consensus value [1,2].
Quality assurance in a testing laboratory is a complex and demanding task. It involves establishing policies and objectives, assigning responsibilities for meeting these requirements, continuously improving laboratory operations through the development and implementation of new testing methods, identifying errors/non-conformities, taking corrective actions, and planning and conducting internal and external quality control through participation in proficiency testing programs [3].

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In every analytical procedure, whether related to scientific, technical, environmental, or health issues, three interconnected parameters are inevitable: the problem, the sample, and the method.
The concept of quality in the field of analytical practice can be succinctly defined as a set of characteristics of a procedure or method that produces analytical results meeting the expected and prescribed requirements, satisfying the needs of the users of those results [4].
Quality control is a mechanism used to verify the acceptability of obtained test results, and it is applied to assess the effectiveness of quality management. Quality control can be internal and external control an program ensures the management and monitoring of the validity of conducted tests. Control results can indicate various aspects of data quality obtained in routine work. If the results fall outside acceptable limits, they should be reviewed until the method is verified or validated.
The foundation for creating a quality control program includes participation in proficiency testing (PT) and internal laboratory control. Criteria for the quality control of testing are established during method validation or verification and encompass parameters, frequency, and criteria for the acceptability of results [5].
In this paper, inter-laboratory comparisons will be presented as a form of external quality control in which the Polihem laboratory has participated.

2. PROFICIENCY TESTING

Proficiency testing, often abbreviated as PT, is a critical component of quality assurance and quality control in various industries, particularly those involving testing and measurement. It is a systematic and objective evaluation process used to assess the accuracy and precision of a laboratory or testing facility's analytical or testing methods.
Key aspects of proficiency testing are:

a) Objective Assessment: proficiency testing is designed to objectively evaluate a laboratory's performance in conducting specific tests or measurements. It provides an external benchmark against which a lab's results can be compared.
b) Independence: Proficiency testing is typically conducted by external organizations or regulatory bodies that are independent of the laboratory being tested. This ensures impartiality and eliminates potential bias.
c) Regular Testing: Laboratories typically participate in proficiency testing programs on a regular basis, often annually or semi-annually, depending on the industry and the specific tests being performed.
d) Sample Exchange: A proficiency testing program involves the exchange of test samples between the testing laboratory and the external provider. The laboratory analyzes these samples using their standard methods, and the results are submitted to the external provider for evaluation.
e) Assessment and Feedback: The external provider assesses the laboratory's results by comparing them to known or reference values. They provide feedback to the laboratory on their accuracy and precision. If discrepancies or errors are identified, the laboratory is typically required to take corrective actions.
f) Improvement and Compliance: Proficiency testing helps laboratories identify areas for improvement in their testing methods and procedures. It also ensures that the laboratory complies with relevant quality standards and regulations.
g) Quality Assurance: By participating in proficiency testing programs, laboratories can demonstrate their commitment to quality assurance and build confidence in their testing capabilities among clients, regulatory bodies, and the public.
h) Certification and Accreditation: In some industries, proficiency testing is a requirement for obtaining and maintaining certification or accreditation. It is often a key component of ISO 17025 accreditation for testing and calibration laboratories.

i) Cost-Effective Evaluation: Proficiency testing is a cost-effective way for laboratories to assess their performance without the need for in-house validation studies, which can be expensive and time-consuming.

PT is widely used in fields such as healthcare (clinical laboratories), environmental testing, food safety, pharmaceuticals, and materials testing. It plays a crucial role in ensuring the reliability and accuracy of test results, which, in turn, contributes to the safety and quality of products and services in various industries.
Common types of inter-laboratory comparisons include:

a) Successive Testing Technique: In this approach, participating laboratories sequentially test the same sample according to a predefined order. A drawback of this method is the extended testing period. It requires sample stability, consistency, and homogeneity.
b) Simultaneous Testing Technique: In this method, participating laboratories simultaneously test the same sample at a predetermined time set by the organizer. The key factor in this type of comparison is the homogeneity of the sample.
c) Split Sample Technique: This method is often used by laboratory users. A single sample is tested simultaneously in two participating laboratories. It is advisable for the user to retain an additional sample for a "third" laboratory in case of significant differences in test results. This approach is known as „superanalysis“. Each of these techniques has its advantages and limitations, and the choice of method depends on the specific goals and requirements of the inter-laboratory comparison [6].

Laboratories should participate in programs relevant to their scope of testing, including reference proficiency testing (PT) schemes, national programs, and internal proficiency testing programs. Additionally, they must have a documented policy for participation in PT activities in their internal laboratory documents, procedures for analyzing PT results, and procedures for taking corrective actions.

2.1. Plan and Program for Participating in PT Activities

When selecting appropriate PT schemes, a laboratory should consider:

a) The compatibility of available PT activities.
b) The alignment of the PT sample with the test subject.
c) Whether the quantity of PT sample provided is sufficient to conduct the testing method within the measurement range corresponding to the parameter being tested.
d) Whether the PT provider has defined a statistical plan (planning, data collection, analysis, reporting of proficiency results).
e) Compliance with ISO/IEC 17043 [7].
f) The deadline for submitting results.

When determining the level and frequency of participation, other means of ensuring confidence in testing results should also be considered. This includes the possibility of using certified reference materials, comparing analysis results obtained using different techniques, and other internal/external comparisons (blind testing) in the laboratory.
Furthermore, attention should be paid to factors that can impact the level of risk (the number of tests conducted, staff experience and education, availability of reference materials, validation reports, and the significance and ultimate use of the results). Legal regulations that prescribe the frequency of participation in PT activities should also be taken into account.
Accredited testing laboratories should pay particular attention to the selection and participation in PT schemes, as this builds and demonstrates confidence in the testing results and allows them to monitor the trend in their results (improvement or deterioration of performance) [8, 9].

2.2. Evaluation of Testing Results in PT Program

The evaluation of testing results for individual analytes is performed by the organizer of the proficiency testing (PT) program. Based on this evaluation, an official document is issued, providing an assessment of the performance or proficiency of all participants in the program for determining specific analytes in a particular material. Typically, this assessment is done by comparing reported results with calculated z-scores.
For the evaluation of reported results from participating laboratories to be valid, the PT program organizer must ensure that the sample is homogeneous, that the assigned value for the analyte is determined using an appropriate method, and that the target standard deviation is established. The procedure for determining the assigned value is provided in ISO 13258:2015. When the material used in the PT scheme is a certified reference material (CRM), the certified reference value is used as the assigned value.
The target standard deviation (σ) is calculated as the product of the assigned value (X) and the inter-laboratory coefficient of variation (CV). The z-score indicates how much the reported result differs from the assigned value. The assigned value (X) and the standard deviation (σ) are critical elements in calculating the z-score and must be calculated using appropriate methods to ensure a realistic assessment of laboratory performance or proficiency.
The formula for calculating the z-score (z) is as follows:

$$z = \frac{x - X}{\sigma} \quad (1)$$

Based on the determined z-score, reported results are assessed as follows:
a) Satisfactory when $z \leq 2$,
b) Questionable when $2 < z < 3$, and
c) Unsatisfactory when $z \geq 3$.
This evaluation helps determine the accuracy and reliability of the results reported by participating laboratories in the proficiency testing program [10,11].

3. PARTICIPATION IN PT POLIHEM LABORATORIES

Laboratory Polihem participated in Proficiency Testing (PT) with the following objectives:

1. To identify potential deficiencies in laboratory practices.
2. To guide staff in implementing corrective measures necessary for improving these practices.
3. To assess the reliability of methods, materials, and equipment and propose appropriate corrective actions.

In addition, this external verification was essential for the laboratory's accreditation by the Accreditation Body of Serbia (ATS). Laboratories applying for accreditation are required to participate satisfactorily in relevant and available PT activities at least once before accreditation is granted. The recommended minimum participation for accredited laboratories is once for each major sub-discipline within the scope of accreditation for the accreditation validity period. If significant changes occur in the laboratory (equipment changes, key technical personnel changes, etc.), ATS may require reconfirmation of the laboratory's technical competence through participation in PT activities when deemed necessary.
The provided figure displays the z-score related to the testing of copper content in water. The organizer of this PT scheme is LGC, a provider accredited to ISO 17034 [7]. The PT scheme took place in January 2023, and participating laboratories are identified by identification numbers. Laboratory Polihem's Lab ID is CN1095. Based on the results shown in the figure, it can be concluded that Polihem achieved a satisfactory z-score, confirming their expertise in copper determination in water using the ICP-OES method.

Analyte: Copper

Lab ID	Method	Result (mg/L)	z score
CN0022	ICP-OES	7.80	-0.62
CN0117	ICP-OES	8.70	1.61
CN0726	ICP-MS	9.27	3.03
CN0822	ICP-MS	7.43	-1.54
CN0923	ICP-OES	7.11	-2.34
CN1039	ICP-OES	77.23	171.88
CN1042	ICP-MS	8.47	1.04
CN1095	ICP-OES	8.04	-0.02

Histogram

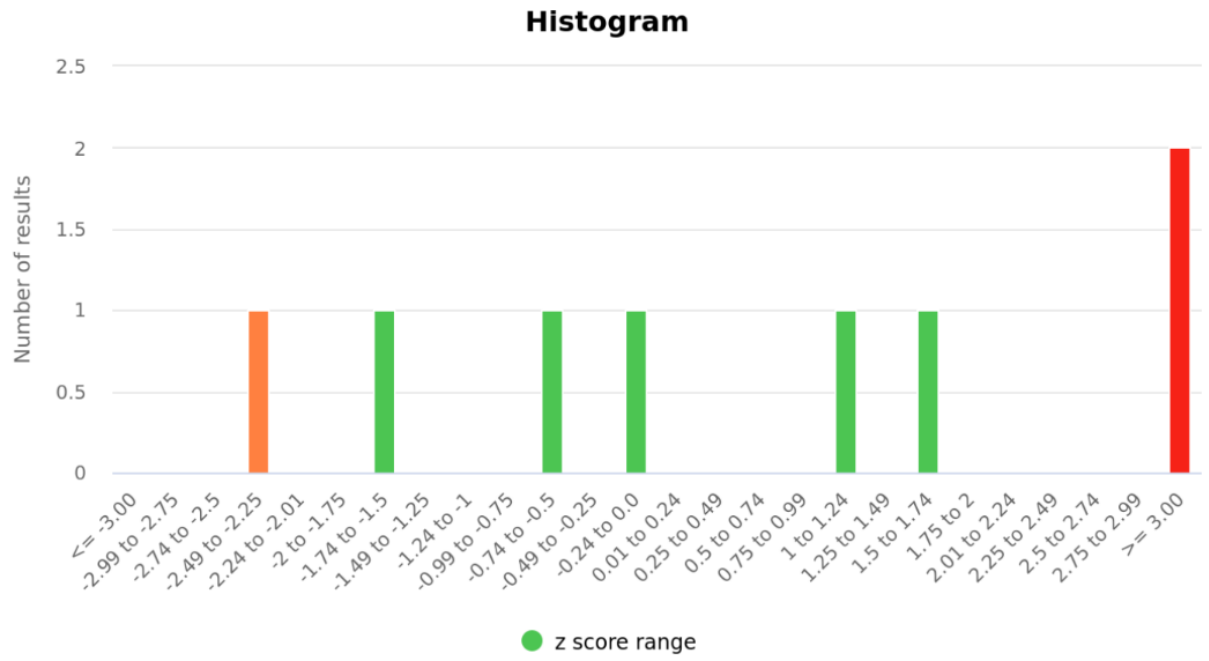

Figure 1. The Statistical report of the PT scheme
Source: https://portal.lgcstandards.com

4. CONCLUSION

Proficiency testing serves as a powerful and indispensable tool for maintaining and enhancing the quality of laboratory test results in the realm of environmental pollution analysis. This practice not only ensures the accuracy and reliability of data but also instills confidence in the outcomes of environmental assessments and regulatory compliance. Laboratories that actively engage in proficiency testing demonstrate their commitment to excellence, continuous improvement, and the highest standards of analytical competence. As environmental concerns continue to grow, the role of proficiency testing remains vital in providing the trustworthy data needed for informed decision-making, safeguarding public health, and protecting the environment. Based on the results from PT , i PT scheme it can be concluded that Polihem achieved a satisfactory z-score, confirming their expertise in copper determination in water using the ICP-OES method.

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MONITORING OF THE SURFACE WATER QUALITY IN COPPER MINING AND METALLURGY OPERATION AREAS IN BOR

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Abstract: *The influence of copper mining and metallurgy operations on the quality of surface water in Bor area watercourse has been taken into consideration in this paper. Monitoring of the water quality was performed on five rivers and one industrial wasterwater. The concentration of Cu, As, Ni, Cd, and Pb ions during four selected quarters in period November 2019 – June 2021 were determined on all samples. Water samples were analysed using atomic emission spectrometry with inductively coupled plasma or mass spectrometry with inductively coupled plasma depending on the ions concentration. The highest values of the concentration were recorded for the As ions in the metallurgical wastewater. Also, the concentration of Ni, Cd, Pb, and Cu ions had the highest values in samples from metallurgical wastewater.*
Keywords: mining, metallurgy, monitoring, surface water quality, heavy metal ions.

1. INTRODUCTION

The mining industry brings substantial economic growth and benefits to countries, generating revenues and creating jobs. Mining operations can have a huge local impact on the environment and population. They produce many types of air, water and soil pollutants that may ultimately affect human health. Furthermore, the disposal of an enormous volume of waste materials (from mining and metallurgy operations) poses a serious risk to the surrounding environment through air pollution with fine particles blown by the wind, land degradation by erosion and leaching of soluble inorganic potentially toxic chemical species (Cu, Ni, Pb, Zn, Cd, Cr, etc.) occurring in a variety of minerals present in those materials. Last but not the least, in the area of disposal of the mining waste, the acid mine drainage (AMD) is generated from sulphide-rich minerals.
Taking into account the complexity of the pollution produced by mining and metallurgy operations, adverse health effects of those leaving near, downstream or downwind of mines can be substantial. According to the EPA classification some of these pollutants are very harmful and belong to the group of substances that have been proven to be carcinogenic to humans [1].
The main goal of monitoring is to provide timely response and warning to possible negative processes and accident situations, gain a more complete insight into the state of the environment and determine

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the need to take protection measures depending on the degree of threat and type of pollution. Knowledge of water and soil quality from the point of view of the content of organic and inorganic pollutants is reflected in the possibility of risk assessment, location and remediation of polluted areas as well as urban planning in terms of identification and relocation of pollution sources.

Water monitoring involves testing the content of a number of inorganic elements and organic compounds by modern methods of instrumental chemical analysis. Some of the most hazardous elements that can be found in acid mine waters are arsenic, cadmium, lead, nickel, copper, etc.

Arsenic (As) and Cadmium (Cd) are widely distributed in the environment, come from natural and anthropogenic sources and have no biological role for human. Important anthropogenic sources of As and Cd include mining (usually wastewater), industry and waste management activities [2]. Arsenic induces the formation of reactive oxygen species and exposure deregulates several cellular processes at the molecular level [3]. Cadmium exposure is commonly associated with renal tubular dysfunction, osteomalacia, and osteoporosis as a result of calcium competition, endocrine disruption, glucose metabolism disorders, cerebral infarction, and heart failure [4,5]. Both elements can cause multiple cancers in humans [6]. Once inside the human body, cadmium and arsenic accumulate at high levels in several organs [7].

Lead (Pb) is the most toxic element present in the environment as a result of natural and anthropogenic sources. It is not necessary for human health, because it is not involved in biological processes. When absorbed, lead binds to erythrocytes and travels through the blood to various tissues (liver, kidneys, lungs, brain, spleen, muscles, heart) and further moves to bones and teeth, and affects every organ in the body by disrupting basic biochemical processes and has numerous effects on human health [8].

Nickel (Ni) is a metal broadly distributed in the environment. It is released from both natural sources and anthropogenic activity and is present in the air, water, soil and biological materials. Literature data illustrate that nickel at high doses and in certain forms is toxic to both humans and animals [9,10]. In case of consumption of water contaminated with nickel salts, the registered health effects were: gastrointestinal disturbances and altered hematological parameters.

Copper (Cu) has important roles in the metabolic processes of the human body being an essential element required for hemoglobin synthesis, absorption of iron, and cardiovascular integrity [11,12]. The toxicity of copper is relatively low compared with other heavy metals, but excess copper accumulation in subjects following high-dose chronic exposure and in sensitive populations results in hepatic cirrhosis with jaundice, hemolytic anemia, and degeneration of the basal ganglia, cardiotoxicity (hypotension, tachycardia, tachypnea) gastrointestinal disorders (ulcerations, mucosal acute hemolysis, and hemoglobinuria), nephropathy (azotemia, oliguria) and central-nervous-system manifestations (dizziness, convulsions, lethargy, headache, stupor, coma) [13]. In order to find measures and solutions for the reduction, rehabilitation and elimination of polluting substances, it is necessary to be aware of all consequences that more than a century of continuous mining and metallurgical activities have left in Bor area.

The main rivers in Bor mine area are Bor, Krivelj, Ravna, Bela River and Timok. There are also small river creeks and many AMD resulting from mining operations, along with industrial wastewater from metallurgical processes that flow in some of the mentioned rivers. As the consequence of mining and metallurgy activities, Bor and Krivelj rivers became very polluted mostly by heavy metals (Pb, Zn, Cd, Ni, Se, As, Fe). According to the Serbian legislation for surface water, contents for almost all of the analyzed elements in rivers from Bor city to the confluence of Bela River and Timok, are above the maximum allowed concentration (MAC).

This paper presents results of monitoring the water quality from rivers for five selected elements (Cu, As, Ni, Cd, and Pb) during four selected quarters in period from November 2019 to June 2021.

2. MATERIALS AND METHODS

Surface water samples (rivers water and industrial wastewater) were sampled by hand tools according to the standard sampling methods. Containers (cans of 1 l) for water sampling were rinsed three times in the river or water that was being sampled, prior to taking a sample, in order to prevent

contamination of the sample with previous water that was sampled. Water sample was then poured in the plastic bottle of 50 ml without prior washing because there was present 2.5 ml HNO_3 conc (63%). Exactly 50 ml of the sample was poured in syringe and after that the bottle was sealed and labelled. Before using the syringe, it was rinsed three times with water sample and contents were discharged. The samples were properly stored and transported in the laboratory in Mining and Metallurgy Institute Bor for chemical analysis.
Methods prescribed by relevant international and European standards were used to measure pollutant concentrations. The procedure described the analysis of the following heavy metals ions: As, Cd, Cu, Ni, and Pb.Water samples were analyzed using atomic emission spectrometry with inductively coupled plasma (ICP-AES) and mass spectrometry with inductively coupled plasma (ICP-MS).
Quality control of chemical analysis was performed in the laboratory by running certified reference material (CRM). Analysis of replicate test portions will provide an indication of the repeatability and precisions of measurement.

3. EXPERIMENTAL PART

The impact of copper mining and metallurgy activities on water quality is analyzed by monitoring of surface water close to active and abandoned mines and metallurgical plants. Monitoring includes area from the copper mine in Bor, all the way to the confluence of the Bela River and Timok River. This area was chosen because the mine location has a negative impact on the surface water system, Bor, Krivelj, and Bela Rivers that belong to the watershed of the Timok, which is tributary of the Danube. All mentioned rivers flow near to the largest mining and metallurgy complex in the Republic of Serbia where mining activities continuously exist for more than 115 years.
The influence of copper mining and metallurgy operations on the quality of regional surface water has been taken into consideration in this paper. Accordingly, sampling was done from local defined profile of the Bor River (W5), as well as from locations upstream and downstream of the Bor River (marked W4, W6, W7, W8, W11 and W12). Coordinates of the locations of surface water sampling are measured by GPS device (Global Positioning System) and presented in Table 1. Sampling was performed during four campaigns, in the period from November 2019 to June2021.

Table 1. Coordinates and marks of sampling locations

Water sample mark	Sampling location	GPS
W4	Industrial wastewater	N 04880342, E 07591076
W5	Bor River (local defined profile)	N 04877524, E 07594505
W6	Krivelj River	N 04876932, E 07597572
W7	Bela River (after confluence of Bor River and Krivelj River)	N 04876866, E 07597572
W8	Ravna River	N 04876953, E 07597650
W11	Timok before confluence with Bela River	N 04867539, E 07605955
W12	Timok River after confluence with Bela River	N 04884420, E 07625930

4. RESULTS AND DISCUSSION

The present paper is one of the broadest investigations of the multi-element content in wastewater generated from copper mining and metallurgy activities. It may thus represent a reference point for observed concentrations in future studies conducted in Eastern Serbia or other areas of mining waste discharge. The water samples originated from different rivers and industrial wastewater stream are extremely enriched with toxic elements such as arsenic and cadmium. The results show that the concentration of almost all heavy metal ions from collected water samples during the period November 2019 - June 2021 are above the MAC value according to Serbian legislation for surface water.

Table 2. Category of water and MAC values according to the Serbian legislation
Source: *[14,15,16]*

Heavy metal	Category of water and MAC values		
	II category (Danube River from the Hungarian border - to the Bulgarian border)	**III category (from the confluence Bela River and Timok River till to confluence of Timok and Danube River**	**IV category (from Bor city to the confluence Bela River and Timok River)**
Cu, mg/l	0,005 (T=10) to 0,112 (T=300)	0.5	1
As, µg/l	10	50	100
Ni, µg/l	34	34	34
Cd, µg/l	0.45	0.6	0.9
Pb, µg/l	14	14	14

T - water hardness (mg/l $CaCO_3$)

In the Figure 1 are presented the concentration of As, Ni, Cd, and Pb ions in water samples from: a) I quarter (November 2019), a) II quarter (June 2020), c) III quarter (November 2020) and d) IV quarter (June 2021), respectively.

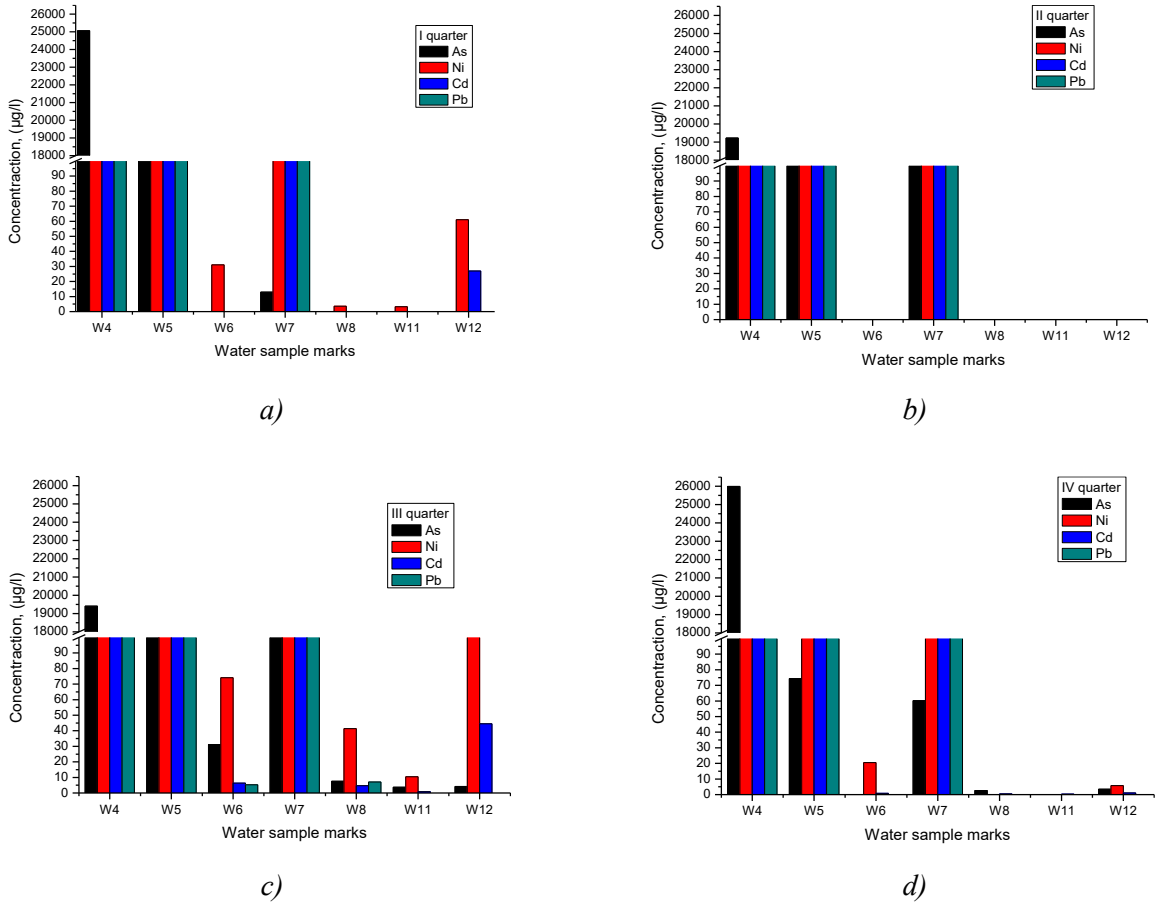

Figure 1. Concentration of As, Ni, Cd and Pb ions in the water samples

Ni, Pb and Cd ions concentration values are higher than MAC values, for samples from locations: W4, W5 and W7. Middle values for concentration of the target ions in Bor River (W5) before the influence of mining and metallurgy activities are as follows, µg/l: As: 5.4; Ni: < 7; Cd: 0.32; Pb:< 2.1; and Cu: 480. Comparing values for Bor River from the Figure 1 with ones before the influence of the mining and metallurgy operations, it is obvious that the concentration of all monitored metal ions became much higher after inflows of metallurgical wastewater. Arsenic ions concentration in the

industrial wastewater is extremely high (more than 19000 μg/l), in all tested samples. As the industrial wastewater inflows in the Bor River it is clear that increasing of As ions concentration is the consequence of its presence in W4 sample. Also, high concentration of Ni, Cd, and Pb ions are the consequence of their presence in W4 which inflows in the W5.
Bela River (W7) which arises by confluence of W5 and W6 is also with high concentration of target ions. Ravna River is out of the influence of mining and metallurgy activities, so the concentration of monitored metal ions are below MAC values.
Negative impact of mining and metallurgy activities on the water in Timok (W12) can be seen in I and III sampling periods. The same situation is registered for the concentration of the Cu ions (Table 3). Higher values than MAC are registered in the samples from the locations: W4, W5 and W7. The concentration of Cu ions in W4 has the direct impact on its concentrations in W5 and W7 samples.

Table 3. Cu ions concentration in the water samples

Water sample mark	Cu (mg/l)			
	I Quarter	II Quarter	III Quarter	IV Quarter
W4	291.40	209.16	171.63	155.27
W5	68.31	38.26	37.09	25.50
W6	<0.005	<0.005	0.58	0.14
W7	46.27	16.70	60.45	19.70
W8	0.04	<0.005	0.37	0.01
W11	<0.005	<0.005	0.10	0.02
W12	0.24	0.05	0.24	0.04

5. CONCLUSION

The recorded values for Ni, Pb and Cd ions concentration are higher than MAC values for the samples from locations: W4, W5 and W7 according to the surface watercourses category, excluding W4 which is wastewater originated from the copper metallurgical plants. Based on the results for target ions concentration in Bor River before the influence of mining and metallurgy activities (μg/l): As: 5.4; Ni: < 7; Cd: 0.32; Pb:< 2.1; and Cu: 480, it is clear that industrial wastewater has essential impact on the quality of the surface water.
Bor River (W5) and Krivelj River (W6) form Bela River (W7) which inflows in Timok River before the confluence with Bela River (W11) and after those confluence Timok River (W12) flows to Danube River. The contents of recorded metals exhibited a high degree of contamination, indicating that these surface water may pose a significant to extreme risk to nearby residents.

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ENVIRONMENT AND SUSTAINABLE DEVELOPMENT. MECHATRONICS. OCCUPATIONAL SAFETY AND HEALTH AND FIRE SAFETY. SMART MANAGEMENT SYSTEMS. GRAPHIC ENGINEERING. DESIGN. TRAFFIC ENGINEERING. BIOTECHNOLOGY AND HEALTHCARE. MECHANICAL ENGINEERING. ECOTOURISM AND RURAL DEVELOPMENT.

SUSTAINABLE SYNERGY: ALKALI-ACTIVATED COAL FLY ASH AND CDW IN SUSTAINABLE CONSTRUCTION

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Abstract: *Alkali activation, a process that transforms industrial by-products such as coal fly ash (CFA) and construction and demolition waste (CDW) into viable construction materials, is a promising solution towards sustainable practicies in the construstion industry. This study suggesst the synthesis of alkali activated materials (AAMs) from CFA and CDW as alumosilicate precusors while water glass and sodium hydroxide was used for preparation of the activation solution. The characterization of raw material was performed from chemical and physical aspects while alkali activated materials was studied by Fourier transform infrared (FTIR) spectroscopy, and Scanning electron microscopy (SEM). The compressive strength of the alkali activated materials vares from 12.14 to 34.5 MPa, depending on the CFA/CDW ratio and the solid/liquid content.*
Keywords*:* sustainable, coal fly ash

1. INTRODUCTION

The rapid urbanization and industrialization of contemporary society have intensified the demand for construction materials, resulting in a significant depletion of natural resources and a surge in construction and demolition waste (CDW). To mitigate these challenges and promote sustainable construction practices, researchers and practitioners have turned their attention toward the utilization of industrial by-products, such as coal fly ash, in alkali-activated composites. Alkali activation is an innovative technology that can transform coal fly ash, a by-product of coal combustion, and CDW into eco-friendly construction materials. There are already numerous reviews of AAMs in general [1-5] dealing with characterisation, durability processing and environmental impact of AAMs. Generally, AAMs have broad field of applications like as eco-friendly mortars and concrete [6, 7], in ceramics [8, 9], as well as in refractories [10].
The paper presents the investigation relating to the synthesis, properties, and potential applications of alkali-activated materials based on the utilization of coal fly ash and CDW composites in the way to support construction industry for sustainable circular solutions.

2. MATERIALS AND METHODS

The samples of CFA used in this study were collected from thermal power plant REK Bitola, located in the southwest of the country and CDW (only waste demolition brick – WDB) were collected at local construction/demolition sites in Skopje, N. Macedonia. The raw materials were crushed and then ground up in a planetary mill (Fritsch pulverisette 5) for 30 minutes and passed through a 125 μm sieve. Lasser granulometry (Laser Cilas 1090) was employed for determining the particle size

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distribution of the CFA and WDB (-0.125mm) and chemical composition was carried out by x-ray fluorescence spectroscopy (ARL 9900XP instrument). The picnometric method was used to define the specific gravity of both materials. The specific surface area of the powders was estimated by the Blaine method.
Alkali activated materials (AAMs) were synthetized using CFA and WDB as precursors, mixed in different ratio (10, 20 and 50 wt.% WDB) with an alkaline solution (Na_2SiO_3+NaOH). Curing time of the samples was 24 h at 60^{o}C than 2, 7 and 28 days at room temperature. The prepared AAMs were characterized using Fourier transform infrared (FTIR) spectrometer (Perkin Elmer Sigma 100) in the wavenumber range between 4000 and 700 cm^{-1} at a resolution of 4 cm^{-1} using the attenuated total reflection method (ATR). Scanning electron microscopy (SEM, instrument JEOL, JSM-IT200) was used to determine the microstructure of the samples. Compressive strength was detected on samples with dimension 50 x 50 x 50 mm after 7/28 days using the ToniNORM Toni-Technic testing machine (Zwick) at a loading rate of 0.04 kN/s. Three samples were used and the results was averaged.

3. RESULTS AND DISCUSION

The chemical composition of CFA and WDB is presented in Table 1.

Table 1. Chemical composition of CFA and WDB

Oxide [wt%]	**SiO_2**	**Al_2O_3**	**Fe_2O_3**	**CaO**	**K_2O**	**Na_2O**	**SO_3**	**MgO**	**LOI**	∑
CFA	58.79	13.60	9.28	3.59	2.51	3.83	0.18	1.72	5.79	99.11
WDB	61.12	17.58	8.45	7.82	0.29	0.33	/	3.01	0.86	99.64

The chemical composition shows the presence of typical oxides: SiO_2 and Al_2O_3 (lower presence of CaO, MgO, Na_2O, K_2O) accompanied by 9.28 wt.% Fe_2O_3. The higher CaO content (7.82 wt. %) in WDB is associated with the presence of cement in waste material, while higher content of LOI in CFA (5.79 wt.%) is associated with the presence of unburned coal particles in the investigated fly ash. Both selected materials are promising aluminosilicate precursors since it contains amounts of SiO_2 and Al_2O_3 that are necessary for the alkali activation reaction.
The specific gravity of CFA and WDB was 2.65 g/cm^3 and 2.70 g/cm^3, while the specific surface area of CFA and WDB was 3.09 m^2/g and 0.5597 m^2/g, respectively. The mean diameter (D_{50}) for CFA and WDB was 17.99 and 12.33 μm, respectively. The morphology of CFA and WDB is presented in Fig. 1.

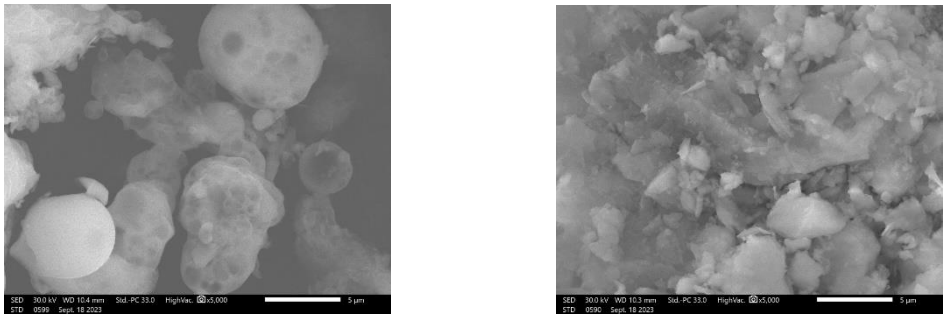


Figure 1. SEM micrographs of CFA and WDB, x5000 bar 5μm

As seen from Fig. 1 the CFA particles are mostly spherical corresponding to the typical morphology of CFA reported in the literature [11], while the WDB particles are sharp edges with irregular geometry. Fig. 2 presents the scheme for the synthesis of AAMs, while Fig. 3 present the moulded and final samples of AAMs.

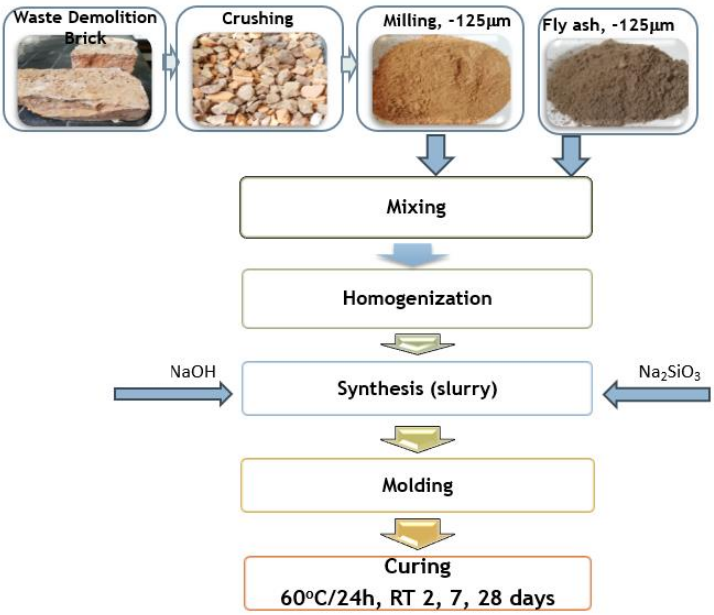


Figure 2. Scheme for AAMs synthesis

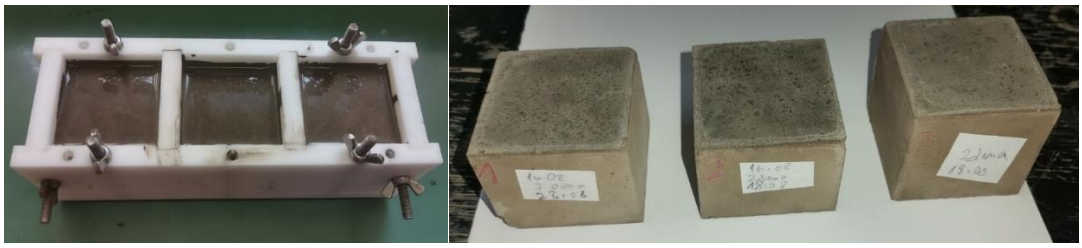


Figure 3. Moulds and final samples of AAMS

The FTIR spectrum (Fig.4) is mainly characterised by the presence of a broad band in the region 3700-3100 cm^{-1} (O-H stretching vibration) and the band at about 1650 cm^{-1} (H-O-H bending vibration) in the spectra of all AAMs are related to the water present in the samples. The silicate structure is characterized by the main peak located at 1000 cm^{-1} related to the stretching Si-O-T (T=Si, Al) vibration, while vibrations at 1400 cm^{-1} are characteristic of the $[CO_3]^{2-}$ ions, indicating carbonization [12].

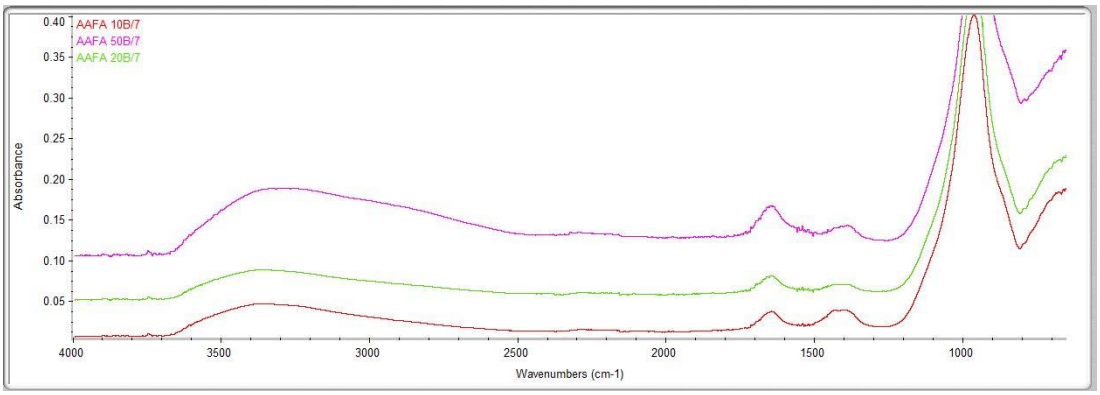


Figure 4. FTIR spectra of some AAMs

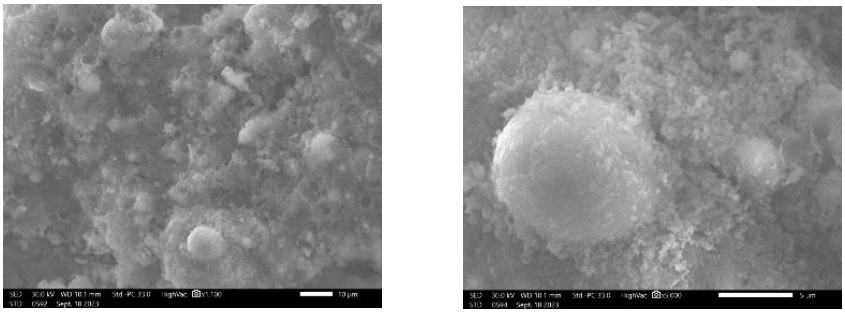
The compressive strength after 7 and 28 days of curing are shown in Table 2. Generally, the compressive strength for all samples was growing gradually throughout the curing period, as it was expected. AAMs containing 50 wt.% WDB (AAFA50B) shows the lower compressive strength i.e. 12.14 MPa and 16.5 MPa, respectively, after 7 and 28 days of curing. Generally, the higher CFA

content (lower content of WDB), the higher the compressive strength, most probably due to the amorphous nature of the CFA. The highest compressive strength was achieved by 10 wt.% WDB addition to CFA.

Table 2. Compressive strength of the AAMs

Sample	AAM (CFA)	AAM with 10wt.% WDB	AAM with 20wt.% WDB	AAM with 50wt.% WDB	AAM (CFA)	AAM with 10wt.% WDB	AAM with 20wt.% WDB	AAM with 50wt.% WDB
Cured time, days	7	7	7	7	28	28	28	28
σ [MPa]	18.2	22.3	18.34	12.14	23.7	34.5	21.4	16.5

Figure 5 shows the SEM micrographs of AAM with 10 wt.% WDB, cured for 28 days. The spherical particles of unreacted CFA covered with a gel and closed pores are clearly seen within the AAMs microstructure. The small number of spherical pores were likely formed as a result of the entrapment of air during mixing of the slurry.



(a) (b)

Figure 5. SEM images of the AAFA10B cured for 28 days a) x1000 bar 10μm, b) x5000 bar 5μm

4. CONCLUSION

The paper presents the preliminary results for designing alkali activated materials based on coal fly ash and construction and demolition waste (waste demolition brick). The best results, in the frame of the current investigation, in respect to compressive strength has the alkali activated material with 10 wt.% addition to fly ash. Further investigations in relation of mineralogical composition have been in progress to clarified the corelation compressive strength – mineralogical composition. This approach addresses waste disposal challenges in line to the principles of circular economy (lower environmental footprint) positioning alkali activated materials as a potential solution for a greener and more resilient construction industry.

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GLOBAL ESG PERSPECTIVES AND THE CHANGING WORLD OF 2023: A SUSTAINABILITY ODYSSEY

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Abstract: *The paper summarizes global environmental, social and governance (ESG) perspectives in 2023. ESG, presented with those three succinct letters, represent a profound global shift that has captivated our world. ESG related topics are reshaping business operations, performance measurement, and risk management, introducing both new challenges and opportunities. Key insights and perspectives of ESG are provided, exploring a growing recognition, various initiatives, factors and value creation using ESG in recent years. In spite of presented developments, a need to raise the flags and create an open marketplace of innovation and global sharing on solutions is present. The conclusion leads to the call on a joint journey towards sustainability, requiring stronger coordinated efforts at the global, national, and local levels from governments, businesses, and individuals.*
Keywords: ESG, global, environment, sustainability, governance.

1. INTRODUCTION: ESG - A 2023 Odyssey

In recent years, there has been a growing recognition of the significant economic and financial impacts of climate change and environmental, social and governance (ESG) risks. Forward-thinking companies' approach in ESG analyses, investments and reporting is not merely a box-checking exercise, but a meaningful way to create value for their organization. Beyond benefiting the planet and society, ESG and sustainability measures create value and correlate with financial performance [1]. This paper briefly summarises this global trend, offering a step into a realm beyond time, a journey through the territories of ESG. Therefore, this is not the typical ESG narrative, but an enriching odyssey filled with intelligent insights and facts. The conclusion leads to the call to embark on the journey towards sustainability together, because only together, with joint efforts of all parties, it can be achieved.

2. ESG - A BEACON OF CONTEMPORARY DISCOURSE

Gone are the days when ESG was a cryptic abbreviation. In 2023, it embodies the zenith of modern wisdom. ESG has risen as a prominent protagonist in the global sustainability narrative. Sustainability, once a peripheral concern, has assumed a centre stage. Multinational corporations have taken solemn vows to achieve net-zero emissions. Governments have woven environmental consciousness into the fabric of their policies, and even modest businesses champion ethical practices. ESG has become an integral part of our collective consciousness.
ESG has emerged as a beacon of contemporary discourse mostly due to its ability to address and provide a framework for some of the most significant challenges and expectations facing the modern world. It is influencing corporate behaviour, investment decisions, and public policy discussions, making it a central topic in today's economic, environmental, and social dialogues.

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Still, the most recent KPMG study published in October 2023 found that 75% of companies are still in the early stages of ESG assurance preparedness, across a range of key factors including governance, skills, data management, digital technology and value chain, with even the top 25% of identified “leaders” having significant work ahead to become ESG assurance ready [2]. The study indicated that 56% of companies are publicly reporting ESG data, and while 93% of these are providing some level of external assurance, only 14% are obtaining reasonable assurance, and 16% limited assurance. Among other, capacity building and collaboration with external stakeholders may provide the necessary support and guidance for companies lagging in readiness. Fostering initiatives aimed at SMEs and firms in regions and sectors where readiness is low can offer significant help in bridging the compliance gap across the business landscape [2].

3. CARBON NEUTRALITY - A RESOUNDING CALL

Carbon neutrality, also known as climate neutrality or net-zero emissions, refers to the state in which an entity, such as a country, company, or individual, balances the amount of greenhouse gases (GHGs) it emits into the atmosphere with an equivalent amount removed or offset. Achieving carbon neutrality is a critical goal in the fight against climate change, as it helps limit global warming to well below 2^0 Celsius above pre-industrial levels, as outlined in the Paris Agreement. It is a complex and challenging goal, but it is increasingly recognized as essential for addressing climate change and ensuring a sustainable future for the planet. It requires coordinated efforts at the global, national, and local levels from governments, businesses, and individuals.

In 2023, carbon neutrality is a growing concept and an epoch-defining call. Many countries and regions have set ambitious targets to achieve carbon neutrality. Some notable examples include: European Union, aiming to become carbon-neutral by 2050, with many member states adopting similar targets; United States, UK and Japan has also set a goal to reach carbon neutrality by 2050, while China, the world's largest emitter of greenhouse gases, has pledged to achieve carbon neutrality by 2060.

Corporations and businesses are committing to carbon neutrality as part of their environmental and sustainability efforts. They are setting targets to reduce their emissions and are investing in renewable energy, energy efficiency, and carbon offset projects to achieve their goals. Numerous corporations engage in a spirited race, vying to reduce their carbon footprints with a zeal matching the rapid proliferation of renewable energy. The spotlight shines on Tesla, a pioneering electric vehicle manufacturer, while global food giants like McDonald's embark on ambitious initiatives to curb greenhouse gas emissions. Carbon neutrality, once an elusive goal, is now an attainable and commendable pursuit [3].

4. THE RENAISSANCE OF ECO-WARRIORS

In a world electrified by environmental consciousness, a legion of eco-warriors takes centre stage. It is important to note that addressing climate change and other burning issues in environment today requires a collective effort, and eco-warriors play a crucial role in driving action, influencing policies, and inspiring others to make positive changes in their own lives and communities. Their dedication is instrumental in the fight against the global climate crisis. For example, Greta Thunberg symbolizes the face of a global uprising, with young activists leading the charge, receiving Nobel prize nominations consequently from 2019 to 2023 [4].

These eco-champions hold governments and conglomerates accountable for their ecological transgressions. These sustainability torchbearers are not just representatives of the future; they are present-day eco-chivalric heroes. They may be involved in a variety of activities and initiatives, including: 1) advocacy and lobbying for climate-friendly policies, participating in protests, 2) education, research and outreach, 3) promotion of sustainable living, use of renewable energy sources, sustainable agriculture etc., 4) conservation efforts, such as reforestation projects, wildlife protection, and habitat restoration, 5) involvement in environmental organizations, such as

Greenpeace, the Sierra Club, the World Wildlife Fund or local civil society organizations, 6) social media and online activism, as social media platforms are powerful tools to raise awareness, connect with like-minded individuals, and advocate for change.

5. THE INCLUSION REVOLUTION - AN ODE TO EQUITY

There is a growing recognition that ESG, diversity, equity and inclusion are interconnected. Companies that prioritize ESG often incorporate diversity and inclusion initiatives within their strategies. This is because promoting diversity, inclusion, and equity is a social responsibility aspect of ESG, and it can contribute to a more sustainable and socially responsible business model. It also aligns with broader societal goals of reducing inequality and promoting social justice. Therefore, businesses often strive to create inclusive workplaces, and government policies and initiatives also aim to address systemic inequalities in society.

Amid the limelight on environmental sustainability, the resonance of the Inclusion Revolution resonates with the cadence of justice. In 2023, women rise to prominence in corporate leadership, leaving an indelible mark as entrepreneurs and visionaries. Diversity and inclusion, once ethereal ideals, are now critical pillars of progress. Gender pay gaps are narrowing, workplaces are becoming bastions of inclusivity, and ESG has evolved into a revolutionary force for justice and equality.

6. ETHICAL GOVERNANCE - A DEFINITIVE PARADIGM

ESG and ethical governance go hand in hand, with ESG principles encompassing environmental, social, and governance responsibilities, and ethical governance serving as the framework for ensuring that these responsibilities are met in an ethical, transparent, and accountable manner. Both concepts are essential for fostering sustainability, trust, and ethical behaviour in the business world. The custodians of ethical governance have taken the stage, ensuring the adherence to corporate rectitude. Unscrupulous practices no longer evade scrutiny. Whistleblowers are celebrated emissaries of transparency, wielding the power of revelation. ESG metrics have established a framework of corporate accountability, anchoring corporate behaviour to principles of responsibility. Corporate boards are evolving to embrace diverse voices, and ethical governance is not just an option but an essential mandate [5].

7. SUSTAINABILITY FOR ALL

Sustainability is no longer the province of stereotypical 'hippies.' In 2023, it is an inclusive doctrine. Sustainable practices have transcended niche realms and are embraced by a diverse range of participants. Even unexpected candidates have become fervent proponents. Fast-food giants are championing eco-centric initiatives, while tech behemoths are taking monumental strides in recycling and waste reduction. Sustainability has morphed from a niche concern into a universal movement. Notably, the electric vehicle market anticipates a 35% growth in 2023 [6], with projections showing its expansion to $1,716.83 billion by 2032 [7].

8. THE GUARDIANS OF ETHICAL INVESTMENT

In the last quarter of 2023, CFA Institute responsible investing organization Principles for Responsible Investment (PRI) and the Global Sustainable Investment Alliance (GSIA) announced the release of Definitions for Responsible Investment Approaches, a new guideline aimed at harmonizing sustainable investment terminology for more effective investment industry communication and to reduce greenwashing risk. The guidance was developed in response to a set of sustainability-related investment and finance recommendations published in 2021 by the International Organization of Securities Commissions (IOSCO), the leading international policy

forum and standards setter for securities regulators, which included developing common terminology for sustainable finance terms and ESG approaches [8].
The guardians of ethical investment are no longer mere 'watchdogs,' but formidable sentinels of moral virtue in the financial realm. Rating agencies and data analysts have become potent forces, guiding investors along the path of ethical investment. ESG scores embody the ethical compass of investing, steering capital toward virtuous ventures. The finance sector has been transformed by the ascent of ESG, no longer a domain of rampant greed, but rather an ethical crucible where data replaces the sword. We are seeing more whistle blowers and warriors fighting to bring equality into investing, governance and aligned areas.

9. CONCLUSION

Internationally, industry participants, investors, regulators, and policy makers have stepped up their efforts to address sustainability-related risks, opportunities, and impacts and to help improve ESG-related disclosures. As we bid farewell to this expedition through the ever-evolving ESG landscape in 2023, one truth remains undeniable: the world is changing, and sustainability is no longer optional. ESG has transcended its status as an acronym, evolving into a global movement. It's no longer the domain of activists and environmentalists; it has become a mainstream narrative.
The world has awakened to the imperatives of responsible business, ethical governance, and environmental stewardship. Institutions, like the Global Reporting Initiative (GRI), which have been the torchbearers on Sustainability Practices are coming up with more relatable, globally acceptable, and refined Sustainability Standards and Practices to follow [9]. It’s a code of conduct all nations must adhere to in order to achieve the mammoth goal in front of us as we approach 2030. To gain broader stakeholder confidence and mitigate the risk of greenwashing, ESG reporting should be subject to a level of scrutiny comparable to the financial information that users depend on [2]. In this cerebral yet entertaining odyssey through the world of sustainability in 2023, we have witnessed governments, corporations, and individuals uniting to address the challenges of our time. We have celebrated the rise of eco-warriors, the champions of justice, the embrace of ethical governance, and the elevation of sustainability as an integral aspect of daily life. Achieving the UN's 2030 Sustainable Development Goals (SDGs) is like setting sail on a global adventure where every nation has a treasure map to a brighter tomorrow. To begin this quest, we need a crew of nations, corporations, and individuals who are as united as a well-oiled pirate crew chasing after the same target on the map. Instead of plundering gold, our treasure is a world free of poverty, inequality, and the impending doom of climate change. At the moment, we are in an era where ideas can cross borders faster than one can imagine. Therefore, a need to raise the flags and create an open marketplace of innovation and global sharing on solutions is present, which will benefit the world. For example, if we would imagine trading ideas like Pokémon cards, however these cards hold the solutions to real-world problems, such as clean energy innovations, healthcare breakthroughs or similar. With a sprinkle of creativity, a hearty dose of determination, and a touch of humour, there is an opportunity to turn our world into a sustainable paradise where everyone gets a VIP pass to the greatest show on Earth. A powerful message emerges, as we must leave it a better place than we came at. It is not just about saving the planet. Finally, it needs to be taken into account that the future is promising, with the potential to be more inclusive, green, and equitable. In order to reach it, embracing sustainability is not merely a perspective; it's a way of life. Together, we have the power to mould a world marked by sustainability, inclusivity, and transformation.

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ENVIRONMENT AND SUSTAINABLE DEVELOPMENT. MECHATRONICS. OCCUPATIONAL SAFETY AND HEALTH AND FIRE SAFETY. SMART MANAGEMENT SYSTEMS. GRAPHIC ENGINEERING. DESIGN. TRAFFIC ENGINEERING. BIOTECHNOLOGY AND HEALTHCARE. MECHANICAL ENGINEERING. ECOTOURISM AND RURAL DEVELOPMENT.

DETERMINATION OF POLYCHLORINATED BIPHENYLS IN WASTE OIL

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Abstract: *Polychlorinated Biphenyls (PCBs) are synthetic chemicals with a biphenyl structure and varying degrees of chlorination. In this final paper, the determination of selected polychlorinated biphenyls (PCB 138 and 153) in waste oil was conducted using gas chromatography with an electron capture detector. The determination of PCBs in waste oil was carried out using the internal calibration method. The methodology of this research utilizes extraction with dimethyl sulfoxide (DMSO) and hexane isolation to identify the presence of PCBs in oil samples. The results of this work emphasize the importance of detecting PCBs in waste oils and indicate the need for strict regulations and advanced analytical methods to protect the environment and ensure human safety.*
Keywords: PCB, waste oil, chromatogram

1. INTRODUCTION

Waste oils encompass mineral or synthetic oils that are no longer usable for their original intended purposes, such as hydraulic, motor, turbine oils, marine oils, insulation oils, heat transfer oils, and others. Waste oils contain various harmful components that can pollute the air, soil, and waterways, directly impacting the health of humans and animals. When considering the management of this type of waste, it is important to emphasize that it may contain PCBs as unwanted pollutants. The presence of polychlorinated biphenyls in waste oils may result from the previous use of electrical transformers and other equipment where PCBs were used as insulating fluids. The management of waste oils is regulated by the rules and procedures outlined in waste oil management regulations. [1].
Polychlorinated Biphenyls (PCBs) are synthetic organochlorine compounds that are exclusively produced as a result of human activity. PCBs feature a modified biphenyl structure where hydrogen atoms are replaced by chlorine atoms. These modifications involve different degrees of chlorination, resulting in the creation of various PCB compounds (congeners). While theoretically there could be 209 different congeners, around 130 have been identified in practice.
PCB compounds are lipophilic and very poorly soluble in water. As such, they readily bind to organic particles in aquatic and biological systems, soil, and sediments. With an increase in the number of chlorine atoms in biphenyl, solubility in fats increases, as does stability. They are stable at high temperatures and resistant to degradation by light and chemical agents such as bases, acids, and oxidants. PCB compounds are difficult to break down due to strong covalent bonds between carbon-carbon and chlorine atoms. These bonds require high energy to be broken, contributing to the

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molecules' stability. Because of their persistence, PCBs are classified as Persistent Organic Pollutants (POPs). They can persist in the environment for extended periods because they degrade very slowly in nature. The half-life is not the same for all compounds and can range from several decades to over a hundred years. They have the potential to accumulate in ecosystems and pose risks to both animals and humans. PCBs can accumulate through the food chain in organisms, further extending their impact on ecosystem [2,3].
Since 1979, their use has been banned due to their toxicity, carcinogenicity, mutagenicity, and other hazardous properties. To determine the presence and accurate concentrations of PCBs in waste oil, direct testing is required, which is the fastest and most efficient way to prevent contamination and maintain the integrity of equipment, as well as process safety. If the presence of a significant amount of PCBs is identified, it may require special measures and procedures for the safe disposal and removal of these oils to prevent their further spread in the environment. One solution applied is the installation of secure and impermeable barriers to prevent their penetration into the surroundings.
Through extensive and complex analyses resulting from intensive scientific and technological progress, it has been determined that PCB compounds can be degraded and eliminated from the environment. The effectiveness of these procedures depends on the chemical composition and the location where their presence is detected. Microorganisms, bacteria, fungi, and algae have the capability for biodegradation when the presence of PCB samples is identified in soil or sediments [4].
In this study, the determination of selected polychlorinated biphenyls (PCBs 138 and 153) in waste oil was carried out using gas chromatography with an electron capture detector (GC-ECD) on the instrument - GC 2010Pro SHIMATZU, with a SHIMATZU RHi-5ms column, 30 m x 0.32 mm i.d., film 0.25 μm. The analysis was performed in waste oil and soldered waste oil using the internal calibration method.

2. EXPERIMENTAL PART

The waste oil sample is extracted using an appropriate solvent. The extract is concentrated by evaporation, and the analysis is performed using gas chromatography. Different compounds are separated using a capillary column with a low-polarity stationary phase. Detection is carried out using an electron capture detector. PCBs are identified and quantified by comparing the relative retention times and relative peak heights (or peak areas) to added internal standards.

2.1. Characteristics of waste oil for the study

For the experiment, waste oil labeled as SAE 5w-30 was used as the sample. According to sampling regulations, the oil has its inventory number, name, designation, sampling time, and the signature of the responsible person. This type of oil is commonly used in light gasoline and diesel engines. The "w" in the name signifies winter, and the numbers 5 and 30 refer to the oil's viscosity, indicating its thickness at low and high temperatures. It can be used within an external temperature range of -35°C to +30°C, making it ideal for engines and applications with relatively low temperature variations.

2.2. Identification PCB in oil

A copper wire with a thickness between 2 and 3 mm is heated using a flame. After a brief cooling period and immersion in the oil sample for a few seconds, the fat remains on the surface of the wire. Then, the wire is heated once again. The appearance of a faint green color in the flame after a certain time indicates the presence of copper ions, which is evidence that chlorine is present in the oil, and the sample can be treated as PCB oil [5].

2.3. Extraction of PCB from Oil

The three different oil sample (1 mL) were dissolved in 10 mL of DMSO in an Erlenmeyer flask and extracted by shaking or sonication for 10 minutes. This process was repeated three times. All the DMSO extracts were combined. The resulting solution was transferred to a separation funnel, and 60 mL of n-hexane and 30 mL of deionized water were added to deactivate the DMSO. With vigorous shaking for 10 minutes, the PCBs transition into the nonpolar phase, i.e., the n-hexane layer. The layers were separated, and the lower DMSO-water mixture was returned to the separation funnel, while the hexane fraction was retained.

The DMSO-water mixture were further extracted in the separation funnel with an additional 30 mL of n-hexane, and then the layers were separated. The hexane fractions were combined, and the extract was further concentrated. Purification of the extract can be carried out using silica gel columns with a volume of 3 mL, commercially available Florisil columns, or by partitioning between DMSO and n-hexane.

2.4. Chromatographic conditions for GC-ECD

The chromatographic conditions for GC-ECD optimized for gas chromatography [6]:

a) Separation column: capillary column;
b) Oven temperature program: 60°C for 2 minutes, ramp at 30°C/min to 120°C, ramp at 5°C/min to 300°C, hold at 300°C for 15 minutes;
c) Injector temperature: 260°C;
d) Undivided injection of 1 μL;
e) Carrier gas: nitrogen at a flow rate of 0.8 ml/min to 1 mL/min.

2.5. Preparation of standard solutions PCB

Calibration solutions of PCB with concentrations of 0.005, 0.01, 0.05, 0.075 and 0.1 μg/mL for waste oil are prepared by serial dilution of the basic standard with the addition of internal standards at a concentration of 0.1 μg/mL. The relative response factors for the original PCB and internal standards are calculated from the obtained calibration curve by plotting the graph of the mass concentrations versus the peak area ratio (or peak height ratio).

2.6. Quantitative and qualitative analysis

Gas chromatography with electron capture detection (GC-ECD) chromatograms of the extracts are recorded. Based on relative retention times, peaks corresponding to PCB congeners and their corresponding internal standards are identified. The presence of each determined compound is verified by repeating the gas chromatographic analysis using a column with a moderate polar phase in combination with ECD.

The quantification of PCBs in the waste oil is determined using the formula:

$$\omega_n = \frac{\left(\frac{A_d}{A_n} - b\right) \times q_d \times 100}{s}$$

ωn – The content of the PCB congener found in the sample, in mg/kg dry mass.
A_d - The measured response of the corresponding internal standard in the sample extract.
A_n - The measured response of the PCB congener in the sample extract.
s - The slope of the calibration function or relative response factor.

b - The intercept of the calibration curve with the ordinate.
q_d - The mass of the internal standard added to the sample, in µg.

This formula allows you to quantify the concentration of PCB congeners in the waste oil sample based on the measured responses and the known properties of the internal standards used.

3. RESULTS AND DISCUSSION

By heating a copper wire immersed in waste oil using a burner, the emission of a greenish flame was not detected, indicating that either the concentrations are low or PCBs are not present (Figure 1).

Figure 1. Heating waste oil on copper

After recording calibration solutions and performing regression analysis, it was concluded that the mentioned calibration curves have a satisfactory degree of regression. Calibration curves have correlation coefficients (R) of 0.995 and 0.996, satisfying the linearity condition. Based on the linear equation, concentrations of each tested PCB (PCB 153 and PCB 138) were calculated, and the values are presented in Table 1. Chromatographic spectra of the recorded waste oil are shown in Figure 2.

Table 1. Concentrations of PCB in the samples

PCB	Concentrations of PCB in sample 1 (µg/kg)	Concentrations of PCB in sample 2 (µg/kg)	Concentrations of PCB in sample 3 (µg/kg)
153	0,008	0,049	0,060
138	0,003	0,042	0,055

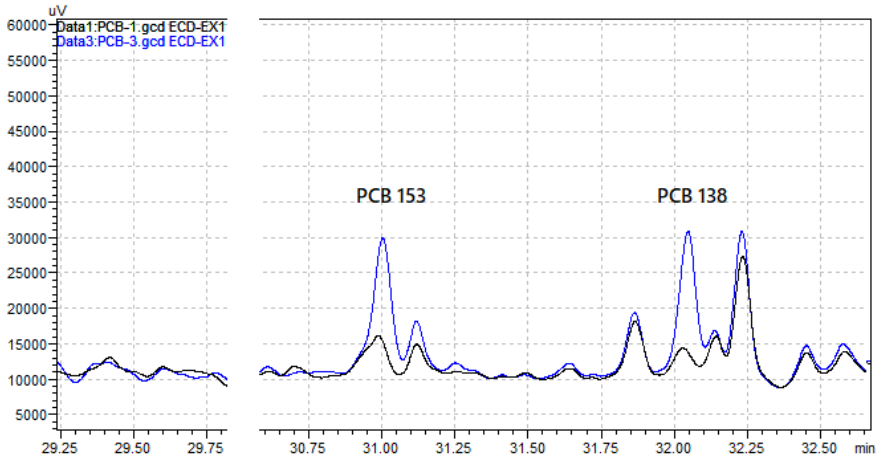

Figure 2. Graphical representation of results, samples 1 and 3

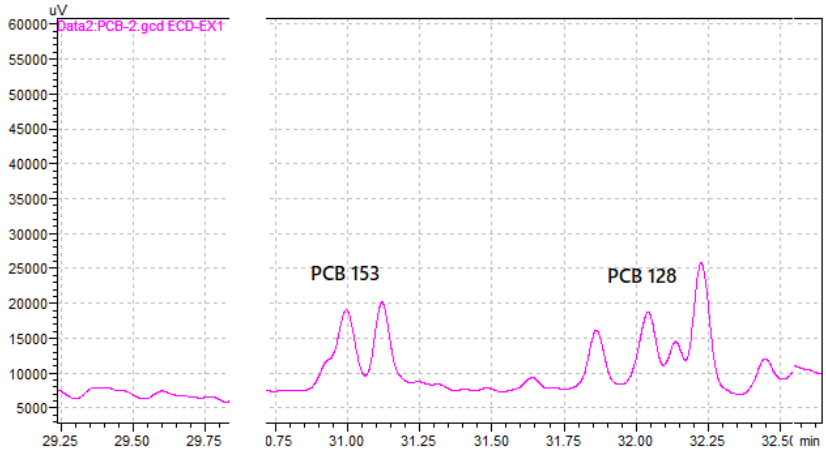

Figure 3. Graphical representation of results, sample 2

Considering that the concentrations in the waste oil sample are very low, we can conclude that the minimal amount of PCB 138 and 153 has been detected. The values are below the limit of quantification, and their precise quantification cannot be performed (Table 1). International laws, as well as the laws of the Republic of Serbia, prescribe different treatments for waste oils depending on the concentration of PCB. Based on the principles of waste oil management depending on the concentration of PCB presence [7], it can be concluded that this oil can be recycled and disposed of in landfills because its concentration is less than 2 ppm.

4. CONCLUSION

This research successfully identified and detected concentrations of PCB 138 and PCB 153 in the waste oil sample. The results show that the concentrations are below the limits prescribed by the European Union, indicating minimal amounts of these compounds in the examined sample.
These findings have significant implications for environmental protection and the use of waste oil. Considering the very low concentrations, it can be concluded that this oil is safe for recycling and disposal in landfills. This research opens doors for further studies in the processing and management of waste oil to enhance environmental protection.

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ENVIRONMENT AND SUSTAINABLE DEVELOPMENT. MECHATRONICS. OCCUPATIONAL SAFETY AND HEALTH AND FIRE SAFETY. SMART MANAGEMENT SYSTEMS. GRAPHIC ENGINEERING. DESIGN. TRAFFIC ENGINEERING. BIOTECHNOLOGY AND HEALTHCARE. MECHANICAL ENGINEERING. ECOTOURISM AND RURAL DEVELOPMENT.

DETERMINATION OF PAHS IN MEDICAL WASTE

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Abstract: *Environmental pollution with phenolic compounds, petroleum derivatives, petroleum hydrocarbons, including polycyclic aromatic hydrocarbons (PAHs), as well as crude oil itself, represents a hazardous risk, both for the ecosystem as a whole and for human health. The increasing prevalence of these toxic compounds, their relatively low biodegradability, and their everyday use in large quantities lead to the pollution of water, soil, and air. PAHs have the ability to intensely absorb into the organic fraction of soil and the ability to evaporate, enabling them to easily spread through the ecosystem. In this paper, the concentration of PAHs, which the European Union defines as important indicators of environmental pollution: acenaphthylene, anthracene, acenaphthene, benzo[a]anthracene, benzo[a]pyrene, benzo[b]fluoranthene, benzo[ghi]perylene, benzo[k]fluoranthene, chrysene, dibenzo[a,h]anthracene, fluoranthene, fluorene, indeno[1,2,3-cd]pyrene, naphthalene, phenanthrene, and pyrene were examined in contaminated hospital waste gloves using the GC/MS method.*
Keywords: medical waste, PAHs, GC/MS method

1. INTRODUCTION

Polycyclic aromatic hydrocarbons (PAHs) represent one of the most widespread groups of organic pollutants in the environment. Chemically, these are organic compounds that contain two or more condensed aromatic rings in their structure. They consist mainly of carbon and hydrogen, but this group of compounds also includes derivatives of PAHs in which carbon atoms are replaced by nitrogen, sulphur, or oxygen atoms, making them heterocyclic aromatic compounds. There are over 100 different PAHs, with varying numbers of condensed rings. The most common in the environment are PAHs containing two to seven benzene rings [1].
In addition to the different number of condensed rings, PAHs also differ in the arrangement of rings and the presence and arrangement of side chains. For example, PAHs with the same number of condensed rings can vary significantly in their properties depending on whether these rings are arranged linearly, angularly, or in a clustered form [1,2, 3].
The toxicity of PAHs is closely related to their structure. Different structures exhibit varying levels of carcinogenic activity, which increases with the introduction of functional groups into the PAH molecules. As the molar mass of PAHs increases, their carcinogenicity also increases, while acute toxicity decreases. When present in the human body, they enter the blood and lymph and undergo

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metabolism in the liver and kidneys, with the absorption of PAHs in the body being dependent on their lipophilicity. The most significant confirmed toxic effects of PAHs are related to carcinogenicity and immunotoxicity [4,5]. Medical waste is defined as all waste, hazardous or non-hazardous, generated during the provision of healthcare services. It is a heterogeneous mixture of waste, with 10-25% of it being hazardous waste that poses a risk to human health and the environment. Waste originating from healthcare facilities is only a part of medical waste, which can be further categorized into several different categories. Gloves represent pharmaceutical waste that arises in the production and distribution of medicines and medical supplies [6,7].

In this paper, the characteristic of hazardous waste with the code H15 was examined. According to the Regulations on Waste Categories, Testing, and Classification, the characteristic of waste H15 is defined as follows: "Waste that has the property to, in any way, after disposal, produce another substance, e.g., leachate, which has one of the specified characteristics (H1-H14)." The characteristic H15 specifies that the concentration of polycyclic aromatic hydrocarbons (PAHs) should not exceed a value of 100 mg/kg dry mass (dm) in hazardous waste. These specific limits for the concentration of PAHs are in place to ensure the safe handling, storage, and disposal of this hazardous waste, considering the potential toxicity of PAHs. Such limitations are important for environmental preservation and the protection of human health in the management of hazardous waste [8].

For the examination, contaminated gloves were used, taken from the medical institution 'Sveti Luka' in Smederevo, and for the extraction of PAHs from the sample, a hexane-acetone solvent system was applied. The determination of the concentration of PAHs from the sample was carried out using the GC/MS method at the Polihem Laboratory.

2. EXPERIMENTAL PART

PAHs were extracted from the samples using an acetone-hexane solvent system. The obtained extract was further purified through column adsorption chromatography. The extract was analysed using gas chromatography with mass spectrometric detection (GC-MS) utilizing a low-polarity capillary column. The concentrations of PAHs were quantified using the external standard method.

2.1 Materials

The following chemicals were used for the extraction: acetone, *n*-hexane, anhydrous sodium chloride, and anhydrous sodium sulphate. For purification, silica gel 60 (particle size ranging from 63 μm to 200 μm) and quartz wool or silanized glass wool were employed. Commercially available purification columns can also be used for the purpose of purification.

2.2 Methods

The procedure for the analysis of PAHs consists of:

a) sampling and homogenizing the sample to enhance extraction
b) extraction is performed to effectively separate PAHs from the sample matrix and convert them into a suitable medium for analysis
c) instrumental analysis by GC 2010Pro by SHIMATZU

2.4. Calibration Curve

The calibration curve for individual PAHs is constructed by plotting the peak area of the ion chromatogram's most intense ion for the analysed compound against the relative response ratio for the original PAH, considering the concentration of the individual PAH. The linear range of the detector is established based on the calibration curve.

2.5. Data Processing

For the processing of the obtained analysis results, the GCMS Postrun program was used. The analysis and processing of the obtained results involve the following steps:

a) Setting up a new batch of samples and standards.

b) Establishing a new quantification method based on the selection of standards with the highest concentration.
c) Selecting the desired components.
d) Automated quantification and result storage.

These steps outline the process for handling the data generated by the GC-MS analysis. The software appears to facilitate the organization of sample and standard data, selection of quantification methods, and automated quantification of the components of interest, with results being saved for further analysis or reporting.

3. RESULTS AND DISCUSSION

Based on the chromatograms obtained by recording the medical waste samples (Figure 1), prepared in an appropriate manner, qualitative analysis can be performed.

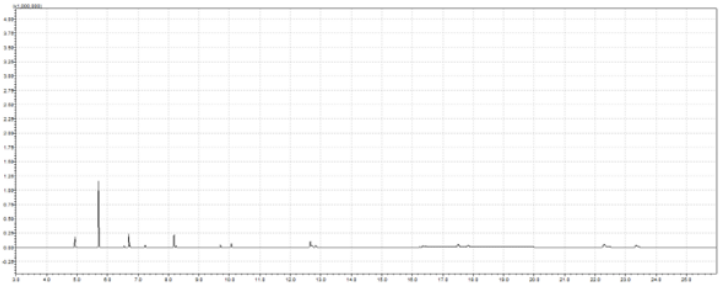

Figure 1. Chromatogram obtained by recording sample 1 in SIM mode

Quantitative analysis of PAHs in the samples was performed based on calibration curves obtained through the analysis of a series of standard solutions. Calibration curves for naphthalene, as well as the R values are shown in Figure 2.

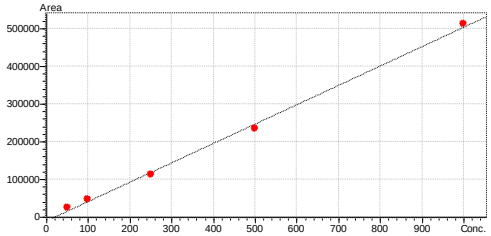

Figure 2. Naphthalene calibration curve, R = 0.9988638

Based on the equations of the line, the concentrations of each of the tested PAHs, as well as the total amount of all PAHs, were calculated in individual samples. The obtained values are shown in Table1.

Table 1. Obtained concentrations of PAHs in the sample

PAH	The obtained value mg/kg	The permissible maximum value for H15 mg/kg
Naphthalene	0,5	
Acenaphthylene	0,2	
Acenaphthene	0,5	
Fluorene	0,05	
Phenanthrene	0,03	
Anthracene	<0,01	
Fluoranthene	0,5	
Pyrene	0,5	
Total	2,3	100*

*- The reference value for the hazardous H15 characteristic

As can be observed from Table 1 and from Figure 2, the values of PAHs in the sample range from <0.01 mg/kg, such as anthracene, to 0.5 mg/kg for naphthalene, acenaphthene, and pyrene. The total amount of all PAHs in this sample is <2.3 mg/kg, which is within the permissible concentrations for PAHs specified under the hazardous characteristic H15, with the highest allowable limit of 100 mg/kg of dry matter.

4. CONCLUSION

This paper presents the determination of the concentrations of individual PAHs in medical waste samples, and quantitative analysis of prepared samples was performed using the GC/MS method. The PAHs were extracted using a hexane-acetone solvent system, and this method has proven to be one of the best for sample preparation.

For the purposes of this study, the concentration of PAHs that the EU prescribes as important indicators of environmental pollution was examined: acenaphthylene, anthracene, acenaphthene, fluoranthene, fluorene, naphthalene, phenanthrene, and pyrene. In a representative sample, the concentration of PAHs was below the permissible values associated with the hazardous H15 characteristic.

The primary sources of contamination of the tested sample were naphthalene, acenaphthene, and pyrene, which were present in higher concentrations compared to all other PAHs. Anthracene had the lowest concentration in the sample, and its obtained value was at the limit of quantification.

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ENVIRONMENT AND SUSTAINABLE DEVELOPMENT. MECHATRONICS. OCCUPATIONAL SAFETY AND HEALTH AND FIRE SAFETY. SMART MANAGEMENT SYSTEMS. GRAPHIC ENGINEERING. DESIGN. TRAFFIC ENGINEERING. BIOTECHNOLOGY AND HEALTHCARE. MECHANICAL ENGINEERING. ECOTOURISM AND RURAL DEVELOPMENT.

EU TAXONOMY AS A FRAMEWORK FOR A FUNCTIONING CIRCULAR ECONOMY

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Abstract: *Clearly defining the concept of circularity has been one of the critical barriers to adopting circular economy principles across various industries. Although progress has been made in developing new circular economy business models, adopting a common understanding of the benefits of implementing more sustainable models is extremely important. To build this new framework, there is the need to create a system of classifying values to ensure a complete understanding of system values' types and categories. The main objective of this science-based classification system is to define sustainable activities clearly. This paper presents an overview of the development of the EU Taxonomy, the technical screening criteria of environmental objectives of this regulation, activities making substantial contributions to the circular economy transition, and difficulties that could arise through implementation processes.*
Keywords: Taxonomy, Circular Economy, Monitoring Framework, Action Plan.

1. INTRODUCTION

The circular economy is a model where resources are used to their fullest potential before being recovered and regenerated. Implementing circular economy (hereafter: CE) principles is increasingly recommended to achieve sustainable development goals. Academics, industrialists, and politicians worldwide agree to use CE-related measuring instruments to facilitate the transition at various systemic levels [1]. Similarly, the analysis of 221 CE-related definitions by Kirchherr et al. (2023) [2] provides quantitative evidence that CE also means different things to different people [1] .
New tools are necessary to assist practitioners, decision-makers, and policy-makers in adopting more CE practices and monitor their effects.[1] When considering the lifecycle of a product, it's important to broaden the scope and take into account the interactions among a range of policies. The complexity of this system is shown by Figure 1, where various policy mechanisms are being explored in different policy arenas of the production-consumption approach [3].
However, there needs to be coordination among these mechanisms. Nevertheless, many policy tools can be used to apply both positive and negative pressures to promote a shift towards a CE. Producers, users, and waste recyclers can be pressured to modify their activities and move towards a circular model using a mix of policies.
The interactions between different actors in a circular economy are numerous and complex. This creates a complicated policy landscape that extends across different parts of production and consumption systems and directly or indirectly affects several other parts in the value chain. Considering these interactions' impacts is crucial to fully understanding the circular economy.

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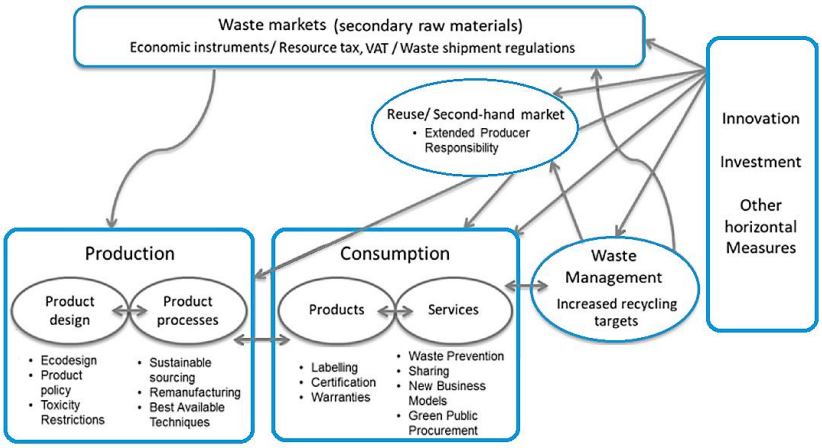

Figure 1. Overview of different policies oriented towards CE

Source: adapted from Milios, L. Advancing to a Circular Economy: Three Essential Ingredients for a Comprehensive Policy Mix, *Sustainability Science,* 13(3), (2018) pp. 861–78. ISSN 1862-4065.

To fully implement the principles of CE, it is crucial to have discussions that establish a shared understanding and language towards accomplishing this goal. Taxonomy, the science of classification in a broad sense, can become a valuable tool for achieving common definitions, criteria, and common metrics within activities in the field of circular economy.

2. CIRCULAR ECONOMY ACTION PLAN

The European Commission introduced the *New Circular Economy Action Plan* in 2020 as one of the main building blocks of the European Green Deal - a new strategy for sustainable growth in Europe [4]. A historical timeline listing policy milestones for the EU Action plan for CE, is shown in Table 1.

Table 1. Timeline of EU actions and initiatives

Source: https://environment.ec.europa.eu/strategy/circular-economy-action-plan_en

2023	Revision of the circular economy monitoring framework
2023	Proposals on green claims and right to repair proposal for a Directive on green claims
2022	Measures proposed in the circular economy action plan (revision of EU rules on Packaging and Packaging Waste)
2022	Proposals for revised EU measures to address pollution from large industrial installations
2022	Package of measures proposed in the circular economy action plan
2021	Proposal for new rules on waste shipments
2021	Proposal to update rules on persistent organic pollutants in waste
2021	Global Alliance on Circular Economy and Resource Efficiency (GACERE) launched
2020	Proposal for a new regulation on sustainable batteries
2020	New circular economy action plan
2019	European Green Deal
	•••
2015	1st circular economy action plan

The new action plan aims to improve the entire life cycle of products, proposing a series of connected initiatives to create a robust and consistent policy framework that promotes sustainable products, services, and business models and encourages a shift in consumption patterns towards sustainable consumption, so that waste is prevented from being generated in the first place while keeping resources in the EU economy for as long as possible. The plan includes legislative and non-legislative measures targeting areas where action at the EU level can bring real added value.

Even the first Action plan (2015) included a clear timeline for the actions proposed and a plan for a simple and effective monitoring framework for the circular economy. *Revised EU monitoring*

framework for the CE (accepted 2023 by the European Commision), that takes account of the CE priorities in the context of the European Green Deal, aims to provide a comprehensive overview by measuring direct and indirect benefits of increasing circularity. It comprises 11 indicators grouped into five dimensions: (1) production and consumption, (2) waste management, (3) secondary raw materials, (4) competitiveness and innovation, and (5) global sustainability and resilience [5].
Even though circularity indicators, known as C-indicators, can provide a comprehensive evaluation of circularity in various contexts, it is essential to understand what the available indicators measure to use them properly. Monitoring frameworks must standardise terminology and definitions, establish quantifiable baselines for metrics comparisons, and find practical solutions to improve data quality and availability to capture the multi-dimensional nature of circularity fully.
Within the monitoring framework, the taxonomy shall serve as a tool to distinguish sustainable from non-sustainable economic activities. The taxonomy aims *to guide capital into innovations that are (or have the potential to be) more circular than the status quo and to accelerate changes towards the circular economy* [6].

3. THE EU TAXONOMY REGULATION

An economic activity should meet specific technical screening criteria to be deemed environmentally sustainable. The Taxonomy aims to provide "a robust, science-based classification system, allowing non-financial and financial companies to share a common definition of sustainability and thereby providing protection against greenwashing" [7].
EU taxonomy for sustainable activities (henceforth "EU Taxonomy") is a framework designed by the European Parliament and Council, adopted in 2020, to classify environmentally sustainable economic activities to promote sustainable finance and investments. The EU Taxonomy is a crucial part of the European Green Deal. It can be interpreted as a dictionary defining a list of economic activities qualifying as sustainable concerning defined environmental criteria [8].
The goals of the taxonomy can be summarised in three key points:

- Reorientation of capital flows towards sustainable investments;
- Establishing sustainability as a component of risk management;
- Foster transparency and long-term investments and economic activity [9].

The EU Taxonomy defines six primary environmental objectives (Figure 2). Each objective specifies a list of economic activities and criteria to ensure that the activity contributes significantly to the objective's goal while not causing significant harm to the other objectives [10].
The current version of the EU Taxonomy covers a limited number of economic sectors. However, more sectors are expected to be added over time [10].

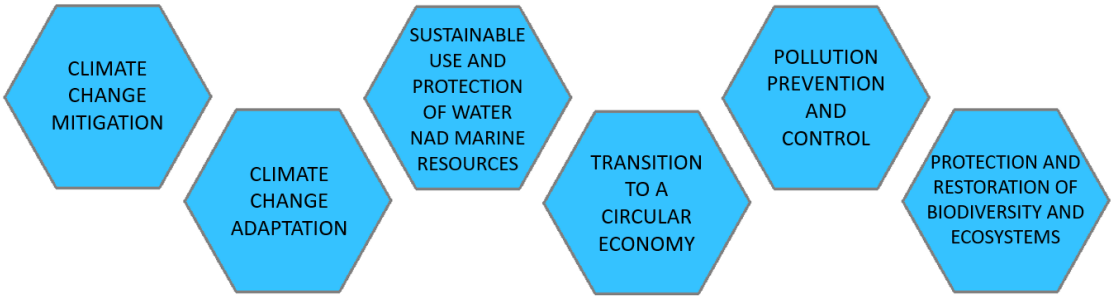

Figure 2. Six primary environmental objectives defined under the EU Taxonomy

One of its six equally weighted environmental objectives is to support the transition to a circular economy [11] and promote the use of secondary raw materials, prolonging the lifespan of products and materials and implementing a closed material loop to prevent waste generation [12].
This framework aims to help companies, investors, and other stakeholders understand and communicate the environmental performance of their assets, products, services, and investments. In addition, it will enable companies to identify opportunities to improve their environmental performance and access new markets and investors interested in sustainable and responsible

investments. By implementing the CE objective of the EU Taxonomy, it is possible to achieve significant economic and environmental benefits [12].

3.1 Activities making substantial contributions to the circular economy transition

The European Commission (EC) published recently (June 2023) the final Environmental Delegated Act, specifies criteria for determining whether economic activities cause significant harm to any of the other environmental objectives and has separate annexes for each environmental objective [13].
The delegated act defines the technical screening criteria of the four other environmental objectives of the Taxonomy Regulation:

i) Sustainable use and protection of water and marine resources;
ii) Transition to a circular economy;
iii) Pollution prevention and control;
iv) Protection and restoration of biodiversity and ecosystems.

Each annex defines the economic activities under the respective objective and the corresponding technical screening criteria.
Annex II of this document gives technical screening criteria for determining the conditions under which an economic activity qualifies as contributing substantially to the transition to a CE and for determining whether that economic activity causes no significant harm to any of the other environmental objectives.
Activities are listed under 21 categories, grouped into five sectors (Table 3):

- Manufacturing;
- Water supply, sewerage, waste management and remediation activities;
- Construction and real estate activities;
- Information and communication, and
- Services.

Table 3. Activities on the transition to a CE / 21 activities within five sectors
Source: Environmental Delegated Act (C(2023) 3851), Brussels (2023); Annex II

Manufacturing

1.1. Manufacture of plastic packaging goods
1.2. Manufacture of electrical and electronic equipment

Water supply, sewerage, waste management and remediation activities

2.1. Phosphorus recovery from wastewater
2.2. Production of alternative water resources for purposes other than human consumption
2.3. Collection and transport of hazardous waste
2.4. Treatment of hazardous waste
2.5. Recovery of bio-waste by anaerobic digestion or composting
2.6. Depollution and dismantling of end-of-life products
2.7. Sorting and material recovery of non-hazardous wastes

Construction and real estate activities

3.1. Construction of new buildings
3.2. Renovation of existing buildings
3.3. Demolition and wrecking of buildings and other structures
3.4. Maintenance of roads and motorways
3.5. Use of concrete in civil engineering

Information and communication

4.1. Provision of IT/OT data-driven solutions and software

Services

5.1. Repair, refurbishment and remanufacturing
5.2. Sale of spare parts
5.3. Preparation for re-use of end-of-life products and product components
5.4. Sale of second-hand goods
5.5. Product-as-a-service and other circular use- and result-oriented service models
5.6. Marketplace for the trade of second-hand goods for reuse

3.2 Potential challenges in implementation

There may be certain difficulties that could arise during the process of putting an EU Taxonomy and its CE objectives into action.
One of the primary challenges is the lack of knowledge and expertise in the CE among companies and investors. This makes it difficult for companies to comprehend and adhere to the technical screening criteria and for investors to evaluate the environmental performance of economic activities. Moreover, the absence of infrastructure (more recycling and refurbishment facilities) and systems (the lack of regulations and policies to facilitate the shift towards a CE) to support the CE also poses a challenge. Companies can also face difficulties or obstacles when transitioning to a CE due to the lack of incentives and support. Additionally, regulations and policies are scarce to support the transition to a circular economy.

4. CONCLUSION

The European Commission's circular economy taxonomy system can be used to create comprehensive criteria for the transition to a circular economy. The framework is extensive and adaptable enough to tackle several challenges in transforming our linear economies into circular ones across sectors. This sustainable finance taxonomy can clarify circular economy activities and direct finance towards them. With regulatory and economic policy instruments, the taxonomy can accelerate sustainable economic activities, but it is still in the early stages of implementation, with numerous challenges on its way. Nevertheless, despite that, new regulation offers hope for closing the financial gap and improving the adoption of circular practices.

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ENVIRONMENTAL CONCERNS OF LITHIUM BATTERY DISPOSAL

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Abstract: *Technological advancements and lifestyle changes have increased reliance on electronic devices, leading to a surge in battery demand, particularly lithium-ion batteries. These batteries are prevalent in consumer electronics and vehicles due to their efficiency and lightweight composition. This study focuses on the vital role of batteries in everyday life, specifically examining lithium-ion batteries, their composition, and types. The paper differentiates between primary (single-use) and secondary (rechargeable) batteries, underscoring the growth in lithium-ion battery production, influenced by global initiatives aimed at reducing carbon emissions. The lifecycle of lithium-ion batteries, encompassing production, disposal, and recycling, is scrutinized. Challenges in battery chemistry variance, collection, and recycling processes are discussed, with manual dismantling of battery modules presented as a more effective recycling method than material shredding. The environmental implications of improper disposal, especially the risks of landfill fires intensified by these batteries, are a significant focus. The release of toxic gases and heavy metals from such fires, adversely affecting air, soil, and water quality, is detailed. Furthermore, the impact of these heavy metals on human health is briefly explored. Conclusively, this paper highlights the extensive environmental footprint of lithium-ion batteries, emphasizing the critical need for enhanced recycling and disposal strategies to minimize their detrimental environmental and health impacts.*
Keywords: Lithium-Ion Batteries, Environmental Impact, Recycling Challenges, Landfill Risks, Toxic Emissions

1. INTRODUCTION

In the wake of technological advancements and evolving lifestyle patterns, the world has witnessed a significant surge in the use of various electronic devices. This increase has, in turn, escalated the demand for efficient and reliable power sources, prominently lithium-ion batteries. Lithium-ion batteries, characterized by their lightweight and high-energy density, have become integral in powering a wide array of devices, from mobile phones and laptops to electric and hybrid vehicles. This widespread adoption, however, brings forth critical environmental challenges. This paper delves into the comprehensive lifecycle of lithium-ion batteries, from their production to eventual disposal and recycling. It highlights the critical distinction between primary and secondary batteries and emphasizes the growing global demand for lithium-ion batteries. This demand is partly driven by international initiatives like the European Green Deal and the UK's ban on internal combustion engines, signalling a shift towards a low-carbon economy [1, 2]. The focal point of this study is the environmental impact of these batteries, particularly concerning their disposal. The improper disposal of lithium-ion batteries poses significant environmental hazards, notably in landfills where they can exacerbate fires, releasing toxic gases and heavy metals [3]. These emissions have far-reaching consequences on air quality, soil, and water, extending beyond immediate ecological damage to pose

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serious health risks [4]. In addressing these challenges, the paper examines various recycling methods, with a special emphasis on manual dismantling as a more efficient alternative to material shredding. The complexities associated with the recycling process, owing to the varying chemistries of lithium-ion batteries, are also explored. Ultimately, this paper aims to shed light on the urgent need for improved recycling infrastructure and innovative disposal methods. By doing so, it seeks to mitigate the harmful environmental and health impacts associated with the growing use of lithium-ion batteries, thus contributing to a more sustainable and environmentally responsible future.

2. CONSEQUENCES OF IMPROPER DISPOSAL OF LITHIUM BATTERIES ON ECOSYSTEMS AND HEALTH

The rapid advancement in technology and lifestyle changes have led to a surge in the use of electronic devices, subsequently increasing the demand for batteries. Lithium-ion batteries, characterized by their high energy density and efficiency, are now ubiquitous in powering a range of devices, from mobile phones and laptops to electric and hybrid vehicles. These batteries are pivotal in modern life, yet their disposal poses significant environmental challenges. A large increase in lithium-ion batteries demand for electric vehicles is predicted in 2030. The entire market will need 1293 GWh, and the largest part will be needed by China with about 500GWh, 320GWh by the US, 280GWh by the rest of Europe and about 200GWh by the rest of the world [5]. Lithium-ion batteries, which utilize lithium as an anode, are preferred for their lightweight and high energy capacity [6]. They come in two forms: primary (single-use) and secondary (rechargeable), with the latter gaining more prominence due to longer lifespan and higher capacity. However, the increase in lithium-ion battery production and use raises critical concerns about their disposal and recycling. The paper particularly distinguishes between the batteries used in consumer electronics, which are smaller and less likely to be recycled, and those in vehicles, which are more frequently processed in recycling facilities. The recycling challenges are amplified by the diverse chemistry of lithium-ion batteries, impacting their composition, performance, and application.

2.1. Recycling of lithium-ion batteries

Recycling lithium-ion batteries is a critical aspect of mitigating their environmental impact. Among the various recycling methods, manual dismantling has emerged as a particularly effective approach. This process involves the physical disassembly of batteries to separate and recover valuable components and materials. Manual dismantling is preferred over other methods like material shredding for several reasons. Firstly, manual dismantling allows for the precise separation of different components of lithium-ion batteries. These batteries consist of several key materials, including lithium, cobalt, nickel, and various plastics and metals. By carefully disassembling the batteries, recyclers can more effectively segregate these materials, reducing the risk of contamination that often occurs during shredding. Shredding, while quicker, tends to mix all materials together, making it challenging to extract pure substances. The purity of recovered materials is crucial for their reuse in new batteries or other applications. Manual dismantling yields a higher return of pure active materials. This purity is vital as it ensures that the recycled materials retain their original properties and functionality. For instance, cobalt and lithium recovered through this process can be reused in the production of new batteries without significant degradation in performance. Moreover, manual dismantling minimizes the loss of valuable materials. During shredding, small particles of precious metals and other materials can be lost or become too difficult to separate efficiently. This is not the case with manual dismantling, where the careful separation process ensures maximum recovery.
Another advantage of manual dismantling is the reduced environmental impact. Shredding processes can generate dust and other pollutants, which can be harmful if not properly managed. In contrast, manual dismantling, when done in controlled conditions, results in fewer airborne pollutants, making it a more environmentally friendly option. However, it's important to note that manual dismantling is labor-intensive and can be more time-consuming than automated processes like shredding. This can

impact the scalability of this method, especially as the volume of batteries needing recycling continues to grow. The labor-intensive nature of the process also raises concerns regarding worker safety and health, as employees are exposed to potentially hazardous materials. To optimize the recycling of lithium-ion batteries, a combination of manual dismantling and automated processes might be the most effective approach. The initial manual dismantling can ensure the purity and maximum recovery of valuable materials, while subsequent automated processes can handle the higher volumes and manage the less critical aspects of recycling. It was estimated that in 2018 97,000 tons of lithium-ion batteries were recycled, of which the most was recycled in China and South Korea with 67,000 and 18,000 tons. A certain amount of batteries have a longer life than expected, while some are reused and other are stored in warehouses immediately after production, reducing the overall number of recycled batteries. Certainly, the greater part of batteries that reach the end of life comes from electronic devices, not from electric vehicles (as much as 80%) [7].

2.2. Disposing lithium-ion batteries on landfills

The disposal of lithium-ion batteries poses a significant environmental and public health challenge, particularly when these batteries end up in landfills. Landfills are the primary method for solid waste disposal. Electronic waste makes up as much as 4% of municipal waste that is disposed of in landfills, and most of this electronic waste consists of batteries [8]. Despite advances in battery technology, the recycling infrastructure for lithium-ion batteries remains underdeveloped, leading to a majority of these batteries being discarded in landfills. These sites, often the go-to solution for municipal waste due to their cost-effectiveness and operational ease, inadvertently become hotspots for environmental pollution. Landfills are not designed to handle the specific challenges posed by lithium-ion batteries. When these batteries are disposed of alongside general waste, they introduce several risks. One of the most hazardous consequences is the potential for landfill fires. These fires can be sparked by the spontaneous combustion of methane—a common occurrence in landfills. Lithium-ion batteries exacerbate this problem. Their composition and residual charge can lead to thermal runaway reactions, especially when damaged or exposed to high temperatures. These reactions can intensify landfill fires, making them more frequent and harder to control.

The fires in landfills release a cocktail of toxic gases and smoke. Among these are polycyclic aromatic hydrocarbons, dioxins, furans, volatile organic compounds, and heavy metals like lead, mercury, and cadmium. These substances are known for their detrimental effects on air quality and public health. For instance, dioxins and furans are highly toxic and can cause problems ranging from skin disorders to more severe health issues like cancer and reproductive disorders. Heavy metals, when inhaled or ingested, can lead to neurological and developmental problems, particularly in children.

2.3. Widespread environmental damage of inadequate lithium-ion batteries disposal

In addition to air pollution, the impact of landfill fires and leachates can extend to soil and water systems. Lithium-ion batteries contain heavy metals and other toxic substances that, when released, can seep into the ground and contaminate soil and groundwater. This contamination not only affects the immediate landfill area but can also spread to neighboring ecosystems. The heavy metals and chemicals in these leachates can be particularly harmful, leading to soil acidification and affecting the soil's ability to support plant life. This disruption can have cascading effects on local ecosystems, impacting not just plant life but also the animals that depend on them for food and habitat.

The ecological impact of such contamination is far-reaching. Heavy metals accumulated in the soil can be taken up by plants, entering the food chain and affecting a wide range of species, from insects to larger mammals and birds. In aquatic environments, these contaminants can lead to the eutrophication of water bodies, disrupting aquatic life and leading to the loss of biodiversity. These ecological imbalances can have long-term effects on the stability and health of ecosystems.

The environmental implications of heavy metal contamination from lithium-ion batteries are profound and multifaceted. Batteries, being a significant source of cobalt, nickel, and manganese,

contribute to the accumulation of these heavy metals in the environment when disposed of improperly. This section delves into the various aspects of such contamination and its cascading effects on ecosystems.

When lithium-ion batteries are discarded in landfills, the heavy metals they contain can leach into the soil and water systems. Over time, these metals accumulate in the environment, leading to several ecological problems. In soil, heavy metal accumulation can result in reduced fertility, altering its composition and affecting its ability to support plant growth. This change can disrupt the balance of local ecosystems, as plants form the foundation of most terrestrial food webs.

In water bodies, these metals can lead to the contamination of aquatic ecosystems. The presence of heavy metals in water can be toxic to aquatic life, causing a reduction in biodiversity and altering the balance of these ecosystems. Fish and other aquatic organisms can accumulate these metals in their bodies, which can then be transferred up the food chain, affecting predators and, eventually, humans who consume these fish.

The presence of heavy metals in the soil can also alter microbial activity. Microbes play a crucial role in soil health, aiding in nutrient cycling and organic matter decomposition. Heavy metal contamination can inhibit these microbial processes, leading to a decrease in soil quality and health. This can have a direct impact on plant life, as plants rely on healthy soil for nutrients and growth.

The long-term environmental consequences of heavy metal contamination from lithium-ion batteries are significant. One of the potential outcomes is changes in land use due to soil degradation. As soil becomes less fertile and more contaminated, it may no longer be suitable for agricultural or recreational purposes, leading to shifts in land use patterns. This can have socio-economic implications, particularly in regions where agriculture is a primary livelihood.

In aquatic ecosystems, prolonged exposure to heavy metals can lead to changes in species composition and a decrease in water quality. These changes can disrupt the ecological balance, affecting not only the aquatic species but also the terrestrial species that rely on these water bodies.

The broader implications of heavy metal contamination include impacts on climate and biodiversity. Contaminated and degraded ecosystems are less capable of performing essential functions such as carbon sequestration, which is vital in mitigating climate change. Additionally, the loss of biodiversity due to heavy metal contamination can lead to the loss of ecosystem services, which are critical for maintaining the balance of the environment and supporting human life.

3. CONCLUSION

The comprehensive analysis of the impact of lithium-ion batteries on the environment and health elucidates a pressing concern in the context of our rapidly advancing technological world. As the reliance on electronic devices continues to escalate, so does the use and disposal of lithium-ion batteries, a cornerstone in powering these devices. These batteries, known for their efficiency and high energy density, have become integral in modern life, but their end-of-life management poses significant environmental and health challenges. The environmental repercussions of improperly disposed lithium-ion batteries are manifold. Landfills, the most common destination for these batteries, become hotbeds for pollution. Here, the risk of fires is heightened by the presence of these batteries, leading to the emission of toxic gases and heavy metals. These emissions adversely affect air quality, contributing to broader atmospheric pollution. The leachates from these batteries further contaminate soil and water bodies, introducing heavy metals and other toxic substances into ecosystems. This contamination disrupts ecological balance, affects biodiversity, and poses a risk to plant and animal life. The health implications of such environmental degradation are profound. Exposure to toxic substances released from discarded batteries can lead to a range of health issues in humans, from respiratory problems to more severe conditions caused by heavy metal poisoning. The long-term effects on human health necessitate a deeper understanding and more robust management strategies. This situation underscores the urgent need for effective recycling and disposal methods for lithium-ion batteries. While current recycling methods, such as manual dismantling, offer a more efficient alternative to material shredding, there is a need for more innovative and sustainable

approaches. Such approaches should not only focus on effective recycling but also on minimizing environmental impact during the entire lifecycle of these batteries. In conclusion, the growing use of lithium-ion batteries, while beneficial for technological advancement, brings with it a responsibility to manage their disposal in an environmentally friendly and health-conscious manner. It is imperative that we develop and implement comprehensive strategies for recycling and waste management to mitigate the adverse effects on the environment and human health. This will require collaborative efforts from governments, industries, and communities to ensure a sustainable and healthy future.

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Student paper

AIR POLLUTION CAUSED BY MODERN-DAY ARMED CONFLICTS

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Abstract: *Since the beginning of time, armed conflicts have killed people, destroyed infrastructure, led to forced migrations, and had many other short and long-term economic, social, and political consequences. An often overlooked fact is how these war activities affect air pollution and the environment before, during, and after the conflict. This paper will examine only the consequences of conventional warfare on air pollution, such as fuel consumption and carbon footprint of military equipment, burning of fuel, biomass, and waste, destruction of infrastructure, use of different kinds of ammunition and other explosive equipment, and increased industrial activity in all stages of the conflict. All these activities cause the emission of different types of pollutants into the air, which has a devastating effect on all living things and the environment, even far away from the conflict zone and, in most cases, long after the conflict.*
Keywords: Air pollution, armed conflict, environment

1. INTRODUCTION

Armed conflict can be defined as an act of war generated by two or more governmental groups, non-governmental groups, or international states that generally involve active military actions [1]. When considering armed conflict, the primary concern is the loss of human life, followed by short and long-term adverse health effects on both military personnel and civilian population, as well as severe economic, social, and political consequences. Still, another often disregarded consequence is damage to the environment where those conflicts occur [2]. Armed conflicts affect all components of the environment - air, water, and soil. This paper will discuss air pollution that occurs in all stages of the conflict. It can be indirect, for example, the carbon footprint that the military has during its activities that include fuel consumption and burning waste, the relocated carbon footprint that refugees have in the country they fled to, or the carbon footprint of post-war reconstruction and rearmament. Nevertheless, often, it is direct as participants tend to use tactics like burning fuel supplies and land biomass or destroying infrastructure and industrial facilities to prevent the opposition from moving over terrain or gaining valuable resources, as well as reducing visibility due to smoke from burning [3]. Those actions and many others can significantly contribute to air pollution in the territory where conflict occurs but also can affect environments far away from the conflict zone, as pollutants travel through the atmosphere. Therefore, the negative environmental effects can extend far beyond the space and time of the armed conflicts that caused them, possibly having long-term global effects on air quality [4]. The overall structure of this paper takes the form of three chapters, each covering one of three parts of the conflict that causes air pollution. Preparation for the armed conflict, the armed conflict, and the post-conflict period. This paper will not discuss political issues and the cause of the conflicts but only their impact on air pollution and the environment [1].

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2. AIR POLLUTION CAUSED BY THE PREPARATION FOR ARMED CONFLICT

Preparation for armed conflict involves many fossil fuel-intensive activities, emitting carbon dioxide equivalent (CO_2e) and other pollutants [5]. Those activities primarily include increased industrial activity due to the production of military equipment, ammunition, and fossil fuel consumption. Fossil fuel consumption is essential to military preparations since almost every land, air, and sea vehicle and a wide range of fuel-powered installations need fuel. Fuel consumption of military equipment is very high due to the prioritization of superior combat performance. Heavy military vehicles and aircraft consume large amounts of fuel and produce thousands of tons of CO, NOx, hydrocarbons, and SO_2 [6,7]. Data on military fuel consumption and greenhouse gas (GHG) emissions is generally limited due to many factors, one being that reporting military emissions is voluntary, as the Paris Agreement states. While sometimes data is reported directly by the military agency, another solution can be emission calculation done by independent researchers based on fuel consumption published by military agencies. Research suggests that if all militaries of the world were a single country, that figure would have the fourth largest national carbon footprint in the world, greater than that of Russia [8].

For example, we shall take the United States Department of Defense (US DOD), the largest energy consumer in the United States and the world's largest institutional consumer of petroleum. Equipment on the field deployed by the US DOD uses an incredible amount of fuel; the same goes for off-field equipment and operations. An example of fuel consumption is a High Mobility Multipurpose Wheeled Vehicle or "Hummve" with roughly 30 to 60 liters of diesel fuel per 100 kilometers, equivalent to three to six medium-sized passenger cars. Besides land, air, and sea vehicles, installations also consume significant amounts of energy and emit CO_2e. For example, the Pentagon building in Arlington, Virginia, emitted 24**,**620 metric tons of CO_2e in 2013 [5]. US DOD primarily uses diesel and jet fuel for its operations; around 70% of that fuel consumption goes to the US Air Force, resulting in jet fuel being the most used fuel by the US military [5]. Military jets fly at much higher altitudes than commercial aircraft, and special additives are used for that and other reasons. The concentration of military aircraft in a specific area can increase air pollution because of additives that include ammonium perchlorate, polyvinyl chloride, lead stearate, polybutadiene, and polyethylene. Furthermore, jet exhaust gases include NOx. Warships are excluded from all major international environmental regulations, resulting in the lack of studies on fuel consumption and environmental impacts [5,7].

3. AIR POLLUTION DURING THE ARMED CONFLICT

Fossil fuel consumption and carbon footprint are further increased when conflict begins, as fossil fuel-powered equipment and installations experience a higher degree of use. There are often airspace bans issued by countries and their allies involved in the conflict. A recent example is the conflict in Ukraine, where Russia and Western countries issued various airspace bans, cutting important airways between Europe and Asia by making nearly 18 million km^2 inaccessible for overflights, which caused airline companies to make detours which resulted in longer flight times, as well higher GHG emissions [6].

Besides air pollution caused by fuel consumption, there is uncontrolled burning of materials in the ambient environment. Open fires occur regularly during peacetime due to natural factors and as a result of accidents [6]. During the conflicts, the number of fires and areas affected by fires is significantly increased compared to peacetime due to shelling, bombing, explosions, and other conflict-related actions. Different materials are burned in uncontrolled settings, and acquiring representative information about emission factors is challenging. Still, overall emission from a source depends on activity level and the amount of combustible material. In the case of open burning, due to its less-than-ideal combustion conditions that include insufficient mixing of fuel and air and not high enough temperatures, there is the emission of soot and particulate matter (PM), carbon monoxide, methane, and other light hydrocarbons, volatile organic compounds (VOCs) and polycyclic aromatic

hydrocarbons (PAHs). Metals can also be emitted into the air during these combustions, such as lead and mercury, as well as polychlorinated dibenzo-p-dioxins and polychlorinated dibenzofurans (PCDDs/Fs) or polychlorinated biphenyls (PCBs) [6,9]. While the primary concern is the open burning of fossil fuels caused by the destruction of fuel storages, oil wells, and energy facilities, there is also the open burning of biomass, structure, and waste [4,6].

Fuel sources are often targeted during armed conflict; they include fuel depots, oil refineries, power stations, oil wells, and other similar facilities. During the uncontrolled combustion of fossil fuels, massive amounts of soot and particulate matter are emitted into the air, along with partially burned hydrocarbons and heavy metals, including nickel, vanadium, iron, aluminum, zinc, arsenic, lead, and other elements. Besides heavy metal release into the air, fossil fuel burning produces a wide range of combustion products, namely CO_2, CO, SO_2, NOx, O_3, VOCs, and acid aerosols [3]. An example of an environmental air pollution catastrophe due to armed conflict occurred during the 1991 Gulf War. While retreating, military forces ignited around 600 Kuwaiti oil wells, causing the emission of 5,000 tons of soot and particulate matter into the air every day while oil wells burned. Also, those oil fires emitted approximately 7,200 tons of vanadium, 2,000 tons of nickel, 900 tons of aluminum, 750 tons of iron, 430 tons of zinc, and 150 tons of mercury and cadmium [3]. Smoke and soot rose to about 3,000 meters, while severe air pollution was registered even at 6,000 meters. Smoke covered large areas, including Kuwait, Bahrain, parts of Saudi Arabia, Iran, and Iraq, severely affecting air quality. Thermal inversion over southern Kuwait and northern Saudi Arabia trapped polluted cold air near the ground preventing it from dispersing natrually, where humans and animals can inhale it. Some research suggests that these stagnation conditions in the atmosphere combined with polluted air led to a sharp rise in common cardiovascular and lung diseases in affected areas. High concentrations of smoke decreased sun radiation and the temperature of air and water, where the average temperature in 1991 on the Saudi coast was 2.5 °C lower than usual [3]. Some research estimated that about 75 to 80% of the sun radiation was absorbed, resulting in a reduction in mid-day temperature of 5-8 °C at 250 km from the source of the fires. Since many organisms in the northern Gulf live under temperature conditions close to their lowest tolerance point, it is indicated that these changes caused by air pollution very likely had a negative effect on them [4,3]. The burning of fossil fuel sources and depots is a trend that started well before the Gulf War and was repeated in almost every armed conflict after it [3]. Another example is the damage to the Pancevo oil refinery during 1999. NATO bombings in Yugoslavia [7]. More recently, missile strikes in Ukraine demolished the Kremenchuk refinery, the only operational refinery in Ukraine with a capacity of three million tons of oil annually. There are also reports of destroying at least 20 other reservoirs with petrol, diesel, liquefied petroleum gas, and fuel oil in the ongoing conflict in Ukraine [7].

Besides fossil fuel, there is intentional and accidental biomass burning during the conflict. Biomass fires are a dynamic process where a moving flame front passes over a fuel source, such as a forest, savannah, or agricultural fields, consuming it. During this type of burning, there is both smoldering and flaming combustion, resulting in different levels of air pollution [9]. The Copernicus programme estimates that during a natural wildfire, the level of $PM_{2.5}$ can reach 500 $\mu g/m^3$; similar levels are observed during wildfires caused by military actions. Those figures are incredibly high compared to the World Health Organisation's 24-hour mean standard of 15 $\mu g/m^3$ [10]. Burning of biomass due to conflict-related activities, especially burning that results in deforestation, also leads to loss of actual and future carbon sequestration [5].

Uncontrolled waste burning is one of the major air pollution factors during armed conflicts. Every human activity generates waste; the same goes for armed conflicts. Due to the destruction of infrastructure and local services responsible for waste management being unable to function, there are improvised solutions for waste disposal, one of which is waste burning, done by both civilian and military personnel during the conflict [11,9]. Armies often use the so-called burn pit to dispose of waste. Research shows that the US military has repeatedly used this method since 2001 at bases outside the United States, in Iraq and Afghanistan. Burn pits are large areas where tons of waste are burned in the open air, often using jet fuel containing benzene as an accelerant. Military waste can include chemicals, paint, medical and human waste, metal cans, batteries, weapons, uniforms,

munitions and other unexploded ordnance, petroleum and lubricant products, plastics and styrofoam, rubber, wood, discarded food, dead animals, and even human body parts. As a reference to how much waste is being made during the conflict, according to the United States Department of Defense, the US military in Iraq and Afghanistan generated close to 5 kg of solid waste per servicemember per day [11]. Burn pits can create large volumes of toxic gases, polluting the air significantly more than controlled burning of waste due to uncontrolled burning and temperatures much lower than those required for complete combustion of materials [12]. Research suggests that toxic matter from these burnings can release known carcinogens and respiratory sensitizers that affect the skin, eyes, respiratory and cardiovascular systems, gastrointestinal tract, and internal organs of military personnel and the local population [13,11].

Destruction and burning of infrastructure, industrial, and residential buildings generate large amounts of debris and emit different air pollutants depending on the destroyed structure. More precisely, they depend on the type of material the building is made of and the chemicals used in the destroyed industrial facility. Among those air pollutants, one of the most dangerous to human health is particulate matter. Debris from industrial facilities can be hazardous, as it can contain a wide range of chemicals depending on the type of facility. The report by UNEP (2009) from conflict in Gaza stated that fire emissions and residue polluted the air with PAHs or dioxins and furans, depending on the material of the destroyed building [7,8]. Another example is the destruction of the Company for Carton Mince and Industry in Lebanon, which generated a significant amount of ash that contained dioxins and other chemical compounds [3]. In the ongoing conflict in Ukraine, damage to the Nord Stream 1 & 2 pipelines caused leakage of large amounts of natural gas, which consist of methane, a potent GHG, which led to severe GHG emission. Some research suggests that this GHG emission is more significant than the current assessment of all emissions combined from that conflict [14]. The destruction of the World Trade Center released many pollutants, including toxic metals, asbestos, dioxins, PAHs, PCBs, and hydrochloric acid [15]. There is also air pollution by radioactive elements. Research suggests that the bombing of two Al-Tuwatha nuclear reactors in the 1991 Gulf War probably released some amount of Cesium-137 and Iodine-131 into the air. Once these radioactive elements are in human organs, they emit radiation, which can induce cancer [3].

Using bullets, shells, missiles, or any other type of explosive military equipment causes air pollution. From the moment of being produced, transported, fired, or launched to the moment of impact or explosion, particulate matter and gases are released in all stages. These pollutants then mix with the air and become its permanent component. In modern-day armed conflicts, bullets, shells, and missiles are produced and used in millions, seriously affecting air quality. For example, generic 152 mm and 155 mm artillery shells used by Ukraine and Russia in the ongoing conflict emit at the point of firing 2.74 kg of CO_2e and 0.19 kg of CO_2e during the detonation [14]. By some calculations, in the first year of the conflict, the total number of this type of shells used by both sides was around 11,250,000. Resulting in a significant CO_2e emission [6]. Besides air pollution at the point of firing and during the detonation, there is also a massive carbon footprint during the production of ammunition and the transportation of it to the conflict zone, which are considerably more significant than the CO_2e emission of the actual use of ammunition. In Ukraine conflict, total emissions of CO_2e from all types of ammunition, including small caliber rounds, all types of explosives, ammunition used by drones, shells used by tanks, land mines, hand grenades, artillery rockets, and air missiles, considering the use, production, and transport during the first year of the conflict is estimated to be around 2,000,000 tons, which is in comparison roughly the emission of 445,000 passenger cars driven for an exact period of one year [16].

3. POST-CONFLICT AIR POLLUTION

Destruction of buildings and infrastructure during the conflict is proportional to the accelerated reconstruction that will take place after it. Some will start during the conflict, but most will occur after it ends. Production of materials, transportation, and accelerated construction generates massive amounts of particulate matter and GHG; this embodied carbon is essential to total air pollution caused

by armed conflict. After the conflict has ended, it leaves a state of deteriorated security. For example, the conflict in Ukraine shows us how peace on the European continent cannot be taken for granted. Resulting in a rearmament of surrounding countries and rearmament of those countries that participated in the conflict. Rearmament, as well as other post-war military and industrial activities, consume a large amount of resources, resulting in considerable GHG emissions [14, 6].

6. CONCLUSION

This paper aimed to examine armed conflicts' effects on air pollution. Research has shown that all stages of the conflict can have severe consequences for the quality of air. Air pollution during the preparation for the conflict mainly consists of GHG emissions caused by increased military industry activity and fuel consumption. Migration of the conflict-affected population before and during the conflict presents a specific situation: their carbon footprint follows them from their country of origin to the countries they migrate to. During the conflict, besides GHG emissions, findings were that pollution could be more severe due to the uncontrolled burning of fuel and other materials and the release of chemicals and radiation due to damaged or destroyed industrial facilities. We can conclude that mid-conflict air pollution in its scope can be very similar to the industrial accidents and wildfires that occur during peacetime, except that local services responding to those catastrophes are unlikely to function correctly during the conflict, resulting in long-lasting emission of the pollutants into the atmosphere. Lastly, post-conflict air pollution, similar to pre-conflict activities, generates increased amounts of GHG due to the reconstruction and rearmament. All three stages of the conflict seriously affect the air quality not only of the conflict-involved countries but through transboundary pollution, it can affect the whole region, even the whole world. Consequences can last for many years after the conflict, especially regarding global warming and the world's problems along the path to decarbonization. The military's decarbonization is very much needed from the air pollution standpoint. Some ideas include using biofuels for ships and aircraft, increasing the energy efficiency of all installations, electrifying vehicles, using more fuel-efficient engines and lightweight materials, and other eco-friendly improvements. For any drastic change to occur, future international climate change treaties must legally bind not only the countries that ratify those documents but also their military actions. Previously, the Kyoto Protocol did not include military activities, such as self-defense, peacekeeping, and humanitarian relief, from emission targets. At the same time, the Paris Agreement made military emissions reporting voluntary.

At the end of the first quarter of the 21st century, armed conflict is an even more complicated phenomenon than before, with many serious negative effects, some environmental. Air pollution related to the conflict is industrial in its scope but lacks the technology and control mechanisms used in other industries to reduce pollution. This problem must get more attention in the future to prevent the long-reaching and long-lasting consequences of armed conflict on the air and the environment.

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Student paper

INFLUENCE OF "STUBO-ROVNI" DAM ON CLIMATE CHANGE IN THE CITY OF VALJEVO

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Abstract: *On the River Jablanica, 15km from Valjevo, between the village of Stubo on the right bank and the village of Rovni on the left bank, the dam "Stubo-Rovni" was built, which formed the reservoir "Stubo-Rovni" with a volume of about 50·106m³. The reservoir was intended to supply water to the city of Valjevo and the surrounding areas. That idea did not come true, however it will not be a subject of this paper. This paper will deal with climate changes in the city of Valjevo that occurred after the construction of the "Stubo-Rovni" dam. The results were derived on the basis of a survey of 49 respondents divided into two groups. In one group there are respondents with a place of residence in the center of Valjevo and Novo naselje, and in the second group respondents who live in the area at a higher altitude.*
Keywords: reservoir for water supply, climate change

1. INTRODUCTION

The town of Valjevo is located in western Serbia, less than 100 kilometers southwest of Belgrade. The city center is located in the valley through which the river Kolubara flows and it's surrounded by the mountains Maljen, Povlen, Jablanik and Medvednik, which rise over 1200 meters above sea level. According to the census from 2011, 90.312 inhabitants live on the territory of the city. Valjevo is located at an average altitude of 185 meters.

On the River Jablanica, 15 km from Valjevo, between the village of Stubo on the right bank and the village of Rovni on the left bank, the "Stubo-Rovni" dam was built, which formed the reservoir "Stubo-Rovni" with a volume of about 50·106 m^3. The reservoir was formed in the valleys of the Jablanica and Sušica rivers. Back in 1979, a study was commissioned for the long-term water supply of the town of Valjevo. This study envisages the construction of the regional system "Rovni" with an accumulation, as well as a plant for the preparation of drinking water with a capacity of 3600 l/s [1].

Data on the dam and reservoir are [2]:

- Basin area: 104 km^2
- Dam height: 74.5 m
- Elevation of the crown of the dam: 363.50 m
- Length of the dam in the crown: 8.0 m
- Elevation of the overflow crown: 360.00 m
- Elevation of normal descent: 360.00 m
- Elevation min. working level: 310.00 m
- Useful volume of the reservoir: 49.5 million m^3
- Maximum depth of the reservoir: 67 m.

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Figure 1. Reservoir "Stubo-Rovni"
Source: https://sn.rs/o6pj9

The regional water management system "Stubo-Rovni" (Fig.1) is intended for water supply population, industry, mitigating the effects of floods, retaining sediment, ensuring the biological minimum and producing electricity [2]. During the summer months of 2015, conditions were met for the beginning of filling the reservoir.

2. THE IMPORTANCE OF ACCUMULATION IN CASE OF FLOODS

The causes of floods can be immediate and indirect, with the existence of a wide range of factors that lead to the occurrence of so-called high waters. The immediate causes for the occurrence of floods are precipitation (rain and snow), the appearance of ice on rivers, the state of the water level at the time of its rise, the meandering of the stream, the occurrence of landslides and the occurrence of the coincidence of large waters. Indirect causes include the size and shape of the watershed, the density of the river network, features of the relief, water saturation of the soil, the state of the groundwater level, the degree of forestation, the way agricultural areas are cultivated, fires that destroy forest segments, anthropogenic factors (non-observance of regulations, irregular maintenance of riverbeds, unregulated watercourses), climate change and the like.
Frontal precipitation that lasts for several days is a critical problem. Flooding often occurs at the transition between winter and spring, when melting snow coincides with heavy spring rains. The coincidence of high water occurs when there is an increase in the height of the water level on both tributaries and the main watercourse at the same time, and then flooding can be inevitable.
In the flood protection and rescue system, preventive measures and immediate protection have an extremely important place. It is important to organize, prepare and implement, primarily, preventive protection measures, in order to reduce the risk of floods. And then there are operational measures and procedures, no less important, which make immediate preparations for the participation of forces and means in protection, with the aim of mitigating and eliminating the immediate consequences caused by floods. Flood defence facilities were built to protect populated areas, industrial plants and agricultural land. In the area of Valjevo these are: the reservoir "Gradac" on the River Gradac in Valjevo; "Kamenica" reservoir in Valjevska Kamenica; the "Pocibrava" reservoir in Petnica and the "Stubo-Rovni" reservoir, the construction and anti-erosion management of which reduced the risk of flash floods and localized them to the tributaries of the River Kolubara downstream of Valjevo [3].

3. CLIMATE CHANGES

Climate changes are changes that are mainly caused by human activity. Long-standing production and burning of coal, oil derivatives and natural gas has led to an increase in the concentration of gases in the atmosphere and consequences for the climate: extreme heat, extremely heavy rains, droughts, reduced yields in agriculture. All these things are connected with the increase in temperature on our planet [3].
Meteorological, and thus climatological research in the Valjevo region began in 1856, only 8 years after the establishment of the first meteorological station in Serbia. The geographically excellent area, together with the forest cover and the morphology of the soil contributed to these areas being conducive to people's life. The general geographical and climatic conditions of the Valjevo region

are affected by the proximity of the vast Pannonian Basin and the transition from plain to hilly-mountainous areas, with a certain degree of continentality. The climate of the Valjevo region can be characterized as moderate-continental. The average air pressure in Valjevo is about 998 mb. Changes in air pressure are significantly greater in winter than in summer. The coldest month is January, and the warmest is July and August. In the area of Valjevo, the average annual amount of sunshine is 198.9 hours, with the sunniest month being July (281.8 hours) and the cloudiest month being December (68.6 hours). Precipitation in the Valjevo region has the characteristics of the Central European, Danube regime of annual distribution. The average annual rainfall in Valjevo is 785.7 mm; the rainiest month is June with 100.1 mm, and the driest is February with 45.9 mm [4].

3.1. Reporting on the state of the environment

On the territory of the city of Valjevo, monitoring of air quality, communal noise level, and soil quality is carried out, and the results are submitted to the Environmental Protection Agency, as defined in Article 73 of the Law of Environmental Protection. Actual city administration of Valjevo, within its internet presentation, has a page on which there are only some of the reports on quality and measurements in the environment. Certainly, this page should be more up-to-date and dedicated to all reports and relevant information related to the state of the environment in the territory of Valjevo. This primarily refers to the local register of pollutants, reports on air quality and the results of noise level measurements in the environment. In this way, the public would be provided with access to information relevant to the state of the environment, together with the results obtained from monitoring [4].

3.2. Survey: The impact of accumulation on the climate in the city of Valjevo

A mini-survey analyzed the opinion of the residents of the city of Valjevo and their subjective feeling about the climate in Valjevo after filling the reservoir, and the idea came from very loud stories about the current topic, although no official document recognized the citizens' appeals.
The survey is composed of 13 questions for which possible answers are offered (I completely agree, I agree, I neither agree nor disagree - I am undecided, I do not agree, I do not agree at all), all in order to facilitate data processing, displaying the processed data and making a conclusion (Table 1 and Table 2).
As it was mandatory to indicate the place of residence as a very important factor of analysis in the survey, the respondents were divided into two groups:

- 1st group: city center, new settlement (lowest points of the city),
- 2nd group: settlements at a higher altitude (from 190m and above).

Only respondents over the age of 25 were included. 49 respondents were surveyed, of which 34 lived in the lowest part of the city and 15 lived in the settlements located in the higher parts.

Table 1. Answers from respondents who live in the lowest parts of Valjevo (City Center, Novo naselje)

Number of Statements/ Questions	Statements/Questions	Answers				
		I totally agree	I agree	I neither agree nor disagree - I'm undecided	I do not agree	I don't agree at all
1.	The climate has changed in the city of Valjevo in the last 10 years	24 (71%)	7 (20%)	3 (9%)	(0%)	(0%)
2.	The air is too polluted	27 (79%)	4 (12%)	3 (9%)	(0%)	(0%)
3.	The biggest source of pollution is traffic	4 (12%)	10 (29%)	5 (15%)	15 (44%)	(0%)
4.	The biggest source of pollution is industry	(0%)	2 (6%)	5 (15%)	15 (44%)	12 (35%)

5.	The biggest source of pollution is the heating plant and individual fireplaces	2 (6%)	2 (6%)	3 (9%)	7 (20%)	20 (59%)
6.	Climate change was largely influenced by the reservoir "Rovni"	20 (59%)	13 (38%)	1 (3%)	(0%)	(0%)
7.	The "Rovni" dam closed the wind rose	30 (88%)	3 (9%)	1 (3%)	(0%)	(0%)
8.	Due to the accumulation, excessive air humidity appeared in the city	30 (88%)	3 (9%)	1 (3%)	(0%)	(0%)
9.	Due to the accumulation, the appearance of fog in the city has become an everyday occurrence	20 (59%)	13 (38%)	1 (3%)	(0%)	(0%)
10.	The air smells of soot	10 (29%)	9 (26%)	5 (15%)	8 (24%)	2 (6%)
11.	Too many people complain of health problems due to air pollution	22 (64%)	4 (12%)	5 (15%)	2 (6%)	1 (3%)
12.	The appearance of wind in the city has become a very rare occurrence	30 (88%)	3 (9%)	1 (3%)	(0%)	(0%)
13.	If I had the opportunity, I would move to another city	3 (9%)	4 (13%)	10 (29%)	4 (13%)	13 (37%)

Table 2. Answers from respondents who live in the lowest parts of Valjevo (settlements Sedlari, Peti puk, Popare, etc.)

Number of Statements/ Questions	Statements/Questions	Answers				
		I totally agree	I agree	I neither agree nor disagree - I'm undecided	I do not agree	I don't agree at all
1.	The climate has changed in the city of Valjevo in the last 10 years	11 (73%)	3 (20%)	1 (7%)	(0%)	(0%)
2.	The air is too polluted	9 (60%)	5 (33%)	1 (7%)	(0%)	(0%)
3.	The biggest source of pollution is traffic	3 (20%)	5 (33%)	1 (7%)	6 (40%)	(0%)
4.	The biggest source of pollution is industry	(0%)	(0%)	3 (20%)	12 (80%)	(0%)
5.	The biggest source of pollution is the heating plant and individual fireplaces	(0%)	2 (13%)	3 (20%)	10 (67%)	(0%)
6.	Climate change was largely influenced by the reservoir "Rovni"	11 (73%)	3 (20%)	1 (7%)	(0%)	(0%)
7.	The "Rovni" dam closed the wind rose	12 (80%)	2 (13%)	1 (7%)	(0%)	(0%)
8.	Due to the accumulation, excessive air humidity appeared in the city	7 (46%)	3 (20%)	1 (7%)	4 (27%)	(0%)
9.	Due to the accumulation, the appearance of fog in the city has become an everyday occurrence	11 (73%)	3 (20%)	1 (7%)	(0%)	(0%)
10.	The air smells of soot	9 (60%)	2 (13%)	1 (7%)	3 (20%)	(0%)
11.	Too many people complain of health problems due to air pollution	13 (87%)	2 (13%)	(0%)	(0%)	(0%)
12.	The appearance of wind in the city has become a very rare occurrence	5 (33%)	1 (7%)	9 (60%)	(0%)	(0%)
13.	If I had the opportunity, I would move to another city	(0%)	(0%)	(0%)	1 (7%)	14 (93%)

4. CONCLUSION

This analysis is based on a very small sample considering the number of inhabitants, but as it showed that the citizens of the city of Valjevo in a huge percentage confirmed that the climate change occurred after the filling of the “Stubo-Rovni” reservoir, it could be the basis for some future research. It is interesting, even if they are not in the same degree of danger, that the citizens from higher altitudes are also of the same opinion as their fellow citizens in the valley.

Over 80% of citizens of both the first and second groups confirmed that the “Stubo-Rovni” dam closed the rose of winds. As the city of Valjevo is located in a valley, surrounded by mountains, it was the only place where favorite “northerner” wind came from in already endangered city, considering its geographical position. In the city itself, low ozone was created, in which, as the air humidity increased, all the pollution remained, which caused an increased number of asthmatics and other respiratory diseases, but that's what it will be about in one of the future papers.

So, as “Stubo-Rovni” dam, which its creators are proud of, went up, so did the excesses of air pollution grow until they exceeded all limits and at some point even placed our city in the first place as the most polluted in Europe, especially during the heating season when the industrial facilities and the huge increase in traffic are joined by the heating plant and individual fire pits. The dam, 75 meters high, got in the way of air currents and thus prevented the natural ventilation of the city. After listening to many experts, and due to the need to produce this paper, the conclusion is that the function of the dam can be, in a positive sense, almost the only regulation of flood and drought waves, which raises the question, did it really have to be of such dimensions and is the prevention of one type eventual catastrophes worth causing a series of others, very possibly with far greater consequences.

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OCCUPATIONAL HEALTH AND SAFETY AND FIRE SAFETY

INTERNATIONAL SCIENTIFIC AND PROFESSIONAL CONFERENCE
POLITEHNIKA 2023
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ENVIRONMENT AND SUSTAINABLE DEVELOPMENT. MECHATRONICS. OCCUPATIONAL SAFETY AND HEALTH AND FIRE SAFETY. SMART MANAGEMENT SYSTEMS. GRAPHIC ENGINEERING. DESIGN. TRAFFIC ENGINEERING. BIOTECHNOLOGY AND HEALTHCARE. MECHANICAL ENGINEERING. ECOTOURISM AND RURAL DEVELOPMENT.

APPLICATION OF 3D RANDOM E-GLASS FIBER COMPOSITES IN CONSTRUCTION HARDHAT DESIGN

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Abstract: *The present paper investigates the potential use of 3D random fibers in the construction of industrial hardhats. The composite system investigated was based on e-glass chopped fibers in the epoxy matrix randomly distributed. This composite system has been of primer interest since the composites intrinsically have better mechanical characteristics than regular polymers (such as HDPE – high-density Poly ethylene) regularly used in hardhat production. Based on applicable standards (EN 397 1995 – Industrial safety helmets), the shock absorption test (section 6.6, EN 397 standard) was simulated using the FEA approach for hardhats made of regular HDPE and E-glass chopped fibers (3D randomly dispersed) in an epoxy matrix. It was found that hardhats made of 3D random fiber e-glass composites in an epoxy matrix, for the fiber volume fraction that renders the equivalent strain field for the same impact energy can withstand higher stresses and improve the strength of the hardhat analyzed.*
Keywords: hardhats, safety, design, composite

1. INTRODUCTION

Construction hardhats, often simply referred to as "hardhats", are essential personal protective equipment (PPE) designed to safeguard the heads of workers in construction and related industries. Their primary function is to provide protection against potential hazards such as falling objects, impact from structural elements, electrical shock, and other workplace dangers. These rugged and purpose-built helmets have become an iconic symbol of safety on construction sites worldwide.
Incorporating advanced materials and ergonomic designs, modern hard hats offer a balance of durability, comfort, and functionality. They are engineered to meet stringent safety standards, ensuring that workers can perform their tasks with confidence and reduce the risk of head-related injuries. This introduction delves into the key components, material considerations, safety standards, and crucial design features that make construction hard hats an indispensable piece of protective equipment in the construction industry.
Construction hardhats, often colloquially referred to as "hardhats," stand as a stalwart shield against potential hazards on construction sites. These critical pieces of personal protective equipment (PPE) are purpose-built to safeguard the heads of workers, providing a vital layer of defense against falling debris, impact from structural elements, electrical hazards, and a range of other potential dangers prevalent in construction and related industries. As an iconic symbol of safety in workplaces worldwide, hardhats represent a commitment to the well-being of workers in environments where risks are inherent.
The history of hard hats is a testament to the evolving understanding of workplace safety. Early iterations were rudimentary, often consisting of leather headgear. It wasn't until the 20th century that more advanced materials and designs were introduced. The transition to materials like steel, followed by the development of fiberglass, and subsequently, high-density polyethylene (HDPE), marked significant milestones in the evolution of hardhat technology.

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The Key Components of a Construction Hardhat:

1. Shell

The outer shell of a construction hard is its first line of defense. Typically constructed from materials like high-density polyethylene (HDPE), fiberglass, or other advanced composites, the shell is engineered to distribute and absorb the force of impacts. Its robust design ensures that even in the event of a falling object or collision with a structural element, the force is dispersed across the surface, reducing the risk of injury to the wearer.

2. Suspension System

The suspension system is the internal harness that cradles the head and helps absorb and spread the force of an impact. It is designed to maintain a gap between the shell and the wearer's head, allowing for shock absorption and ventilation. Made of materials like nylon or high-impact thermoplastics, the suspension system is adjustable to ensure a secure and comfortable fit for individuals with varying head sizes and shapes.

3. Chin Strap (if applicable)

In environments where additional security is crucial, such as working at heights or in windy conditions, some hard hats include a chin strap. This accessory helps ensure that the hardhat remains securely in place, even during dynamic movements or adverse weather conditions.

A typical hardhat and its components are presented in the following picture:

Figure 1. Construction Hardhat
Source: Mooremcphee

Materials used in the construction of the hardhats nowadays are:

1. High-Density Polyethylene (HDPE)

HDPE is a popular material choice for hardhat shells due to its exceptional strength-to-weight ratio. Its high impact resistance makes it well-suited for protecting against falling objects and structural hazards. Additionally, HDPE's resistance to chemicals and UV radiation ensures the hardhat's durability, even in harsh environmental conditions.

2. Fiberglass Composites

Fiberglass composites offer a unique combination of strength, rigidity, and durability. They are often used in hardhat shells, providing robust protection against impacts. The composite nature of fiberglass allows for intricate designs while maintaining structural integrity.

3. Thermoplastic Resins

Certain hardhats incorporate high-impact thermoplastic resins in their construction. These materials provide flexibility and resistance to deformation, ensuring that the hardhat can absorb and distribute forces effectively.

To ensure the efficacy of construction hardhats, regulatory bodies like the American National Standards Institute (ANSI) and the European Committee for Standardization (CEN) have established rigorous safety standards. Compliance with these standards is paramount, as it guarantees that the hard meets specific criteria for impact resistance, electrical insulation, penetration resistance, and other critical safety parameters.

The standard for impact testing of hardhats varies depending on the region or country. Here are some of the most commonly recognized standards for impact testing of hardhats:

1. ANSI/ISEA Z89.1 (USA)

This standard is set by the American National Standards Institute (ANSI) and the International Safety Equipment Association (ISEA). ANSI/ISEA Z89.1 establishes requirements for the performance, testing, and marking of protective helmets, including hard hats, in the United States [1].

2. EN 397 (Europe)

This standard is applicable in European countries (also in Serbia as SRPS EN 397:2014). EN 397 outlines the requirements and testing methods for industrial safety helmets, including impact resistance, penetration resistance, and lateral rigidity [2,3].

3. AS/NZS 1801 (Australia and New Zealand)

This standard is applicable in Australia and New Zealand. AS/NZS 1801 specifies the requirements for industrial protective helmets, including impact testing, penetration resistance, and electrical resistance.

4. CSA Z94.1 (Canada)

The Canadian Standards Association (CSA) sets standards for various personal protective equipment, including head protection. The CSA Z94.1 standard covers requirements for protective headwear, including impact resistance.

5. JIS T 8131 (Japan)

The Japanese Industrial Standards (JIS) specify the performance and testing requirements for industrial safety helmets in Japan.

These standards typically include specific procedures and criteria for conducting impact tests on hard hats. They specify factors such as the size and weight of the impacting object, the height from which it is dropped, and the pass/fail criteria based on the amount of force transmitted to a head from inside the helmet.

It's important for manufacturers, employers, and workers to ensure that the hard hats used on the job site comply with the relevant local standards and regulations. Regular inspection and maintenance of hard hats are also essential to ensure they remain effective in providing protection. Additionally, hard hats should be replaced if they show signs of damage or have been involved in a significant impact.

In this paper potential use of 3D random fiber composites, in hardhat design is investigated, complying with the above-mentioned standards in order to improve workers' safety.

2. 3D RANDOM FIBER COMPOSITE MATERIAL ANALYSIS

3D E-glass random fiber composites (Figure 2) refer to materials that are formed by embedding randomly oriented E-glass fibers within a matrix material. E-glass is a type of glass fiber known for its high electrical resistance, good chemical resistance, and high tensile strength. It is commonly used as a reinforcing material in composite structures due to its excellent mechanical properties. In 3D E-glass random fiber composites, the E-glass fibers are arranged in a random orientation within the composite material. This means that the fibers are distributed in multiple directions, providing reinforcement throughout the material (3D).

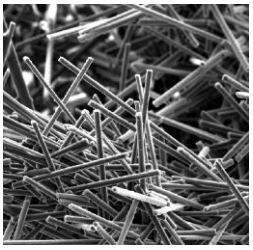

Figure 2. 3D random fibers SEM micrograph

Source: Markforged

A composite material is a combination of two or more distinct materials that, when combined, result in a material with improved properties compared to the individual components. In this case, E-glass fibers act as the reinforcing material, while another material (usually a polymer resin) serves as the

matrix that holds the fibers together. The term "3D" indicates that the E-glass fibers are distributed in three dimensions within the composite material. This means that the fibers are oriented not only along the length and width of the material but also in the thickness direction.
Overall, 3D E-glass random fiber composites are engineered materials designed to take advantage of the high strength and stiffness of E-glass fibers. The random fiber orientation provides reinforcement in multiple directions, leading to a material with enhanced mechanical properties.
Using the Finite Element Approach, the impact response as per EN 397 is performed. Material elastic coefficients required for the analysis are determined, as a function of the fiber type, matrix phase type, and the fiber volume fraction. When designing with composites it is always challenging to select the appropriate material theory for the problem in hand (composites are considered to be anisotropic) and correctly calculate material elastic coefficients (such as Young's moduli, Shear moduli, Poison ratios etc.) [5,6,7].
Several theories predict behaviour of 2D and 3D random fiber polymer composites. Assuming isotropic properties of repair material Pan's theory can be used to determine elastic parameters of 3D random fiber polymer material.
Defining a relationship between the fiber volume fraction V_f and the fiber area function A_f when fibers are not unidirectionally aligned and introducing probability density function defined by a pair of angles (Θ,Φ) in the spatial curvilinear coordinate system, the composite modulus can be expressed as (1):

$$E_c(\Theta,\Phi) = E_f \cdot \Omega(\Theta,\Phi) \cdot V_f + E_m \cdot (1 - \Omega(\Theta,\Phi) \cdot V_f) \tag{1}$$

In the preceding equation E_c is the modulus of the composite, E_f and E_m are moduli of constituents (fibers and matrix) respectively, V_f is fiber volume fraction and $\Omega(\Theta,\Phi)$ is the value of the probability density function in direction (Θ,Φ). In the case of three-dimensional random fiber orientation, the tensile modulus is given by:

$$E_c^{3D} = E_f \frac{V_f}{2\pi} + E_m(1 - \frac{V_f}{2\pi}) \tag{2}$$

and, the Poisson's ratio by the equation:

$$E_c^{3D} = E_f \frac{V_f}{2\pi} + E_m(1 - \frac{V_f}{2\pi}) \tag{3}$$

In equations (2 and 3) E_f and E_m are moduli of elasticity of fibers and matrix, and V_f, V_m are their Poisson's ratios. Using This approach, the elastic coefficients Can be determined, provided that the mechanical characteristics of the composite phases are known and the fiber and matrix volume fractions respectively.
In the present analysis for the materials coefficient's calculation the numerical approach for elastic coefficients calculation is deployed and is based on the lattice model [4]. The representative volume element (RVE) of 3D random fiber (E-glass/epoxy matrix) is presented in the following picture.

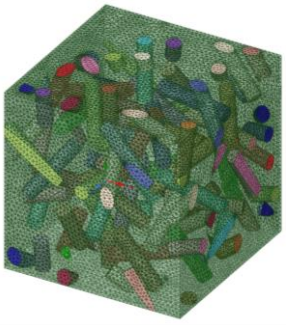

Figure 3. RVE model of 3D random fiber composite
Source: Fraunhofer

The obtained results for the material elastic coefficients are presented in the following table.

Table 1. Random fiber composite (e-glass / epoxy) with Vf=0.12 [-]

E1	5279.5	MPa
E2	5263.4	MPa
E3	5090.7	MPa
G12	1905	MPa
G23	1924.7	MPa
G31	1878.7	MPa
nu12	0.32249	
nu13	0.33662	
nu23	0.34352	

It can be seen that the material analyzed can be considered as quasi-isotopic, and these values are used in the further impact analysis.

3. IMPACT ANALYSIS

Based on the finite element approach, with respect to EN 397 standard, sec 6.6 the drop test on the hard hat top is simulated, and the results of the obtained stress-strain field are analyzed. Stress fields for the two identical hardhats (in the geometry domain) but made of different materials (HDPE and 3D random fiber composite e-glass /epoxy) are calculated and compared in order to justify to potential use of the composites (3D random) in the hard hat design. The finite element model, with the obtained stress field is presented in the following picture.

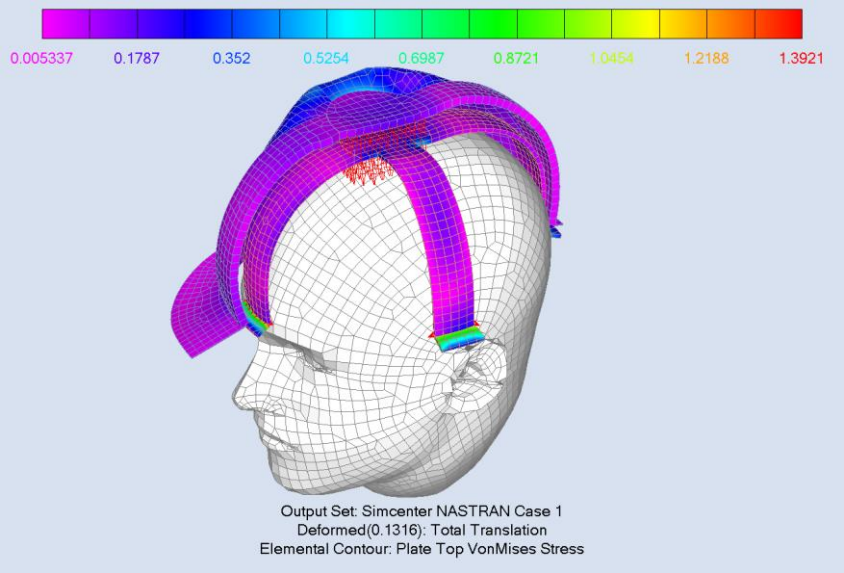

Figure 4. Hardhat Impact test FEA model stress-strain field

4. CONCLUSION

In the present paper potential use of composites in a 3D chopped fiber form is analyzed. Based on the standards applicable the impact test is simulated and the stress-strain fields for hardhats made of HDPE and 3D random fiber composites are compared.
It is found that for the volume fraction of e-glass fibers in an epoxy matrix that renders the same strain field as in HDPE material hardhat can absorb more energy before hardhat break (withstand higher impact loads), which makes the composite hardhats safer. Composites have the potential to withstand

higher impact loads than HDPE (high-density polyethylene) due to their unique material composition and hence represent good material candidates for construction hardhat design.
The recommendation for future work is to analyze other commercially available fibers, such as S-glass, and different carbon fibers, and to assess their potential use in hardhat application. Also, the impact analysis should be performed for the side and back impact.

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ENVIRONMENT AND SUSTAINABLE DEVELOPMENT. MECHATRONICS.
OCCUPATIONAL SAFETY AND HEALTH AND FIRE SAFETY.
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MECHANICAL ENGINEERING. ECOTOURISM AND RURAL DEVELOPMENT.

COST-BENEFIT ANALYSIS IN EMPLOYEE HEALTH AND SAFETY PROTECTION

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Abstract: *Cost-benefit analysis is becoming increasingly relevant in decision-making processes about the justification of investments in programs to lower the risk of disease and injury at work. Thus, the cost approach to risk reduction program investments is replaced by the investment method, and the financial approach to human resource management is replaced by the development approach. Employee health and safety are prioritized in the development strategy, making employees more satisfied, productive, and dedicated to their work and the organization in which they work. The research findings are based on an examination of a practical example using the net present value and simulation methods. All computations and simulations were carried out in an MS Excel spreadsheet.*
Keywords: Cost-benefit analysis, Net present value, Employees, Health and safety

1. INTRODUCTION

People work in complex organizational systems that are not fundamentally secure. People are the ones who create security, unlike organizational systems that put other, very often contradictory demands and expectations before them. Accidents at work can also happen in companies that are dedicated to occupational safety as much as possible. Accidents can cause injuries or injuries with minor or serious consequences. They also cause material losses due to downtime in production, and damage to work equipment or materials. Work-related injuries, illnesses, and deaths result in high economic costs for individuals, employers, government, and society. The negative effects of poor occupational health and safety management include costly early retirement, loss of skilled staff, absenteeism, and "presenteeism" (when employees come to work despite illness, thereby increasing the likelihood of errors), and high medical costs and insurance premiums. It is estimated that the social cost of work-related injuries and illnesses is 3.9% of global GDP and 3.3% of EU GDP, or at least 476 billion € every year [1].
Despite this, practice shows that the top management of numerous companies usually sees investments in the safety and health of employees as an additional cost, not as a benefit. Accordingly, the hypothesis of this paper was also set: The application of cost-benefit analysis in the evaluation of employee health and safety protection programs highlights the development of a more financial approach to human resource management. In order to prove the hypothesis, the results of the research are based on the implementation of a cost-benefit analysis on a practical example using the method of determining the net present value. Solving the problem will be presented not only mathematically, but also using an MS Excel spreadsheet.

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2. THEORETICAL BACKGROUND AND RESEARCH PROBLEM

Cost-benefit analysis is widely used in assessing the expediency of investments. The focus of this method is on the assessment of costs and benefits in the near and distant future. When it comes to financial investments in the protection of health and safety at work, the prevailing opinion is that such investments do not result in adequate financial returns. This leads to minimal, legally prescribed investments in the protection of the health and safety of employees and neglect of the health and safety function within the company. With a forensic approach to monitoring costs that arise as a result of accidents at work and related injuries, downtime in business, court costs, compensation, fines, etc., management can see the financial interest in investing in preventing their occurrence [2]. The necessity of a forensic approach is also confirmed by the fact that the indirect (hidden) costs of accidents at work can be up to 36 times higher than the direct (visible) costs. Direct costs are those costs that can be directly attributed to accidents at work and related injuries and deaths (costs of paid insurance, costs of damage to buildings, equipment, and vehicles, production losses, investigation costs, medical care costs, legal costs, death compensation costs, costs of permanent disability). Indirect costs refer to costs that are not covered by insurance and are less tangible costs [3]. They can be classified as costs arising from the diversion of time to deal with the consequences of an accident, which can also affect productivity, and they include: cleanup of the accident site, costs of hiring temporary equipment, waste disposal, temporary work, costs of consulting and hiring external experts, lost working time, sick pay, overtime and temporary work, and loss of business reputation [4,5,6,7,8].

Here, it seems appropriate to point out the division into corrective and preventive costs. Corrective costs are the result of accidents that have already occurred and their impact on the health and safety of employees and include the costs of wages during sick leave, overtime costs due to the compensation of injured workers, fines and compensation resulting from reduced productivity, costs of turnover, absenteeism, etc. Preventive costs are aimed at preventing accidents at work and worker illnesses and include investments in the safety of working conditions, protective equipment, education, preventive health examinations, etc. Management is most often focused on preventive costs, i.e. their minimization. Such an approach is especially pronounced in times of crisis. Therefore, the task of occupational health and safety experts is to convince management that higher preventive costs mean lower corrective costs, that is, that investments in programs to reduce the risk of accidents at work will result in greater benefits.

The benefits of managing employee health and safety can also be direct and indirect. Direct benefits of health and safety management include cost savings. Additional savings beyond accident costs include time savings, medical care costs, and possible reductions in accident costs as a result of improvements. Direct benefits include: reduction in insurance premiums; reducing litigation costs; reduction of sick leave costs; improving the rate of production and productivity and reducing the rate of accidents reducing material damage [5]. Indirect benefits include reduced absenteeism, improved corporate image, improved job satisfaction, reduced sick pay, less lost time, less overtime, and cleaning. Accordingly, occupational health and safety professionals must learn to speak a language understandable to management, which is the language of money. When it comes to protecting the health and safety of employees at work, it seems appropriate to point out that in recent times risk assessment is usually accompanied by a cost-benefit analysis. The task of such an approach is to evaluate all costs and benefits of control and risk reduction (cf. figure 1).

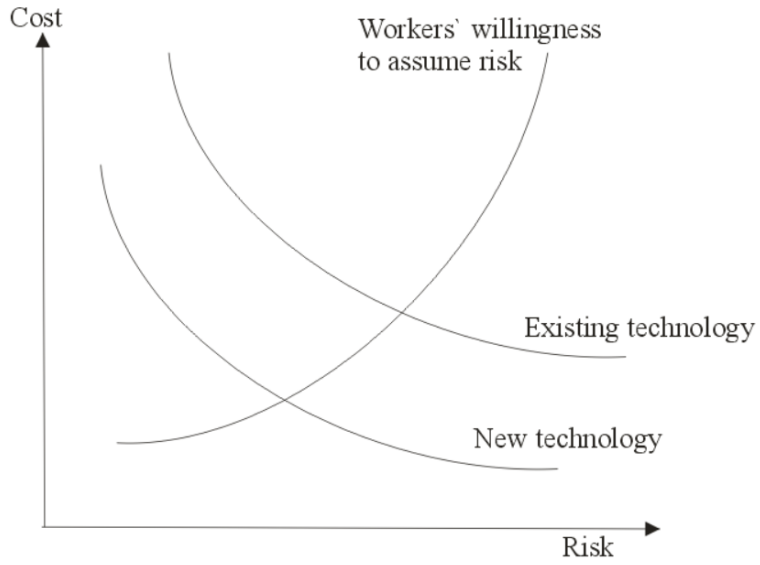

Figure 1. The impact of new technology on risk and health and safety costs
Source: authors` prepared according [9]

On the basis of Figure 1, it is clear that technological progress continuously contributes to the reduction of risks and the reduction of the total costs of protecting the health and safety of employees. Costs can refer to investment costs, maintenance costs, and training costs, while benefits can refer to reduced insurance premiums, higher work productivity, and better product quality. The rate of return on funds invested in risk reduction (except for the smallest ones) is usually estimated over a period of two to five years. Although the benefits are often very difficult to quantify, a cost-benefit analysis is helpful to estimate a certain level of costs with the aim of reducing potential risk.

3. MATHEMAICAL MODEL

When evaluating investment projects, and applying cost-benefit analysis, it is possible to use a number of methods, namely: the net present value method, the internal rate of return method, the benefit-cost ratio method, and the investment payback method. In this paper, the emphasis is on the method of determining the net present value. In this paper, the emphasis is on the method of determining the net present value. The mathematical model for conducting a cost-benefit analysis using the method of determining the net present value derives from the following relationship [10]:

$$\text{NPV} = \frac{B_0 - C_0}{(1+i)^0} + \frac{B_1 - C_1}{(1+i)^1} + \frac{B_2 - C_2}{(1+i)^2} + \frac{B_3 - C_3}{(1+i)^3} + \ldots + \frac{Bn - Cn}{(1+i)^n} \quad (1)$$

That is

$$\text{NPV} = \sum_{n=0}^{t} \frac{B_0 - C_0}{(1+i)^0} \text{ whit condition that NPV} \geq 0 \quad (2)$$

Where are:
NPV – net present value
B - benefits
C – costs
i – discount rate
n – number of years of project duration, from 0 to t
The alternative project or program that provides the maximum possible ratio of NPV ≥ 0, i.e. that provides the highest net present value, is acceptable.

4. DATA AND RESEARCH METHODOLOGY

For the purposes of this scientific discussion, the following practical example is presented. An employee health and safety specialist developed a three-year workplace risk reduction program at his company. It is a new technological procedure that will result in a reduction of the risk level from medium to low. The implementation of the risk reduction program requires initial costs in the amount of €30,000. After the first year, the costs of occupational safety management will be €6,000 higher. However, due to the reduction of the level, there will be a significant reduction in the number of accidents and accidents at work, the new management system will enable annual savings in the amount of €18,500. All amounts are given in current values. Table 1 provides an overview of the cash flow needed to perform a cost-benefit analysis.

Table 1. Overview of the expected cash flow of the proposed occupational health and safety program

Year	0	1	2	3
Estimated cash flow	0	18500	18500	18500
Estimated cash outflow	30000	6000	6000	6000
Estimated net cash flow	-30000	12500	12500	12500

Since the emphasis in this paper is on the method of determining the net present value, it seems appropriate to point out that future flows are discounted using the discount rate, i.e. reduced to the present value (e.g. at a discount rate of 8%, 100,000 € in 20 years is worth the current 21,454 .82 €). The discount rate can be seen as the rate of return required by the investor.

5. RESEARCH RESULT AND DISCUSION

Using the data from Table 1, based on equations (1) and (2), the net present value of the proposed risk reduction program for the workplace was calculated, assuming that the cost of capital (discount rate) is 10%. Such a high discount rate is a consequence of inflationary threats.

Table 2. Calculation of NPV of the proposed risk reduction program for the workplace (€)

Year	0	1	2	3
Estimated cash flow	0	18500	18500	18500
Estimated cash outflow	30000	6000	6000	6000
Estimated net cash flow	-30000	12500	12500	12500
Present value 1 €	1	0,9091	0,8264	0,7513
Present value = future value × p	-30000	11363,75	10330	9391,25
Net present value of the proposed program	-30000	-18636,3	-8306,25	1085

The net present value is greater than zero (€1085), which implies the justification of investment in reducing the estimated risk. The same result can be obtained much faster and more simply by using the MS Excel spreadsheet, that is, by applying the NPV formula in the spreadsheet (cf. Figure 2).

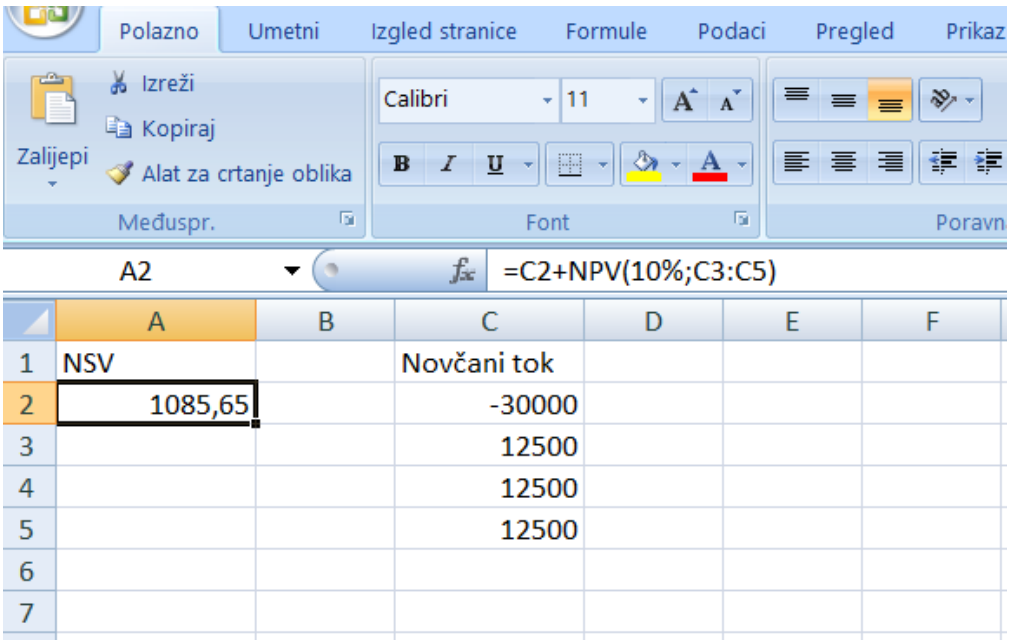

Figure 2. Calculation of NPV using a spreadsheet (in €)

Based on the data from Figure 2, it is clear that first in the address string C2:C5 the data on the predicted cash flow is entered, and then in the address field A2 the appropriate formula for calculating the net present value of the proposed investment (=C2+NPV(10%;C3:C5)). After the formula is entered and the enter key is pressed in the address field A2, the net present value of the proposed risk reduction program (€1085.65) will appear. This simple simulation model also enables numerous "what-if" answers. For example, if it starts from the assumption that investments in the risk reduction program should amount to €32,000 with an unchanged inflow and outflow of money in the three-year period, then the proposed investment would not be economically justified (cf. Figure 3).

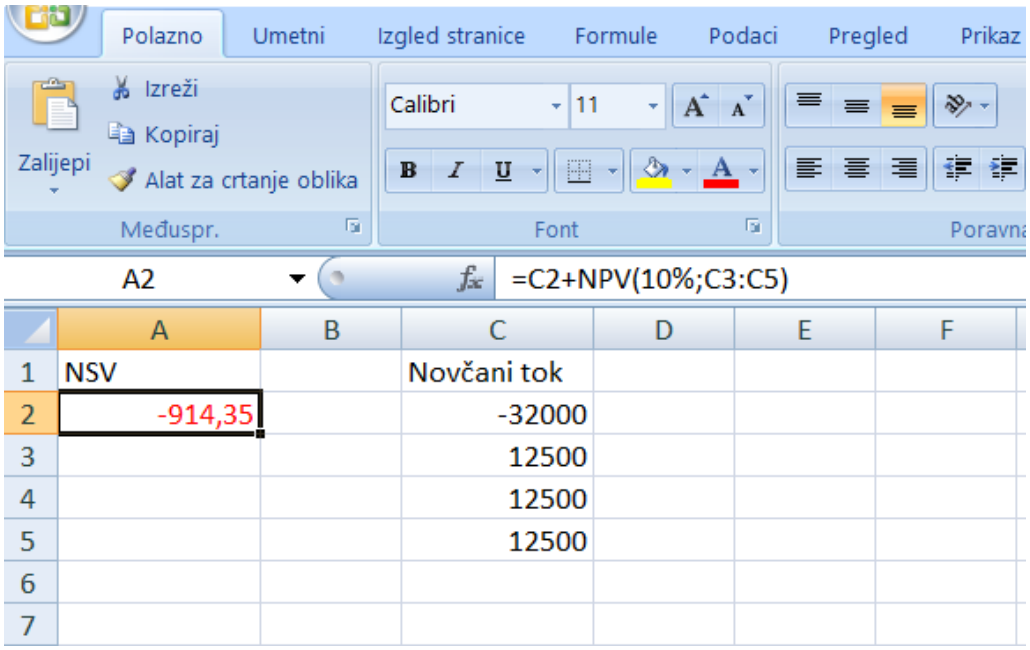

Figure 3. Calculation of NPV under modified investment conditions (in €)

Likewise, if due to high inflation it would be necessary to raise the discount rate to 13%, the investment would result in a negative NPV (-€485.59) and would not be economically justified. All lower discount rates of 13% result in a positive NPV and economic justification of the investment.

6. CONCLUSION

Cost-benefit analysis is increasingly used when assessing the justification of investment projects that aim to reduce risks in the function of protecting the health and safety of employees. Very often, these are investments that bring effects not only for employees and shareholders but also for customers, the environment, and society as a whole. Evaluation of the profitability of projects aimed at reducing risk is an indispensable tool for employees' health and safety protection experts in order to clearly present the economic profitability of such programs to company management. The net present value method represents one of the best approaches to the valuation of individual projects. The paper also demonstrated the effectiveness of the application of the spreadsheet in calculating the net present value and selecting economically justified projects with the aim of reducing risks in the function of protecting the health and safety of employees.

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CENTRALIZED INFORMATION SYSTEM FOR MONITORING WORKPLACE INJURIES

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Abstract: *This paper aims to point to the necessity of introducing a centralized information system in the Republic of Serbia for the software monitoring and analysis of workplace injuries as key indicators of the state of safety and health at work, and to explain the significance of the efficient management of a unique register of workplace injuries, in order to systemattoically act and indicate the necessary amendments to the current Law on safety and health at work. The adequate application of information technologies will enable more efficient risk management in the field of health and safety of employees, a quality analysis of the situation in the subject area with an emphasis on reducing the number of workplace injuries and an up-to-date status at all times, which would more effectively influence legal regulations, that is one of the priorities of the Republic of Serbia in its effort to raise safety and health at work to a higher level.*
Keywords: Safety & health at work, information technologies, software analysis, workplace injuries

1. INTRODUCTION

On 28 April 2023, the International day of safety and health at work, The National Assembly of the Republic of Serbia adopted a new Law on safety and health at work [1] (hereinafter: Law on SHW), which provides numerous changes to the previously defined terms of which we highlight the following below:

- The definition of workplace was changed and it now includes tasks the employee conducts in a working environment in which he/she is residing or has access to during work and which is under the direct or indirect control of the employer.
- The definitions of working from home, as well as work that an employee conducts using information and communication technologies from the place of residence and remote work conducted from another space that is not the residence of the employee, nor a space under the direct control of the employer, were included.
- Terms such as consultant for safety and health at work and associate for safety and health at work, instead of the term person in charge of safety and health at work, were introduced.
- A new term, the Register of workplace injuries as a centralized, electronically-managed database on workplace injuries, which is maintained based on the reports of workplace injuries, was introduced.

The need to introduce a new law after 18 years arose as a result of the changed working conditions. Although the old law partly encompassed working in a different environment, the COVID-19 situation resulted in the need to include working from home and remote work in the new law. The

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law provides the obligation of employers to conduct risk assessments and prescribe the measures for safe and healthy work from home and remote work.
Considering that the new Law on SHW has been in force since 7 May 2023, and taking into account that employers have a two-year deadline to align with the same, there is an obligation to align certain provisions immediately and before all the by-laws are adopted.
The by-laws adopted based on the old law continue to be applied until the passing of the by-laws provided for by this law, which will be passed within 18 months from the day the law came into force. This means that legal continuity has been established between the old and new laws.
Issues in the application of the law previously in force which business entities usually pointed to were reflected in, among others, the implementation of the risk assessment procedure and bringing an act on risk assessment, concluding the agreement on common implementation of safety and health measures at the workplace when several employers share a workspace, the inadequate transmission of the provisions of Directive 89/391/EEC related to organizing safety and health tasks at the workplace, monitoring of employees' health status, informing in a timely manner and cooperation with employees with a view to realizing rights and conditions prescribed by the law [2].
In the last few years, numerous workplace injuries have been recorded, so this new law encompasses this segment as well. The conditions for conducting high-risk jobs are tightened, but responsibility and monetary fines for employees who do not respect safety rules are introduced as well. For the employer, employee training in the field of safety as well as determining the procedure and way a work license is issued are mandatory. Also, the employer is obliged to refer an employee, upon his/her request, for a doctor's checkup at regular intervals. The new law introduces a centralized register of workplace injuries, on which this paper will particularly focus.
The Register of workplace injuries is a centralized, electronically managed database on workplace injuries, which is managed based on reports on workplace injuries. The Register of workplace injuries (hereinafter: the Register) in electronic form is established and led by the Administration for workplace safety and health, with the technical support of the Government service, which is in charge of the designing, harmonizing, developing and functioning of the electronic management system, for the purposes of maintaining statistics on workplace injuries.
The Register contains correct and up-to-date information on workplace injuries and enables users of the data to perform tasks of entering and downloading the data in order to determine the facts necessary for realizing health insurance rights. The Register uses valid codes and classifications.
The data users, in line with their responsibilities, access and use the Register by authorizing access to the Register or by using the data from the Register through a software solution of data users at a service bus of the organ or through a data exchange system. However, what this specifically means what responsibilities users have while entering workplace injuries into the electronic Register which obligations the employer has and what problems employees may face, we will consider later in the paper.

2. EXPERIENCES FROM THE INTERNATIONAL ENVIRONMENT FROM THE POINT OF VIEW OF KEEPING SOFTWARE RECORDS OF WORKPLACE INJURIES

Workplace injury as a term is often mentioned and analyzed both in theory and in practice, but further is a reason for a large number of disputes between employers and employees, not only in Serbia, but abroad as well. Due to this, in this next part of the paper, we will try to further analyze all the relevant aspects of this topic with the intention of especially putting an emphasis on the necessity of the software monitoring of workplace injuries and thus facilitate understanding the implications which follow an incident such as a workplace injury, which would create a more favorable situation in society and thus manage workplace injury records more efficiently, which would later contribute to more precise analyses and suggesting more innovative protection measures.
The rulebook [3] which regulates the current creation and delivery process of workplace injury and occupational disease report form (hereinafter: Report) to the Administration for workplace safety and health was last amended in 2019. It defines that the employer fills out the Report in five copies, at the

latest within 24 hours from finding out that a workplace injury or an occupational disease occurred. After that, all five copies were delivered to the healthcare institution where the checkup was conducted, within 24 hours from the moment of recording the data at the latest. The healthcare institution has a deadline of two days upon reception to fill out the Report and return it to the employer the next day at the latest. Here we can observe the first discrepancy between practice and regulations, since often this part of the process takes significantly longer. The reasons are usually justifiable, since due to the doctors' shift work, it is not possible to fill out the report within two days. When the employer receives all the copies of the Report from the healthcare institution, he/she has two days to deliver them to the competent branch of the Republic fund for health insurance. In the branch, all five copies of the Report are verified, one copy is kept and the other four are returned to the employer. Here, a deadline during which the Report has to be verified and delivered to the employer is not defined. At the end, the employer keeps one copy of the Report, one is delivered to the employee, one to the competent branch of the Republic fund for pension and disability insurance and one to the Administration for workplace safety and health.

2.1 A review of the applied solutions of reports of workplace injuries and occupational diseases in the European Union

The national program for adopting the acquis communautaire of the European Union (hereinafter: EU), adopted on 21 July 2022 [4] has in Chapter 19 – Social policy and employment, defined Serbia's obligation to align with the EU in terms of safety and health at work.
By analyzing the available data on the ways solutions are applied for recording workplace injuries and occupational diseases in EU countries and countries that have a special alignment of their social protection system relationship with the EU [5], we conclude that most countries practice the use of some sort of information system for recording. Most of them have kept the possibility of sending documents electronically, via email. Some of the analyzed countries still leave the option of delivering the documents in paper form.
A few countries have left the possibility of recording workplace injuries and occupational diseases on the part of the employee himself/herself or the doctor who conducted the first checkup directly through the information system for recording.

2.2 Tort liability of the employer abroad

Based on article 100 of the Law on SHW, a fine of RSD 1.5 million to 2 million (between USD 13,500 and 18,100) for an employer as a legal entity and from RSD 50,000 to 150,000 (around between USD 450 and 1,400) for directors, i.e., other responsible individuals, is prescribed if the employer does not report a workplace injury or occupational disease to the competent inspection.
By analyzing the available data in EU countries and countries that have a special alignment of social protection systems relationship with the EU, these amounts are up to a maximum of EUR 50,000 (USD 53,000) (for not reporting more serious workplace injuries or occupational diseases). However, in most countries, the prescribed fines for this kind of violation are within the same range as in the Republic of Serbia.

3. DATA ANALYSIS AND DISCUSSION

The solutions applied in the EU, the disadvantages of the current Rulebook, the provisions of the Law on SHW but also the existing e-Administration system implemented in various spheres of administration can point us to the direction in which we should go concerning the information system which would enable us to monitor workplace injuries and occupational diseases.
Connecting all the subjects in the process would result in significant time savings, better transparency in the process itself with the possibility of controlling the efficiency of each participant, and above all, transferring the biggest part of the communication from the business entity to the state institutions.

Since, if we recall the current process, the employer creates the Report, takes it to the healthcare institution, and then to the competent branch of the Republic fund for health insurance and at the end delivers it to the competent branch of the Republic fund for pension and disability insurance and the Administration for workplace safety and health. The goal of the information system would be to transfer all these steps (after the report is delivered by the employer) to the digital sphere and optimize the processing time, but also contribute to a better analysis of the data itself.

4. SUGGESTION FOR SOFTWARE IMPLEMENTATION

A software solution for managing business processes in the area of workplace safety can have significant connections to healthcare information systems in Serbia, especially in the context of advancing integrated healthcare and better healthcare data management.
It is necessary to provide maximum mutual interoperability of the central safety and health at work and the central healthcare information system at the level of the Republic of Serbia:

- Centralized monitoring and reporting on workplace injuries and occupational diseases will enable a comprehensive review of the health status of employees and identify samples of injuries or diseases connected to certain work tasks or environments.
- Efficient management of employees' medical records, including information on checkups, diagnoses and therapies. This is important for monitoring employees' health status and providing the appropriate healthcare.
- Data analysis can help in identifyingthe the need for preventive measures with the aim of reducing workplace injuries and occupational diseases. Based on this data, plans and strategies for improving safety and health at work can be developed.
- Using this system can improve employee awareness and responsibility..
- Integration with systems for managing the workplace can facilitate monitoring and reporting on workplace safety and health risks.
- A comprehensive assessment of the efficiency of the applied safety and health at work measures through monitoring changes in the health status of employees and the reduction of injuries.

A software solution for managing business processes in the area of safety and health at work can significantly improve the work of the healthcare service in several ways:

- Automatization and digitalization of different aspects of safety and health at work, including monitoring and managing incidents, report preparation, planning trainings and inspections. This decreases the need for manual processes and paperwork
- Better monitoring and reporting of safety incidents, workplace injuries and occupational diseases, as well as generating detailed reports. This helps the healthcare service to better understand workplace safety and health risks and to take preventive measures.
- Managing training and development is of crucial importance for ensuring that employees, who are generally with an appropriate level of digital literacy [6], are familiar with safety and health procedures and that they adhere to the standards.
- Monitoring equipment and assets and personal protective equipment, as well as their regular maintenance. This helps ensure that the equipment is in good condition and reduces injury risk.
- A documentation management system can serve as a central system for managing all documents and regulations related to safety and health at work. This makes documentation more easily accessible, enables the faster updating of policies and procedures and provides all employees access to current information.
- Increased compatibility can help the healthcare service be in alignment with all legal and regulatory demands regarding safety and health at work and reduce the risk of fines.
- Analytics and performance improvement help identify areas that require improvement. Based on these analyses, the healthcare service can bring better informed decisions and implement safety and health at work improvement strategies.

- Better communication and cooperation between employees, management and safety and health at work experts enables a faster response to incidents and exchanging best practices.

Here are a few crucial principles for developing this type of IS:

- **User-Centric Approach**: The main principle of the development of any information system is that it has to satisfy the users' needs. This means including feedback from employees who will be using the system. By using the user experience (UX) design, the system needs to be intuitive, easy to use, and to support users in performing their everyday tasks.
- **Cooperation with safety and health at work experts**: This system needs to be developed in close cooperation with safety and health at work experts in order to ensure that it is suitable for specific needs and standards in the area of health and safety. This also includes cooperation with doctors and medical staff in order to provide the correct use of healthcare data management.
- **Enable complete transparency:** All users need to have a clear picture of how the system works, how data is collected, stored and processed, and how decisions are made. Transparency is key in the field of healthcare information systems due to the confidentiality of healthcare data.
- **Flexibility and adaptability:** IS needs to be flexible and adaptable to changes in legislation, procedures and users' specific needs. This includes the possibility of faster implementation and updating of the system in order to follow the changes in the field of safety and health at work.
- **Alignment with legislation and standards:** The system needs to be aligned with all existing laws and regulations related to data privacy protection, the security of the information and other relevant areas.
- **Maintaining data safety and privacy:** Data safety is crucial in healthcare information systems, especially in the field of safety and health at work where sensitive information is handled. The system has to have strong measures of cybersecurity in order to ensure all data is safe and protected from unauthorized access and abuse.
- **Continuous user training and support:** User training and technical support need to be provided in order to help users use all the advantages of the system and solve problems.
- **Evaluation and improvement:** Regular system evaluations need to be conducted in order to establish its efficiency and identify potential problems.

5. CONCLUSION

Based on article 69 of the Law on SHW, the data is entered into the Register by the employer. The Register takes the data from the integrated healthcare information system of the Republic of Serbia and the information system of the institution competent for health insurance. The employer, i.e., the competent authorized official of the employer who records the data in the Register, enters the data of the employer, i.e. the user employer or the natural person employer, of the injured individual, of the workplace injury, of the direct supervisor and of the witness. The employer is obliged to electronically deliver the data of the authorized official who conducts the data entry to the Administration for workplace safety and health. When the employer enters the data in the Register, the chosen doctor, through the integrated healthcare information system of the Republic of Serbia, enters the findings and the opinions of the doctor who conducted the first checkup of the injured. After the chosen doctor enters the data, the organization competent for health insurance, through the information system, enters the workplace injury assessment. The Administration for workplace safety and health keeps a record of the authorized official. According to the aforementioned, the question of implementing mandatory integrated training of all the aforementioned persons with the aim of efficiently conducting the defined process is raised.

Based on Article 70 of the Law on SHW, data exchange is conducted in line with the regulations governing electronic administration. The employer, chosen doctor and organization competent for health insurance are responsible for the accuracy of the entered and downloaded data in the Register.

Enabling access and data access protection measures in the Register are conducted in line with the regulations governing the field of electronic administration, electronic identification and information security. The Register is located in the State center for data storage and management which secures the physical protection of the data in line with the law governing electronic administration and information security.

It is in the interest of society, all the subjects and each individual to realize the highest level of safety and health at work, so that unwanted consequences such as workplace injuries, occupational diseases and diseases related to work are reduced to the smallest extent possible, i.e. to realize working conditions in which the employee would be satisfied when conducting his/her professional tasks, but also securing the credibility of the electronically gathered data with the aim of quality analysis of workplace injuries. To achieve this goal, a systemic approach to preventive action and connecting all subjects who are the bearers of certain obligations and activities at the national level compatible with international institutions in this area is necessary. It is their duty to take care of the implementation of the established rules, measures and standards on working conditions and their constant concern with their amending and harmonizing with the technical-technological and socio-economic development in order to enhance employees' safety and preserve their health. Perhaps passing special by-laws that would prescribe mandatory software training for employer's representatives who will be in charge of entering the data in the electronic database should be considered, which would further organize this area.

The view of using modern technology with new content of work requires new skills and constant innovation (the use of drones, IoT-Internet of things, 5G, AI-Artificial intelligence) for the successful conducting of work tasks, as well as the efficient delivery of information, should be considered. These changes certainly require a new way of organizing safety and health at work tasks with a view to realizing safe working conditions, the realization of which should catch up with technical-technological progress as soon as possible.

The development of an information system for managing business processes in the field of workplace safety requires careful planning and the application of certain principles in order to achieve successful implementation. For the successful realization and integration of a central safety and health at work information system and a healthcare information system, cooperation between the sectors of safety and health at work, medical staff and IT experts is necessary.

Improving safety and health at work through software solutions can not only reduce workplace injuries and occupational diseases, but also lead to more efficient work of the healthcare service and a better employee experience.

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SAFETY CONCERNING CABLEWAYS

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Abstract: *Modern cableways represent a highly efficient type of transport over short and medium distances for the transport of people and materials with particularly pronounced advantages when operating in mountainous and inaccessible areas. As such, they are defined by safety regulations that determine the conditions for construction, reconstruction, maintenance, etc. At the beginning of the paper, the basic elements of the cableway will be presented. Next, an overview of the most important standards regarding the safety of cableways will be given. Finally, an analysis of incident situations on passenger cableways that have occurred throughout history will be done.*
Keywords: Safety, Cableway

1. INTRODUCTION

Modern cableways represent a highly effective type of transport over short and medium distances (2÷50 km), for transporting people and materials with particularly pronounced advantages when operating in hilly and inaccessible areas. In a broader sense, they represent a continuous transport device where the carrying and pulling element is a rope. They can work on the most difficult terrains with large height differences in the level of the end stations, they enable bridging inaccessible terrains of over 500 m, while overcoming climbs of over 45°, which depends on the relief of the terrain through which the cableway passes. In mountain conditions, cableways have many advantages over other modes of transport, and sometimes they are the only possible solution. In cableway transportation, energy consumption per ton of transported material is very low and the utilization rate of the entire system is very high, reaching up to 95% [1].
Cableways provide very economical transportation, even on completely flat terrain, where they are a more favourable solution than truck transportation with the construction of a new road or than using belt conveyors. Transportation by cableway is 3÷5 cheaper than transportation by trucks [2].
The basic parameters of the cableway are capacity, speed, length, height difference of the end stations and useful load of the trolley. The development of cableways means, first of all, an increase in capacity, which can be achieved by adopting higher cableway speeds, increasing the useful load and reducing the distance between trolleys. The length of the lines of passenger cableways is several kilometres, where the speed and number of people, i.e. the carrying capacity of the trolley, are determined by the specific type of cableway. For fixed cableways with a circular flow, speeds range up to 2.5 m/s. The speeds of single and double rope cableways with a circular motion are limited to 4 m/s, with a capacity of up to 2,000 people/hour. In contrast to them, the speeds of double rope cableways with alternating movement are up to 10 m/s. With freight cableways, it is possible to use higher movement speeds because it is not necessary to meet the conditions of driving comfort and strict regulations for the safety of individual parts of the cableway. The number of people in passenger cableways depends on the shape of the trolley [3]. The number of people is limited to 15 in unescorted cableways and there is no limit to the number of people in escorted ones.

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In the past, in most countries of the world, cableways were used to access remote mountainous areas and inaccessible terrains. In modern times, except in ski centres, in tourist centres there are requests for this type of passenger transport, Figure 1.

Figure 1. Cableway Kotor-Lovćen, Montenegro
Source: www.vijesti.me

2. CABLEWAY BASIC ELEMENTS

Cableways are complex mechanical and construction systems made up of a large number of different elements and objects. Here, only the basic mechanical equipment will be processed, which includes steel ropes, trolleys and towers attached to the cableway line and the characteristics of the drive and tension mechanism as station equipment with their mechanization-automation.

2.1 Steel ropes

Depending on the type of cableway, the steel rope appears as a carrying and pulling rope in double rope cableways and as a transport rope in single rope cableways. The cableway trolleys move on their wheels on a carrying rope that is anchored at one end and tightened at the other by a tension weight. The pulling rope is an endless flexible element to which trolleys are tied at a certain distance. By moving the pulling rope, the trolleys on the carrying rope also move. In single rope cableways, the role of the carrying and pulling rope is taken over by one, the so-called transport rope.

2.2 Trolleys

Trolleys consist of three characteristic parts - the lower part for accommodating cargo or passengers, the middle part representing the frame and the upper part - the driving part. In single rope cableways, the trolleys are firmly connected to the transport rope during movement between stations, while in double rope cableways, the trolleys are firmly connected to the pulling rope and move along the carrying rope via a set of wheels. Trolleys can be open or closed.

2.3 Clutches

Clutches are an integral part of the trolley through which it is attached to a rope. Clutches represent the most delicate part that must work with high reliability. Depending on the type of cableway, there are fixed clutches of single rope cableways, separable clutches with springs that are used in single rope and less often in double rope cableways, and gravity clutches of double rope cableways. Clutches must meet the following conditions:

- the resistance to slippage of the clutch on the rope must be within certain limits - the minimum value must be sufficient to transfer the resulting tangential force, and the maximum value must allow slippage in exceptional circumstances to prevent cableway damage;
- in the case when the rope is stretched during work, i.e. reduced in diameter, the clamping force of the clutch must remain within the permitted limits;
- the clutch must not damage the rope;
- fixed clutches must allow simple movement and easy control of the rope inside the clutch;
- clutches must not cause large shocks when passing over the wheels of the wheel battery;
- clutches must not be opened under the influence of a negative load.

2.4 Towers

The steel ropes on the cableway line rest on towers. Steel towers of grid construction and reinforced concrete towers are used.

2.5 Station equipment

At the end of the cableway line, there are stations that, depending on the purpose, can be loading or unloading, i.e. driving, tensioning or bending. Although the aim is for the route of the cable car to be a straight line connecting the end stations, in some cases, due to unfavourable relief or environmental requirements, the route can be a curved or broken line.

3. SAFETY REGULATIONS

Directive 2000/9/EC defines conditions for the construction, reconstruction, maintenance and other requirements for cableways, conditions for passenger cableways for the protection of health, personal safety and property safety, safety components of passenger cableways, management of passenger cableways, etc. This directive covers many standards, and only the most important ones will be given here.

3.1 EN 1709 – Inspection, maintenance, operation control and pre-commissioning checks

During the implementation of these activities, dangerous situations may occur. It is possible to prevent them by applying this standard. Some of these situations are non-compliance of the construction with the documentation; malfunction of individual components; defects caused by long-term operation; insufficiently qualified and trained persons in charge of inspection and maintenance; incorrect installation of components; the absence or non-compliance with the procedures of prescribed security measures and dangers originating from the environment.
It is necessary to apply the following safety measures in order to eliminate dangerous situations - inspection before commissioning, to confirm the correctness of all components; regular maintenance; regular inspections and checks to determine the working characteristics of the device and all activities should be performed in accordance with prescribed safety measures.

3.2 EN 1908 – Rope tensioning devices

Due to inadequate tensioning of ropes, dangerous situations can occur. Some of the possible dangerous situations are exceeding the permissible limits for tension and variations in the length of the rope; exceeding the permissible limit values of the pressures in the hydraulic tensioning device; rope jamming or pinching; improper operation of the tensioning device; improper behavior of persons near the tensioning device, etc.
Safety measures that can be implemented to eliminate the above dangerous situations are ensuring that the tension of the rope is maintained within the permissible limits; prevention of mechanical failures of hydraulic components, as well as systems for measuring force and pressure; prevention and detection of failure of tensioning devices, etc.
Modern cableways have a device for measuring and wirelessly sending data about rope tension, Figure 2. After being installed on the cableway, it reads and sends data in real time, based on which the rope tension can be adequately corrected. The device has the ability to read the value of the tension force for different dimensions of the rope. The rope is placed between three pulleys and due to the pressure exerted by the rope on them, the tension of the rope can be determined. If the force falls below the permissible limit, a signal is sent wirelessly that activates the rope tensioning device.

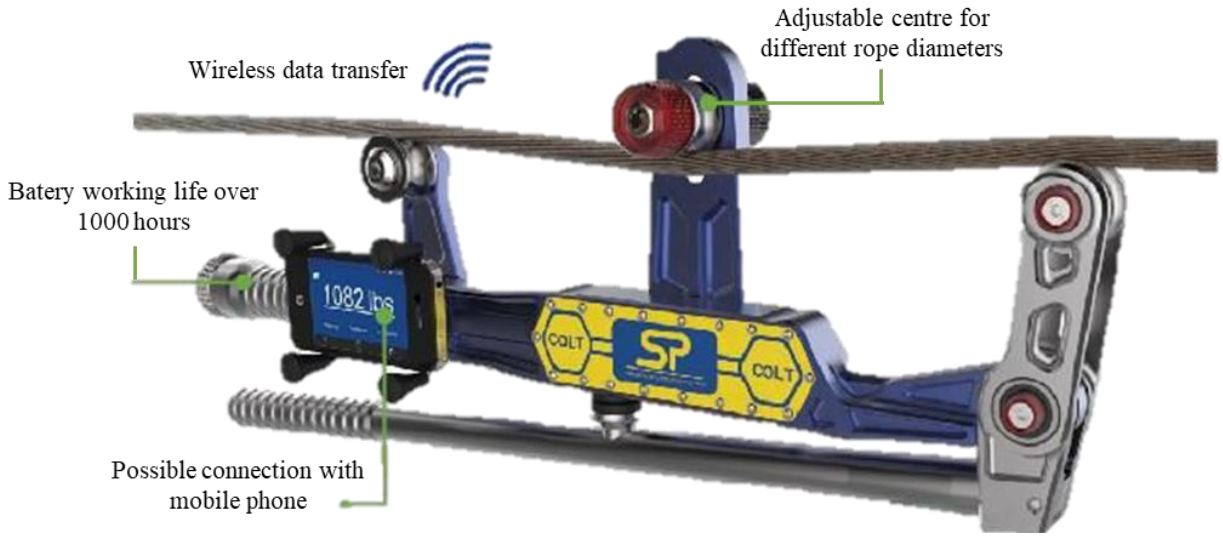

Figure 2. Rope tension measuring device
Source: own archive

3.3 EN 1909 – Rescue and evacuation

Events that can lead to dangerous situations, which can be avoided or limited by applying the safety requirements of this standard, are prolonged exposure to bad weather conditions such as wind, cold, snow, freezing rain; prolonged stay on the cableway; incompetence, incapacity or negligence in the rescue operation of passengers; absence or inadequacy of work organization and rescue organization; inappropriate behaviour of passengers.
All cableways should be designed, constructed and built in such a way that in the event of prolonged downtime it is possible to quickly inform passengers and ensure their safe return, i.e. descent within a reasonable time without jeopardizing their safety or the safety of the personnel responsible for the evacuation. In such circumstances, it is most desirable to return the passengers to the exit stations, and if this is not possible, then it is necessary to evacuate the passengers in accordance with the previously determined evacuation plan. Evacuation is carried out by trained rescuers using appropriate equipment. They approach the passenger trolley via a rope, descend to the passenger and put a safety belt on them, which allows them to safely lower the passenger to the ground. Figure 3 shows the evacuation procedure and the safety belt.

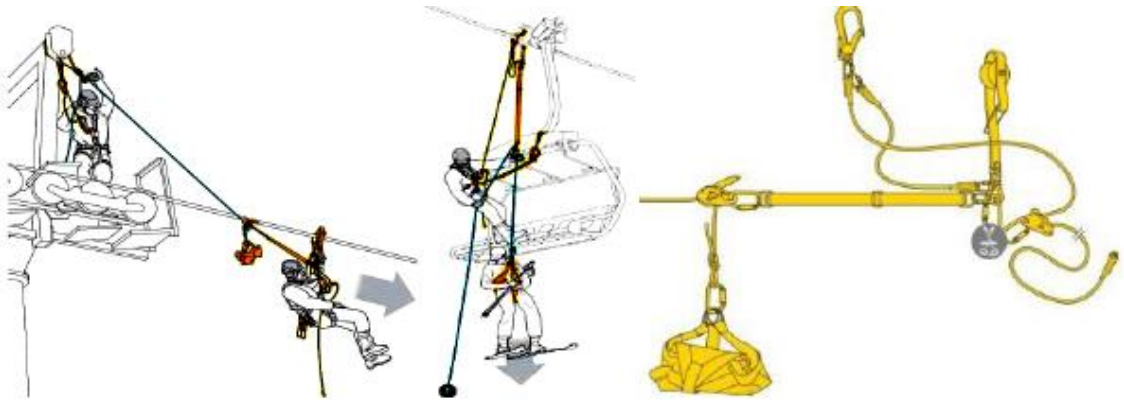

Figure 3. Evacuation procedure and the safety belt
Source: own archive

3.4 EN 12927 – Ropes

Within this standard, there are several sections dealing with safety measures related to steel ropes used in cableways.
In section EN 12927-1, the standard deals with the adequate selection of ropes and connecting elements in order to avoid breaking the rope or failure of the function of the connecting elements, as well as deterioration, i.e. rope damage.
In section EN 12927-2, the standard deals with the safety factors that must be taken into account to ensure the required level of safety for steel ropes – tension factor, bending coefficient and transverse force factor.
In section EN 12927-3, the standard deals with the safety requirements that apply when joining the steel waists of ropes.
In section EN 12927-4, the standard deals with joining and fixing the ends of steel ropes by solid casting, click steel clamps, steel clamps with screws, tension pulley, pressed ends with aluminum eye, steel slings.
In section EN 12927-5, the standard deals with methods of storage, transport and installation of steel ropes. Ineffective protection of the rope during storage can lead to corrosion which can cause premature deterioration of the rope. During transportation, care must be taken that the rope rolls are fixed, and during installation, it is necessary to properly unwind the rolls so that the ropes are not damaged.
In section EN 12927-6, the standard deals with the criteria for replacing ropes. It is necessary to monitor the condition of the rope, especially its diameter. Excessive reduction of the cross-sectional area of the rope may lead to breakage, breakage may occur if corrosion is present, etc.
In section EN 12927-7, the standard deals with safety requirements for inspection, repair and maintenance of steel ropes of passenger cableways. The appearance of deposits on the surface of the rope can lead to the failure of the components of the cableway, such as the clutch.
In section EN 12927-8, the standard deals with the magnetic testing of ropes.

3.5 EN 12929 – General regulations

Within this standard, it is defined that all cableways must be constructed in such a way that the risk will be avoided or limited by appropriate design or construction measures. Furthermore, it indicates the necessity of taking protective measures in relation to the remaining risks that cannot be avoided by design or construction. It defines the precautionary measures that must be taken and the responsible persons informed about them, in order to reduce the risk that could not be completely avoided by previous preventive and protective measures. It is necessary to take into account dangers such as passenger falls, passengers' limbs being caught by elements of the cableway, damage to passenger health due to exposure to adverse weather conditions, etc.

4. CABLEWAY ACCIDENTS

Analysis of accidents is carried out in order to determine the cause and to prevent potential future occurrences of a similar kind. These analyses are performed by experts including forensic specialists, engineers or health and safety consultants. Table 1. gives a list of accidents on passenger cableways with a description of the causes.

Table 1. Accidents on cableways
Source: *own archives*

Year	Description	No. of casualties	Country
1976	Cable failed, 2 trolleys fell on the ground.	42	Italy
1978	Cable failed, trolley fell on the ground.	4	USA
1979	Trolley fell on the ground because of a structural failure.	1	Switzerland
1983	Ship cut the cable, 2 trolleys fell on the ground.	8	Singapore
1984	Trolley fell on the ground because of a structural failure.	1	USA
1989	Trolley fell on the ground because of a structural failure.	8	France
1990	Trolley fell on the ground because of a structural failure.	1	Switzerland
1990	Cable failed, trolley fell on the ground.	15	USA
1991	Unknown reason.	1	Austria
1991	Cable failed, trolley fell on the ground.	2	Venezuela
1992	Cableway trolley became detached from its cable.	3	Slovenia
1993	Cableway trolley became detached from its cable.	1	Austria
1996	Trolley fell on the ground because of a structural failure.	1	Switzerland
1998	Airplane cut the cable, trolleys fell on the ground.	1	Austria
1999	Cableway trolley became detached from its cable.	20	Italy
2003	Cableway trolley became detached from its cable.	7	India
2003	Cable failed, 3 trolleys fell on the ground.	4	India
2005	Concrete block was dropped from a helicopter on a trolley.	9	Austria
2007	Trolley fell on the ground because of a structural failure.	4	India
2021	Cable failed, trolley fell on the ground.	14	Italy
2021	Cableway trolley became detached from its cable.	1	Czechia

5. CONCLUSION

Judging by the current trend, it is to be expected that cableways will be used in the future in the form of cableways with cabins. Open and closed cabins, for comfortable and convenient transport, enable the popularization of this type of urban transporter. The basic requirements that are put before manufacturers are an increase in capacity, an increase in line speed, an increase in the number of passengers in the cabin, additional safety, an increase in the automation of mechanical components, all with the aim of achieving additional safety and minimizing operating costs.

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BASIC SAFETY MEASURES FOR CHAIN CONVEYORS

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Abstract: *Conveyors with a pulling element in the form of a chain, so-called chain conveyors, belong to continuous transport devices. After the adoption of the new Rulebook on the procedure for inspecting and checking equipment for work and testing the conditions of the working environment, they are also subject to periodic inspections and checks, which was not the case in Serbia until now. These conveyors are often of closed construction, so the only places where injury can occur are the loading and unloading area, as well as on the elements of the drive mechanism. This paper will provide basic guidelines on how to implement basic safety measures for chain conveyors.*
Keywords: Safety, Chain conveyors

1. INTRODUCTION

A special group of transport machines with continuous operation consists of conveyors in which a chain appears as the pulling element, and the carrying element is adapted to the purpose of the conveyor, according to which plate, bucket, scraper and overhead conveyors are distinguished.
Plate conveyors are used for transporting bulk and piece material under very difficult working conditions - abrasive materials, material at high temperatures, castings, heavy machinery, etc. These conveyors have found application in various branches of the industry, primarily in mining, metallurgy, chemical, cement and metal industries, for the transport and handling of heavy objects. They are also used in technological processes where, in addition to transportation, certain technological operations are performed (heating in furnaces, cooling, drying, tempering, dyeing, etc.) and during the assembly of heavy machinery. Recently, they have been widely used as feeders and dispensers in loading bunkers [1].
Scraper conveyors are used exclusively for transporting bulk material. The basic characteristic of these conveyors is that the material is pushed in stationary gutters (grooves) by means of pushers - scrapers connected to one or two pulling chains. Scraper conveyors with one chain are used for small widths (<400 mm), and two chains are used for larger widths. These conveyors are not suitable for transporting wet and sticky materials, which stick to scrapers and gutter walls and create difficulties during loading and unloading, which significantly reduces the capacity of the conveyor. They are also not suitable for the transport of highly abrasive materials, which wear out gutters, or for the transport of brittle materials that lose their quality when crushed. Materials heated up to 300°C can be transported.
Bucket conveyors are used to transport bulk materials. The pulling elements of these conveyors are two lamellar chains. Unlike elevators, they can also transport material horizontally, that is, to have a complex route with a closed contour in the vertical plane.
Overhead conveyors are primarily used for the transport of piece material along a complex spatial route. The characteristic of these conveyors is the installation of a supporting structure above the working space (under the ceiling) on which the trolley moves, with a supporting element, which are connected to each other by a pulling chain. These conveyors have a very important role as a means

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of internal transport in assembly plants and warehouses. They are suitable for performing certain technological operations during transportation: assembly, mechanical cleaning, painting, heat treatment, quality control, etc. Thanks to the characteristics of these conveyors, complete automation of the production process is possible.
The paper will describe the safety measures that must be taken when installing chain conveyors and that must be followed during use in order to avoid injury to people and damage to equipment. Since the safe maintenance of conveyors is of vital importance, safety procedures will be explained when approaching mechanical and electrical work on conveyors.

Figure 1. Plate, overhead and scraper conveyors
Source: own archive

2. SAFETY WITH CHAIN CONVEYORS

Conveyors are safe when used properly but can be very dangerous if operators do not follow safety procedures when working on or around them. The transported material should be safely loaded onto the conveyor in order to be transported. In the case of manual unloading of piece material from the conveyor, personel must be especially careful as the material can create pinch points. The way someone is dressed, loose clothing, long hair and jewelry, when working on or around the conveyor can pose a risk of entanglement in the moving elements of the conveyor. When repairing or cleaning the conveyor, all moving elements of the conveyor must be locked or blocked, and the operation controls marked. If it is necessary to clean chains or sprockets while the conveyor is in operation, it is necessary to ensure that the protective elements are in the appropriate place and that no part of the equipment can be accessed. There are other general precautions that everyone should follow, even if they don't work directly with conveyors. No one should ever climb over or crawl under moving parts of the conveyor and never ride on it. It is necessary to pay particular attention to the maintenance and inspection of electrical equipment and devices. All personnel working on or around the system should be aware of and adhere to the prescribed rules [2].
There are many hazards associated with working on or near conveyors, including:

- rotating parts or nip points;
- confined or prefabricated areas (the area between a fixed and a moving object) that can be sheared or crushed;
- parts that slide or reciprocate (press) can be crushed;
- objects that can break or be thrown out of the transport system;
- objects that can fall from the conveyor;
- danger of electricity, fire or explosion.

When an employee works near any conveyor, it is necessary to:

- wears protective equipment;
- ties (and tucks in) long hair;
- knows the location of the emergency "shutdown" device and how to use it;
- ensure that all protective devices, including cages, barriers, guardrails, warning signals and other required safety devices are in place and working;
- knows how to work safely around machinery.

On the other hand, it is forbidden to:

- loose clothing or jewelry is worn;
- climbs, steps, sits or rides on moving elements of the conveyor;
- guards or safety devices are changed or removed;
- jammed objects or debris are removed until the conveyor is switched off and locking is ensured;
- the conveyor is serviced without following lockout procedures.

In order to ensure adequate security, the following steps should be followed:

- implement a training program - only technicians and operators trained to work on the conveyor should be allowed access to its controls or perform service and repair procedures. In addition to safety programs based on Occupational Health and Safety Administration standards, each manufacturer must provide operating, maintenance and installation instructions with the conveyor, which should be used to educate personnel about the equipment and its proper use;
- use safety markings - safety markings are placed on and around the conveyor. These visual signals alert personnel to various potential hazards presented by the equipment, including moving parts, high voltage, pinch points, protection requirements, safe maintenance procedures, contact avoidance, etc.;
- place physical barriers - to prevent personnel from walking or working near the conveyor, place safety barriers or warning colors on the floor to warn operators of the potential danger of getting too close to the equipment;
- do not touch or ride on equipment while in operation - notify personnel of hazards, such as injury or death, associated with climbing, sitting, standing, walking, riding, or touching conveyors during operation;
- allow only qualified, trained personnel to perform maintenance - only technicians and operators trained in the use of the conveyor should be allowed to access its controls or perform service and repair procedures;
- disconnect all power sources before maintenance - all power systems should be locked, blocked or released before servicing the conveyor. The same goes for clearing jams.
- use safety guards - make sure guards and covers integrated into the conveyor are always in place and secure before operation;
- adhere to defined capacity - conveyors are designed to match specific application requirements on load size, weight, shape, distribution, speed, etc. Do not introduce new conveyor materials, without first ensuring that they are in accordance with the designed specifications, otherwise stalling, motor overload, chain breakage, product damage or load falling from the conveyor may occur, increasing the risk of personnel injury;
- use the controls correctly - do not modify or alter the conveyor controls.

3. SAFETY CONTROL DEVICES ON CHAIN CONVEYORS

3.1 Emergency stop controls

Chain conveyors must be provided with controls to stop the conveyor or conveyor system in an emergency. These stop commands are activated manually. The electrical circuit in which the emergency stop controls are implemented should be designed to be safe and effectively protected against failures. Emergency stop controls shall be capable of being operated with minimal effort without danger to the operator and shall be provided where the operating control is clearly visible and readily accessible even to inaccessible conveyors.
Emergency stop controls are provided as follows:

- for conveyors not longer than 2.5 m located less than 2.5 m above the floor, passage or platform - one control in the middle of the conveyor;

- for conveyors longer than 2.5 m located less than 2.5 m above the floor - one control at the ends and at intervals not exceeding 30 m along the conveyor;
- for conveyors placed more than 2.5 m from the floor - in accessible locations at intervals that do not exceed 100 m along the conveyor;
- in positions near the conveyor where the conveyor can be started.
- at each permanent workstation.

Lock-out or Tag-out is a basic procedure that protects people who could be exposed to dangers and risks due to service or maintenance work on the device. The lock-out procedure represents the application of physical locking and preventing access to energy sources on the device. Energy sources can be mechanical, electrical, pneumatic or hydraulic. In this way, the power source is turned off, and there is a clear label on it that warns all personnel in the area. When several people perform tasks as part of a more complex system, it is necessary to apply group locking of the energy source using folding scissors. In this way, each person separately locks the scissors with their own padlock, that is, interrupts the energy selection [3].

Figure 2. An example of a stop button, an isolation switch and a protective grid
Source: own archive

3.2 Remote isolation device

Where it is necessary to remotely isolate a conveyor, the following shall be provided for this purpose:

- the device must be locked in the isolated position and be of the manual reset type;
- the device should isolate the energy source from the drive system:
  - direct isolation of energy sources;
  - indirect isolation of energy sources through the management system;
- when indirect isolation of the energy source through the control system is used, the following shall be reported:
  - the remote isolation device shall cause the isolation of the drive energy from the conveyor through at least two independent means to ensure the integrity of the system;
  - a system must be provided that indicates on the remote isolation device that the drive energy is isolated;
  - a warning system is provided before starting.

3.3 Pre-launch warning system

Where an otherwise uncontrolled hazard may arise when a conveyor or conveyor system is started, an automatic pre-start warning system will alert people to the fact that the conveyor is starting to operate and a potential hazard exists. The system should be in the form of a visual or audible warning within an appropriate time limit given before the conveyor is started. Where audible or visual warnings are provided, they must not be a substitute for physical protective measures.

3.4 Marking of control devices

Any manual stop, start, or other function control shall be marked with markings, signs, or labels in writing that clearly indicate the purpose of the control. Notwithstanding the generality of this requirement, the following also applies:

- emergency stop devices must be marked with a sign;
- emergency stop device actuators must be colored red;
- signs must be placed at each end and every 30 m along the conveyor where an emergency stop rope is used;
- provided isolation devices must be marked with signs that clearly indicate the function and purpose of the device.

3.5 Physical protection

A physical barrier is the most effective means of protection against dangerous points on conveyors. It is a means of physically preventing access to hazardous areas and is a legal requirement. Guards will be designed and installed in accordance with the requirements of occupational safety and machine safety. Guards should be designed to prevent:

- for persons to enter the danger zone;
- that clothes and hair or other parts of the body are caught by moving parts of the conveyor;
- risk of component failure;
- unintentional contact with a dangerous point on the conveyor;
- inadvertent contact with hot or hazardous fluids from fluid couplings or torque converters.

All guards shall be secured so that they cannot be removed without the use of tools unless an interlocking device is provided to automatically stop the conveyor in the event of the guard being removed. Guards should be designed so that they do not need to be removed for minor servicing (e.g. lubrication) or for inspection purposes. Guards must be made of solid material, mesh or equivalent construction. The thickness of the sheet protector must not be less than 1.5 mm. Protective nets should not be less than 1.5 mm wire thickness, or 3 mm for 50 mm square nets and more.

3.6 Places for loading and unloading

Wherever a person has access to a loading, unloading, work station, transfer or unloading area, guards in the form of a fence are installed.

3.7 Safety in mechanical and electrical maintenance

Conveyor lubrication is done when they are not in motion. Only trained personnel who are aware of the dangers of a moving conveyor should be allowed to lubricate an operating conveyor. After the conveyor has been lubricated, it is checked that none of the lubricant or other process fluids have been spilled or dropped on the floor. These liquids create a dangerous condition. If dripping is observed, install a drip tray or other means of eliminating the hazard. When an equipment problem occurs, the first priority is to ensure that power is removed from the affected area, as well as from the control panel where troubleshooting and repairs are performed. Once power is confirmed to be out, be sure to notify other personnel in the area of the situation so that they do not unexpectedly restore power. After all employees have been notified, check the power again to make sure the power is off. When performing any type of maintenance or repair involving electrical components, the following guidelines should be followed:

- never reset a circuit breaker or replace an open fuse before determining and correcting the cause;
- never bypass or use a bypass to replace any limit switch, fuse, circuit breaker or other circuit, protective or safety device;

- never replace an open fuse with another one that is not designed for the appropriate current and voltage, always double-check the correct specifications of the fuse instead of replacing an open fuse with one of the same current and voltage;
- never place tools on motors, gearboxes, connection strips or other control panels or electrical components, all tools used should be stored in a tool box or bag;
- never restore power or restart equipment before checking that all personnel are aware of the condition and are safely away from the equipment;
- always replace and remove safety devices and guards during maintenance or repair before restoring power or restarting equipment;
- always use extreme caution and follow recommended safety procedures while performing any electrical inspections or maintenance operations.

4. CONCLUSION

There are several types of chain conveyors for the transport bulk and piece material from the loading to the unloading point. In order to achieve the greatest possible efficiency, it is necessary to monitor the basic parameters on the conveyors in order to reduce the possibility of breakdowns and personnel injuries.

It is important to carry out periodical services so that the equipment has as long and economically profitable working life as possible. Preventive maintenance is always a better option than emergency maintenance. The devices and equipment should be manipulated by qualified personnel and during these actions, they should wear personal protective equipment and observe safety regulations in order to avoid incident situations.

Safety on these machines is very important, with the equipment manufacturer providing safety guidelines that must be followed. Any deviation from the safety compliance by the operator of the conveyor prescribed by the manufacturer of the equipment, the manufacturer is no longer responsible for the actions that occurred and the responsibility falls on the user of the equipment.

Adequate maintenance, training, marking of devices with safety markings, use of protection and adequate barriers, use of controls and use of personal protective equipment raise the safety of work on chain conveyors to a high level and the possibility of breakdowns and injuries to employees is reduced to a minimum.

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TESTING OF MICROCLIMATE AND PHYSICAL HARMS IN THE SAWMILLS

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Abstract: *The wood industry has a dynamic working environment, so various hazards are present in the workplace. Most often, these are mechanical hazards as a result of working with pieces of wood (logs, sawdust, boards) and with work equipment used in the wood industry (saws, planers, other machines for mechanical processing of wood, conveyors, machines for loading and unloading logs, etc.). In addition to mechanical hazards, there is a danger of high noise levels and unfavourable microclimatic conditions in most workplaces in the wood industry. Assessing the size of the risk arising from those dangers and taking measures to reduce them is key to ensuring safe working conditions. The employer is obliged to ensure the use of only functional and safe machines, which are subject to control. If the inspection determines that there have been changes that endanger the safety and health of the workers, the machine must not be used until it has been restored. The paper presents the results of measuring microclimatic parameters and physical hazard at certain workplaces, that is, on machines used in sawmills*.
Keywords: testing of working environment conditions, microclimate, noise, protection measures

1. INTRODUCTION

In some workplaces in the wood industry, especially in sawmills, workers perform certain work activities outdoors. They are exposed to the influence of microclimate parameters of the environment, which include temperature, relative air humidity, air flow velocity and thermal radiation. Working outdoors in the summer months at high temperatures and in direct sunlight, combined with heavy physical work, can lead to health damage with possible serious consequences, such as burns, sunstroke and heat stroke. By taking some simple preventive measures (avoiding work in the hottest part of the day, taking shorter breaks in the shade more often, drinking enough water, using light, breathable clothing that covers most of the body, using sunscreen, cream with a protective UV factor) the mentioned health risks can be avoided.
The measurement of microclimatic conditions in working and auxiliary rooms is carried out under normal operating conditions with the system for ventilation and heating of the room turned on.
The wood industry is a production activity in which workers are exposed to increased noise levels, which can lead to occupational disease. Most of the workers in sawmills, especially operators of mechanical woodworking machines, are exposed to daily noise that is on average higher than the upper limit value of 85dB(A), (Rulebook 96/2011,78/2015,93/2019), but due to insufficient use of protective equipment, the employees' hearing is damaged. For this reason, it is necessary, primarily by applying the basic rules of safety at work, such as avoiding danger (buying machines where the operators are not exposed to increased noise) or reducing the risk to an acceptable level (by placing the machines or operators in a separate area - remote control) to ensure safe the work of workers. If it is not possible, by applying special rules (organization of work, application of appropriate personal

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protective equipment), ensure that as few workers as possible are exposed to increased noise for as short a time as possible and provide workers who are exposed with appropriate personal protective equipment for hearing protection and ensure that workers regularly use protective equipment, Figure

Figure 1. The selection of personal protective equipment depends on the noise level at the workplace
Source: original copyright

2. RESULTS OF TESTING MICROCLIMATE PARAMETERS AND NOISE IN THE SAWMILL

The measurements of microclimatic conditions and noise level in working and auxiliary premises are carried out under normal operating conditions of machines and devices, during the operation of heating, ventilation and dust removal systems.
The device HT - 3007SD was used to measure temperature and relative air humidity. The TESTO 480 device was used to measure the air flow valocity in the working environment. A phonometer, manufactured by Brüel&Kjær, type 2260, indoor microphone type 4189, was used to measure the equivalent noise level, an instrument with a built-in 1 and 1/3 octave filter. The characteristic quantity to be measured is the equivalent noise level in dB(A).
Examination of working environment conditions is carried out in accordance with the Law (135/2004, 36/2009, 36/2009,72/2009, 43/ 2011), as well as the (Rulebook 15/2023). Microclimate tests in the summer period are carried out when the outside temperature is above 15˚C and in winter period when the outside temperature is below 5˚C. Measurements of noise level were carried out in accordance to (Rulebook 96/2011, 78/2015, 93/2019).
The following machines, among others, are subject to noise level inspection of equipment for work in sawmills, Figure 2: brent with trolley, transverse circular saw, automatic circular saw, multi-leaf circular saw, conveyor, transverse circular saw, bansek, crusher and longitudinal circular saw. Inspection and checking of work equipment used in lathes includes the following description: switches, short-circuit protection and protection against dangerous contact voltage are selected according to operating requirements and technological conditions in the room. Power cables are selected according to the power used to power electrical installations. The cables are properly laid and mechanically protected from contact. Based on the performed inspection and examination of the technical protection measures performed on the device, it is concluded that the prescribed safety measures at work have been applied.

Horizontal circular saw | Transverse circular saw | Cross circular | Bansek | Longitudinal circular

Figure 2. Machines used in sawmills
Source: original copyright

Table 1 shows the results of measuring microclimate parameters and physical harm (noise) in the sawmill, at seven different workplaces, i.e. measuring places.

Table 1. Results of the measuring microclimate parameters and physical harms in the sawmill, at different workplaces

Source: original copyright

1. MEASUREMENT PLACE – Horizontal circular saw (summer period)				
Date of testing 09.06.2022.	**Measured value**	**Allowed value**	**Exposure time**	**Satisfied YES/NO**
MICROCLIMATE (air temperature, air flow velocity, relative air humidity)				
Microclimate (working indoors)				
Air temperature, ˚C	**25.5**	**28**	**8**	**YES**
Air flow velocity, m/s	**0.3**	**0.7**	**8**	**YES**
Relative air humidity, %	**58.3**	**60**	**8**	**YES**
PHYSICAL HARMS (equivalent noise level)				
Physical harms (working indoors)				
Equivalent noise level, Leq dB (A)	**76.4-82.2**	**85 dB (A)**	**8**	**YES**
2. MEASUREMENT PLACE – Cross circular saw (summer period)				
MICROCLIMATE (air temperature, air flow velocity, relative air humidity)				
Microclimate (working indoors)				
Air temperature, ˚C	**25.2**	**28**	**8**	**YES**
Air flow velocity, m/s	**0.2**	**0.7**	**8**	**YES**
Relative air humidity, %	**58.6**	**60**	**8**	**YES**
PHYSICAL HARMS (equivalent noise level)				
Physical harms (working indoors)				
Equivalent noise level, Leq dB (A)	**71.4-74.8**	**85 dB (A)**	**8**	**YES**
3. MEASUREMENT PLACE – Automatic circular (summer period)				
MICROCLIMATE (air temperature, air flow velocity, relative air humidity)				
Microclimate (working indoors)				
Air temperature, ˚C	**25.9**	**28**	**8**	**YES**
Air flow velocity, m/s	**0,3**	**0.7**	**8**	**YES**
Relative air humidity, %	**57.7**	**60**	**8**	**YES**
PHYSICAL HARMS (equivalent noise level)				
Physical harms (working indoors)				
Equivalent noise level, Leq dB (A)	**74.2-81.8**	**85 dB(A)**	**8**	**YES**
4. MEASUREMENT PLACE - Bansek (summer period)				
MICROCLIMATE (air temperature, air flow velocity, relative air humidity)				
Microclimate (working indoors)				
Air temperature, ˚C	**25.5**	**28**	**8**	**YES**
Air flow velocity, m/s	**0,3**	**0.7**	**8**	**YES**
Relative air humidity, %	**58.3**	**60**	**8**	**YES**
PHYSICAL HARMS (equivalent noise level)				
Physical harms (working indoors)				
Equivalent noise level, Leq dB (A)	**76.4-82.2**	**85 dB(A)**	**8**	**YES**
5. MEASUREMENT PLACE - Splitter (summer period)				
MICROCLIMATE (air temperature, air flow velocity, relative air humidity)				
Microclimate (working indoors)				
Air temperature, ˚C	**25.4**	**28**	**8**	**YES**
Air flow velocity, m/s	**0.35**	**0.7**	**8**	**YES**
Relative air humidity, %	**58.2**	**60**	**8**	**YES**
PHYSICAL HARMS (equivalent noise level)				
Physical harms (working indoors)				
Equivalent noise level, Leq dB (A)	**80.4-84.8**	**85 dB (A)**	**8**	**YES**
6. MEASUREMENT PLACE - Sharpener (summer period)				
MICROCLIMATE (air temperature, air flow velocity, relative air humidity)				
Microclimate (working indoors)				
Air temperature, ˚C	**25.2**	**28**	**8**	
Air flow velocity, m/s	**0,1**	**0.7**	**8**	**YES**

Relative air humidity, %	**57.9**	**60**	**8**	**YES**
PHYSICAL HARMS (equivalent noise level)				
Physical harms (working indoors)				
Equivalent noise level, Leq dB (A)	**76.9-82.8**	**85 dB (A)**	**8**	**YES**
7. MEASUREMENT PLACE - Office (summer period)				
MICROCLIMATE (air temperature, air flow velocity, relative air humidity)				
Microclimate (working indoors)				
Air temperature, ˚C	**23.6**	**23-26**	**8**	**YES**
Air flow velocity, m/s	**0.0**	**0.25**	**8**	**YES**
Relative air humidity, %	**58.9**	**40-60**	**8**	**YES**
PHYSICAL HARMS (equivalent noise level)				
Physical harms (working indoors)				
Equivalent noise level, Leq dB (A)	**49.2-55.3**	**85 dB (A)**	**8**	**YES**

According to the (Rulebook 96/2011, 78/2015, 93/2019), standard SRPS EN ISO 9612:2016 and Table 1, the measured microclimate parameters (temperature, relative air humidity and air flow velocity) and noise level in the sawmill, at different measurement places, do not exceed the permitted values. Increased harm was not determined by measurement and there is no risk to the health of workers.

3. PROTECTIVE MEASURES

3.1 Protective measures on machines and tools for wood processing and similar materials

The special occupational safety measures that are applied during the mechanical processing of wood and similar materials are established by (Rulebook 51/1988): all types wooden boards bound with synthetic and mineral binders (chipboards, fibreboards), veneer boards (plywood), carpentry boards (panel boards), chipboards, refined chipboards and fibreboards, decorative laminates, cork boards, wood briquettes, as well as other materials that processed with machines for mechanical processing and wood processing.

Premises in which there are machines for the processing of wood and similar materials must have a built-in system of general and local ventilation, which ensures the removal of sawdust, wood and other dust, gases and smoke. Work tools and other means of work cannot be put into operation, if the device for dusting on the work tools is not turned on and they can only be used if they are working.

Smoking, use of open flames and hot objects are not allowed in places where wood and similar materials are processed and stored. Workplaces must be regularly cleaned of debris and other material. The factory ground area must be fenced and free of canals, pits and other obstacles. If individual pits, canals, pools, etc., are required for the technological procedure and where the work is performed by at least two workers, they are covered or protected by safety fences in accordance with the technological work process. If certain places cannot be fenced off due to the technological process, they must be illuminated and marked with danger warnings in visible places.

Places that serves as a storage area, logs, sawn timber and other material are arranged in such a way as to prevent their falling down and ensure the necessary visibility of the storage area. During work at night and in conditions of reduced visibility, the organization circle must be illuminated. Dangerous places (pools, pits, canals, etc.) within the organization that cannot be fenced off or otherwise protected are illuminated and marked with red light. If there is a track in the working rooms for mechanical processing of wood and similar materials, the upper edge of the track rails must be at the height of the floor surface. Turnstiles for wagons are secured against turning when passing over them.

Before starting work, the machine operator checks whether the tool is functional and safe, correctly positioned and securely attached and the unnecessary tool is put away in the appropriate place. Attaching and removing tools from the machines is done only with the help of the provided tool according to the manufacturer's instructions for handling and maintaining the machines.

4. SPECIAL PROTECTION MEASURES ON MACHINES

4.1 Harvesting machines

Gather must have an audible signal to announce the start of work. For mechanical processing and woodworking, only saws with counterweights secured against shifting can be used. In the case of horizontal gatekeepers, the connecting rod and the flywheel must be enclosed, and the frame must be secured against falling out. When leaving the gather, the ends of the logs are secured against lifting and lowering. During the cutting of logs on the saw, the worker must not be on the log.

4.2 Circular saws

The protective device of the circular saw blade is fixed so that it cannot move along or perpendicular to the saw blade during cutting. It is placed in such a way that it does not reduce visibility during cutting, with the fact that the distance between the device and the upper edge of the object to be cut must not be greater of 5 mm. The circular saw blade with a pendulum is provided with a solid protective cap up to the cutting height. For wood processing only manual circular saws with a movable protective device that automatically covers the entire perimeter of the saw blade when idling can be used. In the case of circular saws with multiple blades and automatic material movement, a kickback protection device is installed. The pressure rollers for the automatic movement of the material to the circular saw are protected by a solid armor. In the case of cylindrical saws for tendons, devices are installed for catching or rejecting the cut tendons.

4.3 Band saws

The band saw blade is provided with a protective shield along its entire length, except for the place where it is directly cut. Manual adjustment of the band saw blade guide is done while the saw is not in operation. In the case of circular saws and log saws, the movement of the log carriage is ensured by an automatic switch. The supports and holders of logs or other objects to be cut with the saw are placed so that they cannot come into contact with the saw blade. The commissioning of the incoming log conveyor from the storage area to the cart of the scraper band saw and log saw is announced by a sound signal.

4.4 Milling machines

The milling cutter tool must be covered with a protective shield. It is not allowed to use the shaft attachment (mandrel) without using the upper bearing on the milling machine. Flattening of material can only be done with round heads (knife holders) or other special tools. The protective shield must not touch the chain on the side of the guide. The tools of the capping machine are protected in all places, except at the point of cutting.

4.5 Veneer cutting machine

Only machines with a mechanism for starting the knives can be used for veneer cutting, which is activated by pressing two switches simultaneously, using both hands at the same time. Machines for veneer cutting (slicing) with horizontal or vertical knives must have a suitable device for stopping the knife in case the worker's body or part of it comes into the dangerous area of the knife.

4.6 Veneer cutting scissors (scissors package)

Only scissors with the mechanism for placing the scissors with the drive adjusted the working part (knife and pressure rod) can be started by simultaneously acting on the two-hand controls or in another

appropriate way, can be used for cutting veneers. It ensures the protection of the workers and stopping the working part in its upper position at the latest. The mechanism for putting the scissors into operation must ensure that, by stopping the action on any of its parts, an immediate stop of the working part of the scissors is automatically performed.

4.7 Wood chipping machines (wood chippers)

A wood chipper must have switches to stop the metal belts for feeding the material being chipped and to run the belts in the opposite direction. The wood chipping machine must have a device to stop the metal strips, in the event that thicker material is encountered than the intended material for chipping. During the operation of the chipping, the workers are on the side of the conveyor that delivers the chipping material, at a safe distance from the machine, i.e. the conveyor.

5. CONCLUSION

The microclimatic parameters of the working environment (air temperature, relative air humidity and air flow air velocity) and noise were measured during working hours and during the execution of the normal work process. Based on the measurements, it can be concluded that the air temperature at the measuring points does not exceed the maximum allowed value prescribed by the reference legal acts for the summer period; that the air velocities at the analyzed measuring points does not exceed the maximum allowed value; that the relative air humidity at all the analyzed measuring points is within the permitted limits according to the valid legal acts for the summer period and that the registered noise levels at the analyzed measuring points are within the limits according to the reference valid legal acts.
Regulations in Serbia prescribe only some protection measures during processing of wood. It must be emphasized that it is not possible to process in detail and include all the protection measures of the technological procedure for all machines, but by installing various protections on existing or purchasing more modern machines, the safety of workers can be increased.

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NOISE LEVEL INVESTIGATION IN PRODUCTION PROCESS

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Abstract: *This paper deals with the noise problem in production halls at two factories. In both factories, noise values were measured at seven presses, which are the sources of noise. From the measured equivalent noise levels and from the noise exposure for the whole shift, the normalized levels of noise exposure $L_{A,EX,8h}$ for individual employees were calculated. Results were presented in table and diagram for better understanding.*
Keywords: noise, working environment, pressing devices

1. INTRODUCTION

The work environment is defined as a set of factors affecting human activity in a certain space, or a set of conditions under which the work process takes place. These conditions must be in accordance with the physiological, hygienic, psychological and aesthetic requirements of the workers. The working environment is then one of the most important working conditions that affect the performance, satisfaction and reliability of workers [1]. Safety and health protection at work must be ensured on the basis of valid legislative regulations, while it must constantly progress and improve in order to eliminate work accidents, occupational diseases and, last but not least, the death of an employee.

In every production organization, we encounter risk factors that can harm the health of the employee, therefore an active approach to safety, compliance with the prescribed measures and the use of appropriate personal work equipment are necessary. Engineering plants have a specific position in industry. The nature of the production, the focus and the technology of the production process is the first prerequisite for the machine equipment of the production halls. For this reason, we encounter very diverse devices in them. They are either single-purpose or multi-purpose machines that are the source of noise. Noise sources are mainly grinders, benders, hammers, cutters, presses, welding units, leveling tables, compressors, milling machines, automatic chisels, etc. The noise level of individual devices depends on the operating load. In a production or assembly hall, there is a mutual interaction of noise sources, each of which has its own characteristic directional radiation. Obstacles of the screen of the reflective surface of the halls condition the creation of a sound field in a closed space. With the help of acoustic measurements, the noise situation in this space (isobar) is objectified and the noisiest sources can be identified, which makes it possible to implement anti-noise measures at the source, but also in the path of propagation of sound energy [2].

Among the most serious risk factors in the production organization when working with pressing equipment is noise, which is the most common and very difficult to eliminate in such work. Noise has adverse effects and affects each employee differently, it can also affect their performance, not just their health. Employees who are exposed to noise for a long time may have health consequences in the form of gradual damage to the hearing organs, or hearing loss may occur, and increased noise may also cause accidents during the performance of work.

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Specific causes of noise and vibration in mechanical engineering include impacts on objects (heavy machines, hammers, presses); aerodynamic forces (aerodynamic noise), noise from variable friction mechanisms of individual machine distributions. Other causes are electromagnetic forces (electric motors, transformers) and hydrodynamic processes (hydraulic devices). All these causes are related to the function, work and technological process in production. The effects of these causes intertwine during the work process, therefore acoustic measurements are important during the operation of machines directly in the production process (noise level, sound pressure and power level or currently intensity). On the basis of specific results, anti-noise measures can then be chosen [2].
The prevention of excessive noise and the negative impact of noise already occurs in the preparatory phase of the production organization, when all possibilities are addressed to keep the noise level as low as possible. If the limit values for noise exposure are exceeded, it is necessary to take corrective anti-noise measures, which can be defined by [3,4], on minimum health and safety requirements to protect employees from risk factors related to noise exposure. Anti-noise measures can include organizational changes, technical changes, technological changes, or personal protective work equipment.

2. MATERIALS AND METHODS

2.1 Description of the companies

Factory 1 deals with the sale and production of fasteners and screws aimed to the automotive industry, chemical-heat treatment of metals, assembly of screws and surface treatments of metals. The company also deals with production of various components and technical springs for automotive industry. In addition to the group's production, this company also offers its services as a custom color shop with heat treatment with a protective atmosphere for external customers. Supplies special fasteners mainly for the European market of the automotive, aviation and consumer industries with a focus on small and medium series production, which produces approximately 2000 types of products. Noise measurement was carried out on 7 pressing devices out of 15. Measurements were not performed on all presses due to planned equipment shutdown and maintenance.
Factory 2 deals with the production of anchoring and supporting elements for reinforced concrete constructions. In the hall there are 11 forging presses - for the production of steel material, which are operated by employees classified as forging press operators. Employees in the profession of hydraulic press operator use a hydraulic press to bend material. Noise measurement was carried out on 7 pressing devices.

2.2 Measuring device and method

Brüel & Kjær is an integrated sound level meter type 2240. This sound level meter is easy to use and meets all current standards for its use. It ranks among the sound measurement accuracy class 1 - it can be used to measure the average value or the direct value of the sound pressure. It is also possible to simultaneously measure the maximum value, the instantaneous value and the peak value.
Brüel & Kjær 2240 sound level meter can be used in the assessment of environmental noise, it can be used to measure noise in the working environment, and it can also be used to perform various general noise measurements, such as the noise level of household appliances and many others.
The measurement was carried out in a hall of press plant according to the [4]. Pressing equipment of various sizes and parameters are sources of noise. Other auxiliary machinery is not considered a potential source of noise. Noise was measured at points that were pre-selected in the preparatory work, before the actual measurement. The measurement points are distributed according to the equipment in the production halls where the measurement was performed. The height of the measuring sensor was at the height of the hearing organ of the press operator on the sensor. If the height of the workplace was changed sensor, the height of the measuring point was also changed. The measuring device was held in the position of the hearing organ at a distance of approximately 0.5 m

from the head. The length of the measurement was performed for 5 minutes, 3 repetitions at each noise source. The results of measurements are presented in Table 1.
The following values were measured with the measuring device:

- L_{AF} – instantaneous sound pressure level,
- L_{AFmax} – maximum sound pressure level,
- L_{Aeq} – effective sound pressure level value,
- L_{Cpeak} – the maximum value of the sound pressure level.

The level of daily exposure to noise, normalized to a nominal eight-hour working day, $L_{A,EX,8h}$, expressed in decibels, is given by the equation:

$$L_{A,EX,8h} = L_{A,eq,Te} + 10 \log (T_e/T_0) \quad (1)$$

where is:
T_e – effective duration of the working day
T_0 – reference duration of the working day (8 hours).

If the effective duration of the working day T_e is equal to 8 hours, $L_{AEX,8h}$ is equal to equivalent noise level, $L_{A,eq,Te}$. The equivalent noise level can be calculated according to the relation [4].:

$$L_{A,eq,Te} = 10 \log \left[\frac{1}{k}\Sigma_{i=1}^{n} 10^{0.1 L_{A,EX,8h}}\right] \quad (2)$$

3. RESULTS AND DISCUSSION

Tables 1 and 2, shows the results of noise level measurements at seven measuring points, both production halls as well as the calculated values of the level of daily exposure to noise, normalized to a nominal eight-hour working day, $L_{A,EX,8h}$ and effective sound pressure level value, L_{Aeq} according equations (1) and (2).

Table 1. Measured values of the noise level
Source: original copyright

	Pressing device	L_{Aeq} **(dB) (A)**		L_{AEX8h} **(dB) (A)**		p_{peak} **(dB) (A)**	
Factory 1	P1	78.4	79.1	84.6	88.1	101.2	105.8
		78.7		86.3		103.7	
		80.2		93.5		112.5	
	P2	80.3	80.4	86.8	88.9	102.6	106.5
		80.1		86.3		103.7	
		80.7		93.7		113.1	
	P3	79.9	79.3	88.3	88.3	103.3	103.9
		78.7		87.6		103.8	
		79.4		88.9		104.6	
	P4	80.1	79.4	84.1	87.0	101.0	104.7
		78.8		84.4		102.3	
		79.4		92.5		110.9	
	P5	79.8	80.0	88.0	88.1	105.3	104.7
		80.2		87.9		104.3	
		80.1		88.5		104.6	
	P6	89.7	89.9	95.4	95.2	112.7	113.0
		89.5		94.7		112.8	
		90.6		95.5		113.6	
	P7	79.9	80.0	88.8	89.5	105.7	106.0
		80.7		88.6		105.2	
		79.6		91.0		107.3	

Factory 2	P1	89.9	90.4	101.5	102.0	120.6	120.8
		90.8		102.3		121.0	
		90.5		102.2		120.8	
	P2	91.2	91.1	104.7	104.8	121.7	121.9
		90.8		104.6		122.1	
		91.3		105.1		121.9	
	P3	88.6	88.4	110.3	110.4	118.4	118.2
		88.4		110.6		118.3	
		88.2		110.3		117.9	
	P4	87.1	87.5	100.1	100.2	119.2	119.4
		87.6		100.4		119.3	
		87.8		100.1		119.7	
	P5	91.9	91.7	101.6	101.8	117.8	117.6
		91.5		101.8		117.7	
		91.7		102.0		117.3	
	P6	88.6	88.5	101.9	102.3	120.6	120.5
		88.7		102.6		120.7	
		88.2		102.4		120.2	
	P7	96.2	96.1	123.1	123.4	129.9	130.1
		95.8		123.5		130.2	
		96.3		123.6		130.2	

Table 2. Calculated values of the noise level

Source: original copyright

Factory 1	**L_{Aeq} (dB) (A)**	**$L_{AEX,8h}$ (dB) (A)**
P1	79.8	81.4
P2	80.6	82.2
P3	79.3	80.9
P4	79.5	81.1
P5	80.0	81.6
P6	89.6	91.2
P7	79.8	81.4
Factory 2	**L_{Aeq} (dB) (A)**	**$L_{AEX,8h}$ (dB) (A)**
P1	89,3	89,9
P2	90,0	90,6
P3	87,3	87,9
P4	86,4	87,0
P5	90,6	91,2
P6	87,4	88,0
P7	95,0	95,6

The obtained measurement results for the production processes are shown in form of diagrams on Figure 1 and Figure 2.

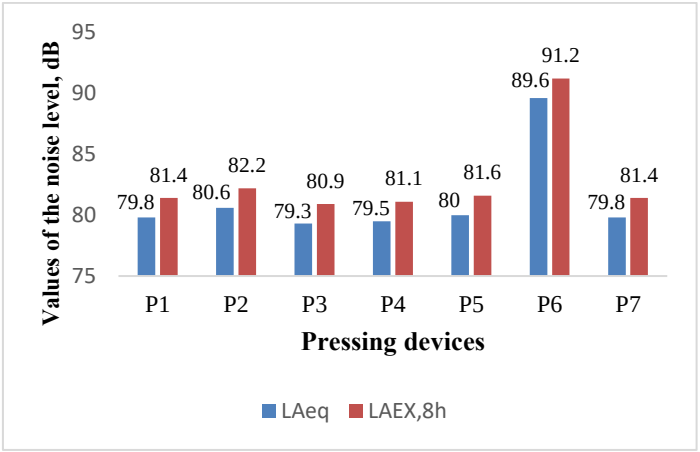

Diagram 1. Factory 1

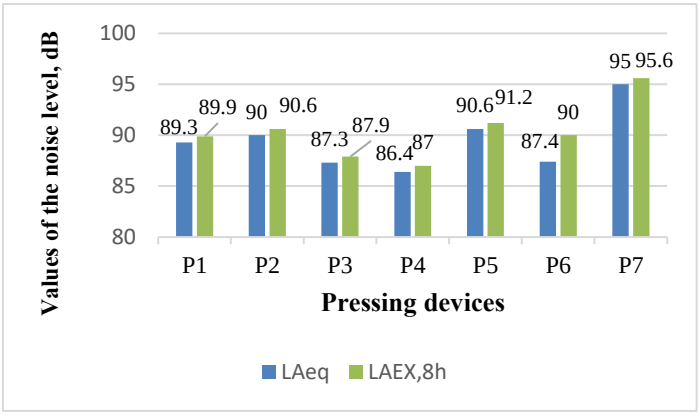

Diagram 2. Factory 2

The purpose of the work was to evaluate the noise level in two production halls, because according to [5,6], the impact of noise on people can cause an effect that is annoying and thus can harm health and create obstacles in the performance of the given activity. These noise impacts they depend on the given number of acoustic and non-acoustic subjects. Safety and health protection at work can be improved by various preventive measures, controls, which may be random or announced. Every employer has an obligation to improve the working conditions of employees, thereby reducing their psychological well-being but also physical load, to eliminate risks that can cause occupational accidents and illnesses from the profession and various other damage to the employee's health during work activities [7]**.**

According to the measurement results, it was determined that the measured values of noise exposure on certain devices exceed the prescribed values, in accordance with the Rulebook [4]. The calculated value of noise exposure on the pressing equipment, Factory 1, only in the case of pressing device, P5, exceeds the permitted values (4), while in the case of Factory 2, the calculated values of noise exposure on all pressing devices, are higher than the permitted values. All possible corrective measures in the form of organizational and technical changes, technological changes and personal protective equipment (PPE) were considered. All possible corrective measures in the form of organizational and technical changes, technological changes and personal protection equipment (PPE) were reviewed. Most manufacturing organizations solves such a situation by purchasing appropriate PPE because according to [8], PPE, which protect employees' hearing organs from adverse and harmful effects of long-term exposure to noise can reduce the noise to a reasonably safe level. According to the [9], the employer must provide PPE for employees. The solution is to exchange the original PPE for more effective PPE. Disposable plug protectors are often exchanged for more functional, shell protectors. Corrective action in the form of technical changes would be addressed in the company, while the anti-noise partitions would be assembled at the given noisiest devices. Anti-noise partitions can be located in the production hall, while their main function is soundproofing, which is possible up to 52 dB.

4. CONCLUSION

Based on the measurement results, certain risks have been identified that affect the safety and health protection during the work of workers, therefore it is necessary to take corrective measures in the form of appropriate PPE - working clothes, headphones or gloves.

Noise exposure has been assessed at production facilities that show increased noise production. Employees face this kind of threat to their health on a daily basis. During time and increasing wear and tear of the equipment it is necessary to separate noisy devices from others with a noise barrier, less noisy equipment and thus prevent the transmission of noise and at the same time increase protection employees. Anti-noise partitions are made of materials that they can absorb noise and are also used to reduce the level of reflected sound.

Last but not least, the employees who work on this equipment must be familiar with its operation, they should also be qualified and regularly trained. The equipment must undergo regular inspection and maintenance.

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ENVIRONMENT AND SUSTAINABLE DEVELOPMENT. MECHATRONICS. OCCUPATIONAL SAFETY AND HEALTH AND FIRE SAFETY. SMART MANAGEMENT SYSTEMS. GRAPHIC ENGINEERING. DESIGN. TRAFFIC ENGINEERING. BIOTECHNOLOGY AND HEALTHCARE. MECHANICAL ENGINEERING. ECOTOURISM AND RURAL DEVELOPMENT.

COMPARATIVE ANALYSIS OF RISK ASSESSMENT IN THE FIELD OF CONSTRUCTION

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Abstract: *The main purpose of assessing safety risks at the workplace and in the working environment is the preventive assessment and prevention of injuries at work, occupational diseases as well as all other work-related diseases. The application of risk assessment directly affects the safety and health protection of employees. Many methods and types of risk assessment matrices are used to assess occupational risks. Work in construction is one of the riskiest activities in terms of injury and endangering the health of workers. After reviewing the existing state of safety and health at work in the workplaces in the field of construction, recognizing, determining, and analyzing hazards and harms, it is possible to perform a risk assessment, take certain measures and activities to protect the life and health of employees in the field of construction and other persons. The work aimed to use the PILZ and Risk Matrix 5×5 methods for assessing professional risks at the workplace in the field of construction, as well as to perform a comparative analysis to point out the possible advantages or disadvantages of the chosen methods. Based on the risk assessment using both methods, the same conclusion was drawn that the workplace in the field of construction with an increased risk was analyzed.*
Keywords: The risk assessment, PILZ method, 5×5 Risk Matrix

1. INTRODUCTION

Improving safety and health protection at work is a prerequisite for safe and humane working conditions for employees. In the field of construction activity, there are numerous and very different products that require different production technologies and create great opportunities but also obligations in terms of ensuring the safety of workers. Safety and health at work in construction are of particular importance, especially considering the relatively difficult working conditions during the construction of buildings. The safety of workers at work during the construction of buildings implies that the workers are safe [1]: (i) in all phases of work on certain parts of the building, permanent and temporary (stairs, passages, fences, entrances, trenches, excavations, scaffolding, etc.); (ii) when using (handling) various machinery and other mechanically or electrically powered devices, tools and equipment; (iii) when installing various materials or installations; (iv) in all processes and procedures, when applying the provided technologies for the execution of construction, construction-craftsmanship and installation works; (v) from the beginning of construction of the building to its end, i.e. on the entire building, as long as the work on it lasts and on the revitalization of the surroundings after the completion of the works on the building itself.
Safety must be ensured both for the workers performing the work and for other persons (surrounding population and passers-by, while the construction is in progress) and then also for the users of the given facility. Assessing risks at the workplace and in the working environment is the first step to eliminate all risk factors that endanger the lives and health of employees [2] and ensure safe and healthy working conditions.

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This paper aims to assess the risk of hazards and harm for the rebar worker workplace in a construction company, that deals with high-rise and civil engineering. The risk assessment after the recognition and analysis of hazards and harms at the rebar worker workplace was performed using the 5x5 Risk Matrix method (OHSAS standard) [3] and the PILZ method [3].

2. TECHNOLOGICAL PROCESS AND ORGANIZATION OF THE WORK PROCESS

In this paper, an analysis of the workplace of a rebar worker in a construction company, which deals with the execution of construction and construction-rough works, was carried out. The activity of the company is the construction and reconstruction of buildings, the upgrading of already existing buildings, the preparation of construction sites for later construction activities, which includes the preliminary removal and demolition of existing buildings, the construction of all types of retaining walls, and protection against soil erosion.
Objects used as working and auxiliary space in a construction company are a construction site, a container for a wardrobe, a sanitary unit, and a container for tools and other necessary materials.
In the process of work, the rebar operator uses measuring devices (meter, plummet, spirit level, string), hand tools (reinforcing pliers, hammer, keys), an electric hand sander, a rebar table, mechanical scissors, and cantilever crane [4].
From the raw materials and materials at the workplace of the rebar worker, the employees use concrete iron, and rebar [4].

2.1 Equipment and means for personal protection at work

When performing technological and work processes, employees at the workplace rebar worker use means and equipment for personal protection at work, which include [5]:

- one-piece work suits or cloth work coats,
- leather gloves with reinforcement in the area of the fingers and palms,
- safety glasses that have a frame with side protection,
- Safety leather shoes with steel toe cap and anti-slip and anti-puncture soles,
- protective helmet,
- hearing protection devices (the use of protective cotton wool for the ears, earplugs, and earmuffs is determined by a noise level of 75 dB, over 85 dB to 105 dB),
- protective belt for positioning which has a wide back support with adjustable rope for positioning and carabiner,
- raincoat made of rubberized and waterproof material with hood and fastening on the front,
- leather shoulder protector, if a heavy object (weighing more than 15 kg) or an object with sharp edges is carried on the shoulder,
- Protective bras to protect against spine deformation due to constant carrying of a load on the shoulder or back,
- leather knee pads for working in a kneeling position.

2.2 Description of the rebar worker workplace

Jobs and tasks in the rebar worker workplace include loading and unloading the armature at the construction site, transferring the armature to the workplace, hand, and machine cutting, straightening, bending, tying, and installation of rebar, wire, and prestressing ropes [4].
The conditions for performing the work of a rebar worker are the completion of secondary vocational education and the passing of a professional exam. Rebar workers are over 21 years old, in good health, with good vision, hearing, and sense of balance, satisfactory physical strength, endurance, and psychomotor dexterity, and have a medical certificate for working at heights. Employees are subject to periodic medical examinations every 12 months [5].

From 5 to 10 male employees, among whom there were no persons with disabilities, were hired to perform rebar work in the observed construction company. Working hours are from 7:00 a.m. to 5:00 p.m., with two 30-minute breaks. The work is done six days a week. The work is done six days a week. During the performance of work at the workplace of the rebar worker, there may be a deviation from the established work organization on an emergency call.

3. ANALYSIS OF DANGERS AND HARMFULNESSES OF THE REBAR WORKER WORKPLACE

Identification and determination of hazards and harm in the analyzed workplace and the working environment was carried out based on data collected from the documentation owned by the employer, by observing and monitoring the work process at the workplace, obtaining the necessary information from employees and information from other sources, and classifying the collected data into the types (possible dangers or possible harms) to which these data indicate.
Based on the record of injuries at work in the period from 2016 to 2020, nine minor mechanical injuries occurred at the workplace of rebar workers. Six injuries are superficial wounds, in which only the skin is injured (peel off the skin and shallow cuts), while the other three injuries are deep wounds, where in addition to the skin, deeper tissues (muscles, blood vessels, and bones) are also injured. Professional diseases and diseases related to work were not recorded at the place of work of rebar workers in the period from 2016 to 2020.

3.1 Mechanical dangers arising from the use of work equipment at the place of work of the rebar worker

Mechanical dangers that occur when performing work using a grinder for cutting reinforcement as well as when using a cantilever crane due to rotating or moving parts of this work equipment can cause insufficient safety for employees. Rebar workers are exposed to the free movement of parts or materials that can injure them during the lifting and lowering of loads (rebar) with a cantilever crane, in the event of falling material stack, when unloading loads from a truck, as well as if the rebar is forcibly pulled from a pile of materials, et cetera. Also, they are exposed to dangers from the movement of work vehicles and machines on the construction site, which are used to transport construction materials and remove waste from the construction site.

3.2 Dangers that arise in connection with characteristics of the workplace

When installing reinforcement and moving over uneven ground surfaces and scaffolding on the construction site, rebar workers come into contact with dangerous surfaces that have sharp edges, spikes, and protrusions. The work of installing reinforcement and reinforcing mesh, accepting materials on a cantilever crane is performed by rebar workers working at height by the regulations on safety and health at work.
When performing reinforcement works, tripping may occur from construction material (rebars). If the tool is placed in places not intended for it, there is a tripping danger. When working with the sander, electrical cables are stretched across the floor and can cause tripping. Also, in the winter, the paths for the movement of employees can be slippery, which can cause slipping.

3.3 Dangers arising from the use of electricity

When working with a mechanized tool, that is powered by electricity, if the cable is damaged, the employees at the workplace of the rebar worker can be exposed to the danger of direct contact with parts of the electrical installation and equipment under voltage.

3.4 Harmfulnesses that arise or appear in the work process

The harmful impact of noise from construction machines and tools, although it is present on the construction site, is slightly less pronounced due to working in an open area. The workplace where the work of a rebar worker is carried out involves working outdoors (construction site), as well as staying in premises under construction that do not have windows and doors, which implies exposure to inappropriate flow speed and air humidity; in the summer under the influence of very high temperatures, while in the winter period under the influence of very low temperatures.

3.5 Harmfulness resulting from psychological and psychophysiological efforts

The work of the rebar operator, such as manual bending of the rebar mesh, manual transfer, and loading of the rebar onto the cantilever crane, is performed with great physical effort and body strain. While performing the work, the rebar worker is generally in a bent position, or crouching, or kneeling, that is, he has an unphysiological body position.

3.6 Harmfulness related to the organization of work

Since the organization of work in the construction industry depends on several factors, occasionally employees in the position of rebar workers have to perform tasks longer than full-time.

4. APPLICATION OF THE PILZ AND RISK MATRIX 5×5 METHODS FOR THE WORKPLACE OF THE REBAR WORKER

After identifying the dangers and harmfulnesses of the analyzed workplace, a risk assessment was performed [6, 7] using the PILZ method [3] and the 5×5 Risk Matrix (OHSAS standard) [3].
The probability of injury or disease, frequency of exposure to dangers and harmfulnesses, severity of possible injury and disease, and number of persons exposed to danger or harmfulness are risk factors used in risk assessment using the PILZ method.
Using the 5×5 Risk Matrix method (OHSAS standard), two parameters for risk assessment about hazards and harmfulnesses were analyzed, namely the probability of injury or disease and the possible severity of injury or health damage.
A comparative analysis of the estimated occupational risks using these two methods is shown in Table 1.

Table 1. Comparison of the level of professional risks at the workplace of rebar workers assessed using the PILZ method and the 5×5 Risk Matrix (OHSAS standard)

Identified dangers and harmfulnesses	Level of professional risks assessed by PILZ method	Level of professional risks assessed by 5×5 Risk Matrix
Insufficient safety due to rotating or moving parts of the work equipment	High risk (R4)	Moderate risk (R3)
Free movement of parts or materials that may cause injury to the employee	Moderate risk (R3)	Moderate risk (R3)
Internal transport and movement of work machines or vehicles, as well as movement of certain work equipment	Moderate risk (R3)	Moderate risk (R3)
Dangerous surfaces	Low risk (R2)	Low risk (R2)
Working at height in terms of occupational safety and health regulations	Unacceptable risk (R5)	Very high risk (R5)

Possibility of slipping or tripping	Moderate risk (R3)	Low risk (R2)
The danger of direct contact with live parts of the electrical installation and equipment	Moderate risk (R3)	Moderate risk (R3)
Physical harmfulness	Moderate risk (R3)	Moderate risk (R3)
Harmful climatic influences	Moderate risk (R3)	Moderate risk (R3)
Effort and body strain	High risk (R4)	High risk (R4)
Unphysiological position of the body	High risk (R4)	High risk (R4)
Work longer than full-time	Low risk (R2)	Moderate risk (R3)

Both methods use a risk ranking on a five-point scale. The analysis shows that by applying the PILZ method and the 5×5 Risk Matrix (OHSAS standard), risks of different ranks were assessed about two dangerous and one harmfulness.
This deviation can be related to the analysis of different parameters when applying these methods. It can be seen that by applying the PILZ method, there is a possibility of seeing the dangers and harmfulnesses through more parameters than is the case with the Matrix method.
Using both methods (PILZ method and Risk Matrix 5×5 (OHSAS standard)) the assessed risks in terms of dangers (work at heights, insufficient safety due to rotating or moving parts) and harmfulness (efforts or body strains and non-physiological body position) indicate that the workplace of a rebar worker is a workplace with increased risk.

5. CONCLUSION

This paper analyzes the dangers and harmfulnesses at one workplace in the field of construction and makes a comparison of the levels of occupational risks assessed using the PILZ method and the 5×5 Risk Matrix (OHSAS standard). Using both risk assessment methods, the rebar worker's workplace was assessed as a workplace with increased risk.
The results showed that the PILZ method takes into account the probability of injury or illness, the frequency of exposure to dangers and harmfulnesses, the severity of possible injuries and illnesses, and the number of people exposed to dangers or harmfulnesses, unlike the 5×5 Risk Matrix (OHSAS standard) which is based only on probability and the possible severity of the injury or illness.
Unlike the 5×5 Risk Matrix (OHSAS standard), the PILZ method is slightly more precise because it uses more factors for risk analysis, therefore the PILZ method is more reliable than the 5×5 Risk Matrix (OHSAS standard).

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ANALYSIS OF ASSESSED PROFESSIONAL RISKS AT THE WORKPLACE OF FORKLIFT DRIVERS IN THE LOGO COMPANY WITH COMPARATIVE RISK ASSESSMENT METHODOLOGIES AND REFERENCE TO THE CURRENT LAW

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Abstract: *In the modern era of business, we face an increasing number of professional risks as products of danger and damage to which employees are exposed during work. Professional risks due to inadequate risk management can lead to injuries at work, which can be minor, serious and fatal, as well as to the occurrence of occupational and work-related illnesses. Due to Article 4, point 21 of the new Law on Safety and Health at Work, according to which the position of the forklift operator is pre-classified as a workplace with increased risk without prior assessment by any of the methodologies, a research and comparative analysis of three methodologies for risk assessment was carried out in order to see if any of the methodologies define the workplace of a forklift operator as a workplace with increased risk in accordance with the applicable law.*
Keywords: Professional Risk, Risks, Risk Assessment Methodology

1. PROFESSIONAL RISK - Definition, division and purpose

The term risk means exposure to the action of various factors that can lead to unwanted consequences through their actions and activities, which is usually reflected in practice in the creation of certain types of costs or, what is much more significant, in the impairment of the health of employees or the creation of minor and serious injuries at work. The risk of the working environment (R) is most often defined as the product of the probability of occurrence of a risky event (Prd) and the severity of it's consequences (Cp) [1]:

$$\mathbf{R = Prd \times Cp} \quad (1)$$

1.1 Division of professional risks

Occupational risks can be:

- Internal - Risks occur at the workplace and in the working environment of the employer (business facilities of the company and the working environment where employees move).
- External - Risks occur outside the employer's workplace and facilities (public areas where the employee performs work for the employer's account or on the way from home to work and vice versa).
- Mixed - a combination of internal and external professional risks.
- Continuous - Risks that occur over a longer period of time, represent the risk of the business itself (mining, chemical industry, health care and security structure).
- Risks due to professional incompetence - They occur most often during the employee's work at workplaces on the employer's premises or in the field, and arise as a result of the incompetence of the Occupational Safety and Health Advisor to properly assess all dangers and hazards within the company, perform a proper risk assessment and determine measures to reduce the resulting professional risks, using one of the generally recognized methods of assessment and quality selection and allocation of personal protective equipment [2].

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These are just some of the divisions by which occupational hazards can be classified, but it should be pointed out that many more subcategories of occupational risks can be made based on them.

1.2 Prevention and management of professional risks

Occupational risk prevention PRL consists of a set of prevention plans and measures implemented in companies to prevent and detect risky situations. PRL aims to eliminate or, if it is not possible to do so completely, then at least reduce the danger or risk that poses a danger to employees. PRL activity is regulated in most European countries and is carried out through specialized courses intended for company personnel. In Serbia, in accordance with the Law on Occupational Safety and Health, occupational risk prevention and risk management are carried out by the Occupational Safety and Health Committee. This Committe is made up of representatives of the employer and employees, or in the case if an Occupational Safety and Health Committee has not been formed, it is carried out by the Employer with the help of the Occupational Safety and Health Advisor and the Employee Representative [3].

2. GOAL OF ASSESSMENT OF PROFESSIONAL RISKS AND THE MOST COMMONLY USED METHODOLOGY IN ASSESSMENT

The main goal of the assessment of professional risks is to determine critical places in the work and technological processes where injuries and endangering of the employee's lives can occur. After the risk assessment, it is necessary to manage the risks, eliminate them or, in the case of impossibility of elimination, reduce the risk to an acceptable level, using for example, personal protective equipment, continuous education, medical examinations, examination of work equipment.
In the Republic of Serbia, there is no adopted Methodology for risk assessment, but several of them are used and it is up to the risk assessor which method to apply and use. The most common method in our country for assessing professional risks is the KINNY method. During risk assessment, many assessments are done in a uniform, copying manner, and the entire assessments for individual workplaces are copied from one company to another, without taking into account, for example, the probability of injury, the frequency of exposure to hazards and harm [4], and the consequences and possible injuries and diseases.
The assessment of occupational risks for many workplaces should be made by combining and comparing several methodologies, which is not always easy because such a thing requires the experience of the assessor and more time for the preparation and analysis of the assessed risks and methods.
In the continuation of the work, an analysis of the estimated risks will be performed using the LatiPro Methodology developed in Serbia by a multidisciplinary team of experts, the KINNY methodology and the Singapore (3×3) Methodology.
The main goal of the work and the analysis of methodological solutions is the assessment of professional risks for all recognized hazards and harms, in order to obtain a unique conclusion on the levels of risk for the workplace of a forklift operator and finally compare it with the provisions of the new Law on Occupational Safety and Health, as well as measures for additional risk reduction, through quality risk management.

3. USED METHODOLOGIES AND ASSESSMENT METHODS OF PROFESSIONAL RISKS AT THE FORKLIFT OPERATOR'S WORKPLACE

The basic legal basis for conducting risk assessment at the workplace and in the working environment is defined by Article 16 of the Law on Safety and Health at Work and the Rulebook on the method and procedure of risk assessment at the workplace and in the working environment [4,5].
Currently, in the Republic of Serbia, there is no single methodology for assessing professional risk, but several recognized methodologies are in use. A unique methodological procedure for the

assessment of occupational risk would enable a simple insight into the state of occupational safety and, therefore, a better management of occupational risk in economic entities by employers [6].
In accordance with the Rulebook on the manner and procedure of risk assessment in the workplace and in the working environment, articles 8 and 9, hazards and harms in the workplace and in the working environment are defined [4].
For the workplace of a forklift driver, the following hazards and harms have been determined, which we will adhere to in the assessment of professional risks using different methodological solutions.

Table 1. Hazards and harms at the workplace and in the working environment
Source: Rulebook on the manner and procedure of risk assessment at the workplace and in the working environment

Hazard group	Code	Hazard subgroup
1) Mechanical hazards arising from the use of work equipment such as:	(01)	Insufficient safety due to rotating or moving parts.
	(02)	Free movement of parts or materials that may cause injury to the employee.
	(03)	Internal transport and movement of work machines and vehicles, as well as movement of certain work equipment,
	(05)	Impossibility or organization of timely removal from the workplace, exposure to closure, mechanical impact, collision, etc…
2) Dangers that appear in connection with the characteristics of the workplace such as:	(07)	Dangerous surfaces (floors and all types of treads, surfaces with which the employee comes into contact with sharp edges, edges, spikes, rough surfaces, protruding parts, etc.).
	(10)	Possibility of slipping or tripping (wet or slippery surfaces)
	(16)	Danger of indirect contact with electricity. Installations and equipment under voltage.
	(18)	Danger due to tire impact and consequences of atmospheric discharge.
Harm group	**Code**	**Harm subgroup**
1) Harms that arise or appear in the work process, such as:	(21)	Chemical hazards, dust and fumes (inhalation, suffocation, introduction into the body, penetration into the body through the skin, burns, poisoning...
	(23)	Biological damage (infections, exposure to microorganisms and allergens).
	(24)	Harmful effects of microclimate (high or low temperature, humidity and speed of air flow).
	(25)	Inadequate-insufficient lighting.
	(27)	Harmful climatic influences (outdoor work).
2) Harms resulting from psychological and psychophysical efforts that are causally related to the workplace and tasks performed by the employee, such as:	(30)	Efforts or physical strain (manually carrying loads, pushing or pulling loads, various long-term increased physical activities, ...).
	(31)	Non-physiological position of the body (long-term sitting, sitting, crouching, kneeling,...).
	(32)	Efforts when performing certain jobs that cause psychological burdens (stress, monotony,...).
3) Harms related to work organization such as:	(34)	Work longer than full time (overtime), shift work, part-time work, night work, emergency preparedness

The first methodology used is the LatiPRO methodology developed in Serbia by a multidisciplinary team of experts.

The LatiPRO methodology uses four parameters in the assessment, which in the formula indicate: TP - severity of potential injury, UI - frequency of exposure to hazards, VP - probability of injury, BO - number of exposed persons, so it is:

$$\mathbf{RISK = TP \times UI \times VP \times BO} \quad (2)$$

Table 2. Risk categorization for the LatiPRO method
Source: *latipro.com*

Risk category	**Risk = TP x UI x VP x BO**
R1-Negligible risk	**0-5**
R2-Little risk	**6-50**
R3-Moderate risk	**51-250**
R4-High risk	**251-500**
R5-Unacceptable risk	**>500**

The second method used is the most commonly used, the Kinny method, where the occupational risk is the product of (V) the probability of occurrence of hazards, (P) the consequences of the occurrence of hazards and harms, and (U) the frequency of occurrences of hazards and harms:

$$\mathbf{R = V \times P \times U} \quad (3)$$

Table 3. Risk categorization for the KINNY method
Source: *Choice of method for risk assessment*

Risk category	**Risk = V x P x U**
R1-Very little risk	**R<20**
R2-Little risk	**20-70**
R3-Moderate risk	**71-200**
R4-Big risk	**201-400**
R5-Extremely high risk	**R>400**

The third method used is the Singapore method (3×3), where the risk is expressed as the product of the probability of occurrence of a work-related injury, health damage and illness (V) and the consequences of the severity of the injury, health damage and work-related illness (T):

$$\mathbf{R = V \times T} \quad (4)$$

Table 4. Risk categorization for the method (3x3)
Source: *Choice of method for risk assessment*

Risk category	**Risk = V x T**
R1-Negligibly low risk	**Acceptable risk**
R2-Very little risk	
R3-Little risk	
R4-Medium risk	**Increased risk**
R6-Big risk	**Unacceptable risk**
R9-Very high risk	

4. OBTAINED RESULTS OF ASSESSED PROFESSIONAL RISKS USING THREE METHODS

After the risk assessments, the most rigorous results were obtained using the Singapore 3×3 method, where we obtained as many as eight points of the third rank R3– (increased risk). Using the KINNY method, we obtained two points of the third rank R3– (medium risk). Using the LatiPRO methodology, we obtained two risk levels: R1– (negligible risk) and R2– (small risk), while the risks of the third level are not defined.
From the presented results, it can be concluded that the workplace of a forklift operator in the Logotem company is not a workplace with increased risk and that it is in violation of Article 4, Clause 26 of the Law on Occupational Safety and Health (Official Gazette No. 35/2023).
Although the ranks of the assessed risks differ, it should be taken into account that they represent the individual perception of the assessor and the employee, based on the answers received during the interview of the employee and the determination of the dangers and harms for the given workplace.

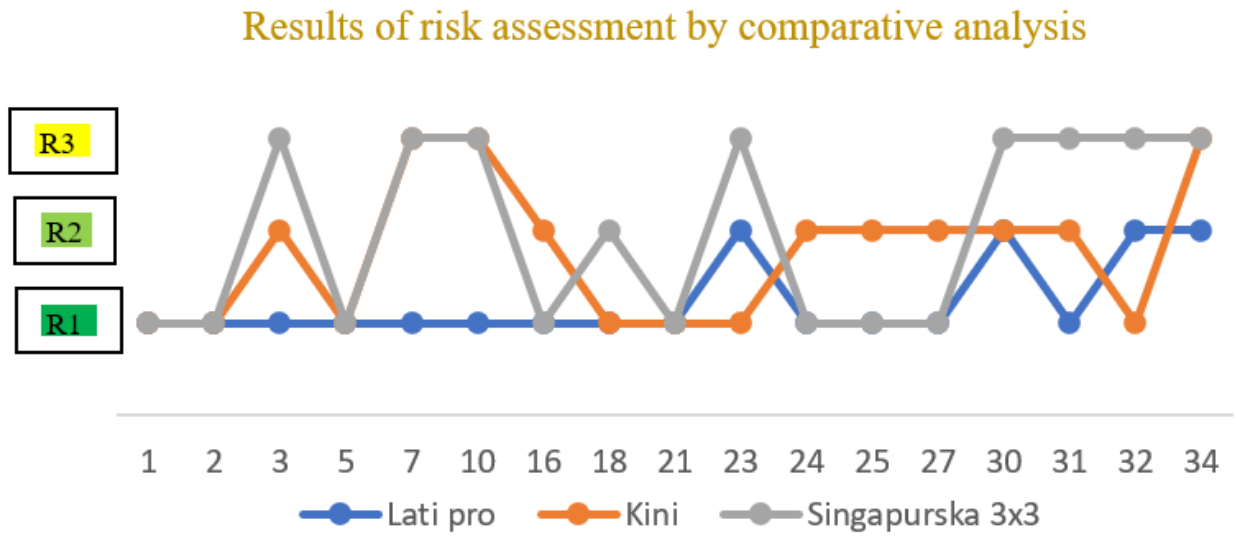

Figure 1. Results of risk assessment by comparative analysis for the workplace of a forklift operator

5. MEASURES TO REDUCE RISKS FOR THE WORKPLACE OF FORKLIFT OPERATORS THAT ARE APPLIED IN THE WORKING PROCESS

In order to properly treat the obtained levels of risk ranks and provide them with quality professional management, measures were determined to eliminate existing low risks and reduce moderate risks:

- An employee working as a forklift operator must be professionally trained in forklift operation at an accredited educational institution that has a license from the Ministry of Education;
- The employee must have a completed medical examination and a positive assessment on the fulfillment of the conditions for performing the duties of a forklift operator - periodically, once a year;
- The employee must be trained theoretically and practically for safe and healthy work at the workplace, with a knowledge check once a year;
- The forklift must be tested by an accredited laboratory every three years;
- All defects on the vehicle must be repaired immediately, and in the event of a defect, the employee is prohibited from working with the vehicle;
- It is forbidden to use a mobile phone while driving;
- The employee must be trained to move safely through the work area;

- The employee must wear personal protective equipment in accordance with the Act on risk assessment at the workplace and in the working environment;
- The employee must use the assigned personal protective equipment;
- The employee must handle the cart carefully;
- Aisles in the warehouse must be cleared of bulk and palletized goods;
- The employee must comply with all instructions and work procedures;
- The employee must move carefully on wet and slippery surfaces and use appropriate protective footwear prescribed by the Risk Assessment Act;
- Employees should correct their body posture while working, combined with breaks and occasional light stretching;

6. CONCLUSION

The term professional risk refers to the exposure of people and businesses to the action of various factors that can lead to unwanted consequences through their actions and activities, which in the practice is usually reflected by creation of certain types of costs or, what is much more significant, in the impairment of the health of employees or the creation of minor and serious injuries at the work of employees, occupational diseases and diseases related to work.
By dividing professional risks, we can get a more complete picture of the nature of the risks themselves and how they arise, as well as the prevention of professional risk, which consists of a set of prevention plans and measures implemented in companies to prevent and detect risky situations.
The main goal of the assessment of professional risks is to determine critical places in the work and technological processes where injuries and endangering the lives of employees can occur. After the risk assessment, it is necessary to manage the risks, eliminate them or, in the case of impossibility of elimination, reduce the risk to an acceptable level, using, for example, personal protective equipment, continuous education, medical examinations, examination of work equipment and the like.
The risk assessment for the forklift operator's workplace was performed using three methodologies LatiPRO, Kinny and Singapore (3×3).
From the presented results, it is concluded that the workplace of a forklift operator in the company Logotem is not a workplace with increased risk and that it is in contradiction with Article 4, Clause 26 of the Law on Occupational Safety and Health (Official Gazette No. 35/2023).
Although the ranks of the assessed risks differ, it should be considered that they represent the individual perception of the assessor and the employee, based on the answers received during the interview of the employee and the determination of the dangers and harmfulness for the given workplace, and that after assessing the risks, corrective measures for elimination should be taken risks or their reduction.

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ENVIRONMENT AND SUSTAINABLE DEVELOPMENT. MECHATRONICS. OCCUPATIONAL SAFETY AND HEALTH AND FIRE SAFETY. SMART MANAGEMENT SYSTEMS. GRAPHIC ENGINEERING. DESIGN. TRAFFIC ENGINEERING. BIOTECHNOLOGY AND HEALTHCARE. MECHANICAL ENGINEERING. ECOTOURISM AND RURAL DEVELOPMENT.

IMPLEMENTATION OF STRATEGIES FOR THE DEVELOPMENT OF CRITICAL THINKING IN ENGLISH LANGUAGE TEACHING AMONG THE STUDENTS OF THE OCCUPATIONAL SAFETY AND HEALTH STUDY PROGRAM AT THE ACADEMY OF APPLIED TECHNICAL STUDIES BELGRADE

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Abstract: *The process of foreign language teaching at the tertiary level of education should not be based on techniques that direct students to passive listening and mere memorization and reproduction of the teaching material. Accordingly, the methods applied in teaching should develop students' cognitive actions that are related to higher cognitive functions. Strategies for improving foreign language teaching at higher education institutions must also include the use of teaching methods that develop students' deep approach to learning, understanding problems, connecting knowledge from different fields, connecting new knowledge with the existing knowledge, connecting theoretical knowledge with everyday experience, etc. This paper deals with the implementation of strategies for the development of critical thinking in English language teaching among the students of Occupational Safety and Health study program at the Academy of Applied Technical Studies Belgrade. The paper presents strategies and specially designed activities that direct students to active participation in classes, nurture and develop the use of critical thinking in the process of learning English, with the purpose of improving the quality of English language teaching at the Academy.*
Keywords: Critical thinking, Occupational Safety and Health

1. INTRODUCTION

"Critical thinking is a reasonable reflective thinking focused on deciding what to believe and do" [1]. In order to understand the strategies that are employed to develop critical thinking skills, it is necessary to understand the process of learning. According to Marton, and Säljö, there are three approaches to learning: surface, deep, and achieving [2]. Surface and deep approaches describe the level of student's engagement in the actual assignment, while the achieving approach describes how students perform the organization the temporal and spatial contexts in which they do the assignment. These three approaches lead to diverse kinds of learning outcomes [3]. They basically study the connection between the student's approach to learning and the level of understanding that they eventually demonstrate. Students who demonstrate the surface approach towards learning possess the following characteristics: They learn with the specific goal of meeting the course demands, they are unable to connect previously gained knowledge with the new knowledge and they simply memorize and reproduce the material. On the other hand, students who have the tendency to learn by employing the deep learning approach will demonstrate the following characteristics: They acquire knowledge, understand the material and are able to connect the concepts. They exhibit the capability of relating ideas to previously gained experience and they can see the connection between the evidence and the conclusion. They demonstrate critical thinking skills and are able to provide independently drawn conclusions [2]. What matters is that when teachers set objectives of learning they incorporate the

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strategies for the development of critical thinking among students, because critical thinking represents one of the main aspects of successful language learning.
According to Bloom, cognitive processes are classified into six different categories (Figure 1). In order to develop and improve the level of critical thinking it is necessary to apply strategies that would employ higher cognitive functions, such as invent, develop, assess, etc. [4].

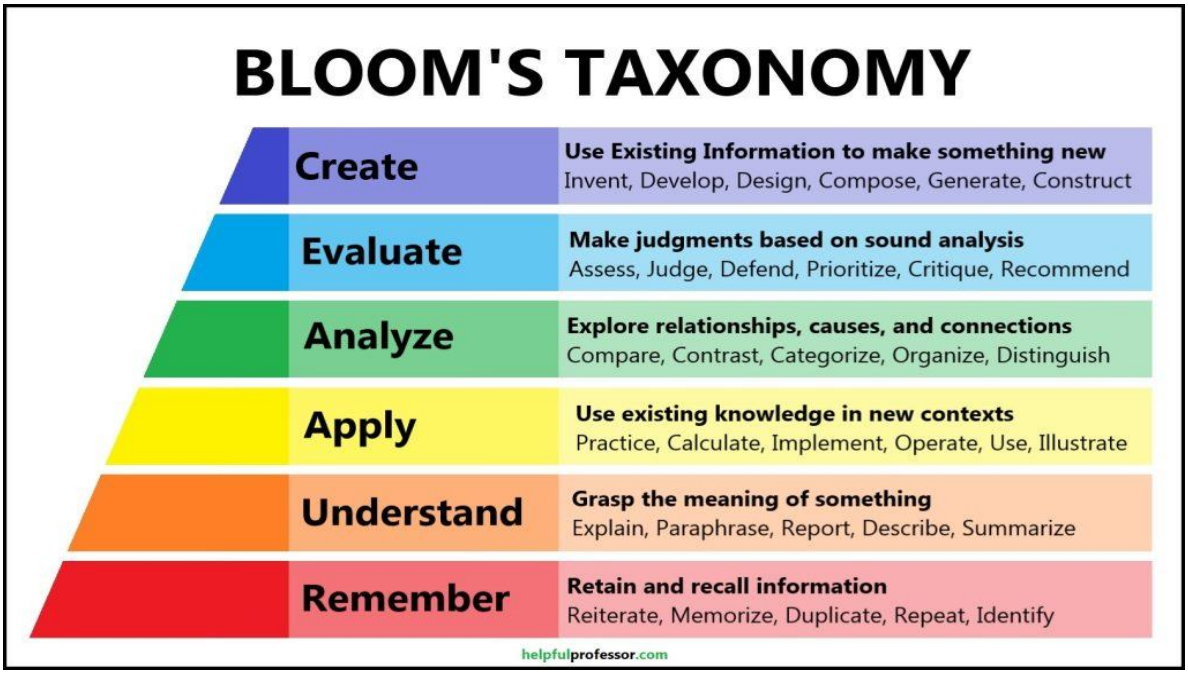

Figure 1. Bloom's Taxonomy
Source: https://helpfulprofessor.com/

2. ACTIVITIES

The main reason why students of Occupational Safety and Health study program were elected among other study programs to be the part of this paper is the fact that they must think critically if they want to perform their duties professionally. Their primary assignment is to keep people safe and healthy, which is the most important aspect of every job. They need to be capable of recognizing hazards, and they need to know how to formulate plans to prevent these hazards from happening. They need to establish security guidelines, as well to take precaution measures to protect the workers and secure the buildings. All of this is achieved and improved by nurturing critical thinking among students and enabling them to draw their own conclusions, solve problems, develop and create. By incorporating these strategies into every aspect of their education they are provided with the opportunity to do so, and thus further sharpen their critical thinking skills. This is why it is essential to incorporate some of the following activities into their English language learning:

1) **A selection of photos and the question**: *What's going on in this picture?* [5]. A teacher should prepare a selection of photos that do not possess any kind of written title or explanation. This exercise can be done individually, in pairs or in groups. The answer can be a written description or an oral discussion. Students will have the opportunity to improve their critical thinking skills, analyze the photos, improve their vocabulary range, as well as to enhance their knowledge of grammar constructions.
2) **TED Talks and more video/listening resources:** Various video resources have proven to be very useful in English language acquisition. Apart from listening to native English language speakers, learning new information, new vocabulary and grammar constructions, the students can discuss the videos in groups, use dictionaries to find new vocabulary, use it in sentences. They can suggest their ideas for problem-solving situations, give their opinion and reinforce it with facts from the video.

3) **A long written text about Occupational Safety and Health and its analysis**: There are numerous activities that can be carried out using this material. They include writing a title for each paragraph, sentence transformations, making the glossary of the words from the text, transforming the words into different parts of speech, using new vocabulary in a sentence, giving suggestions for problem solutions, text translation, etc.
4) **Scenario Discussions:** The students get previously written scenarios about hypothetical situations concerning Occupational Safety and Health. Their tasks include coming up with possible solutions to the problem, giving suggestions, predicting possible problems, obstacles, proposing preventive measures, etc. This assignment can be done individually or in a group. This type of exercise has proven to be very useful for the development of critical thinking skills, since students are provided with the opportunity to think of solutions, present their point of view, discuss possible changes to the solutions, and hear other students' opinions concerning the given scenario. At the same time, they improve their English language skills, since they are supposed to prepare the solution's presentation in English, so they expand their vocabulary range by using dictionaries, online resources, etc. They also improve their grammar, writing skills as well as their speaking fluency.
5) **Ethical Dilemmas:** This kind of exercise has proven to be very beneficial in terms of development of critical thinking skills. The students are faced with an ethical dilemma. Bear in mind that the students of Occupational Safety and Health will have responsibilities that will include the safety of people. This is why there are endless options that can be used in this type of exercise. Students will have to assume a certain point of view and reinforce it with arguments supported by evidence.
6) **Presenting and active listening:** A student is appointed to prepare a presentation on a certain topic that is related Occupational Safety and Health. The rest of the class has to listen carefully, analyze, ask questions, and give impressions and suggestions. Students can be asked to paraphrase what the speaker has said, to write a short summary, reflect, ask questions etc., in order to check whether they understood the material, as well as to practice speaking.
7) **Classification:** classification will help students not only to memorize new vocabulary, but to put new words into context, thus giving them the opportunity to create certain associations to words, that they might use in future. For example, they can classify vocabulary into categories: PP equipment, types of safety officers, types of hazards, dangerous chemicals etc. Students can also classify vocabulary according to grammar features or parts of speech.
8) **Identifying arguments:** Stance (topic sentence), Evidence (supporting ideas, cited research, quotes), Explanation (explaining the evidence from your point of view), [6].
9) **Error correction:** Students are given a text with errors. Their task is to find the errors and fix them. By doing this exercise, students get multiple benefits. They develop critical thinking skills, identify text aspects, practice grammar and vocabulary etc.
10) **Argumentative essay writing:** Argumentative essay writing is one of the strategies that has proven to be very successful in developing skills such as careful thinking (reflective thinking), objective analysis and evaluation (rational thinking), and judgment formation (reasonable thinking) [7].Students are presented with the instructions on how to write argumentative essays. At first they write the outlines and present their ideas to the class. After class discussions, where they can point out the mistakes, give suggestions, but also to point out good aspects of the presented outlines, their assignment is to write the complete essays based on the outlines. Once again their work is the subject of class discussions.

3. CONCLUSION

Taking all the facts into consideration, it is clear that critical thinking is omnipresent in all aspects of foreign language acquisition. It is necessary for teachers to promote independent learning and explain how important it is. The reason for this lies in the fact that students with deep approach to learning tend to have developed critical thinking skills because they use cognitive skills of higher order.

However, students need to possess theoretical knowledge that they will use as a foundation that will be gradually upgraded. The combination of techniques for teaching theory and techniques that engage students into interactive activities that will develop their critical thinking skills has proven to yield excellent results in the acquisition of English language at the tertiary level of education.

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BUSINESS COMMUNICATION OBSTACLES IN ENGLISH LANGUAGE IN OCCUPATIONAL HEALTH AND SAFETY EDUCATION

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Abstract: *In this paper the authors try to explain business communication obstacles in English language in Occupational Health and Safety education. Business communication is very important for students' future career. The main obstacles are sociocultural, psychological and organizational. All three of them have specific influence on students. The authors explain these obstacles more precisely in order to be more understandable. These obstacles can be solved by better understanding and determining business communication obstacles.*
Keywords: business communication, obstacles

1. INTRODUCTION

Communication in general sense implies message transmission from sender to recipient. The aim of communication is not only to receive the message but to understand it. It is important in all aspects of live. Its basic characteristics are: 1. It is comprehensive and represents the main element of culture, 2. It is continuous, endless, 3. It is based on message exchange, 4. It works in many , and between two or more groups, 5. It is held by equals and unequals no matter of gender, age, social status and education, 6. It contains predictable, expectable or conventional elements, 7. It has irreversible character and 8. It is contextual because it depends on context in which it is held.

2. COMMUNICATION OBSTACLES

Business communication is a type of communication which is used in business world. It represents the discipline of writing, presentation and communication in professional manner. Unfortunately, there are many obstacles in business communication. We can divide them into: sociocultural, psychological and organizational obstacles. They consist of everything that prevents the message to be received and understood. They are mainly of human origin, not technological.

3. SOCIOCULTURAL OBSTACLES

By participating in some culture, consciously or unconsciously, we obey social norms. Social norms are implicit or "informal" rules about what, how, when and where is something done. From the communicational perspective it is interesting that social norms and cultural characteristics are not important only because they enable better communication, but because these same norms can be communication obstacles. Key sociocultural elements that can become obstacles are: group thinking, conflict between values and beliefs, stereotypes and ethnocentrism, language and slang. Group thinking is the social phenomenon which appears when group behavior domineers or suffocates the process of decision making. It appears when social norms or group's tendencies to reach consensus overpower tendency to achieve decisions that are in the best interest of the group. It also happens

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when common values and conformism get out of control. Characteristics of group thinking are: similarity and hidden differences, reliance on mutual rationalizations, collective models of defensive avoidance, the lack of awareness, hiding worrying deficiencies, unjustified optimism and thinking in slogans. Conflict between values and beliefs appears as a consequence of unsuccessful communication caused by ignoring mutual basic values and norms. Stereotype is an attempt to predict one's behavior based by their membership in certain group. It represents obstacle in communication because, due to them, we do not look at people as individuals and we do not listen to their messages. Ethnocentrism links to the stereotypes. Ethnocentric people look upon their culture as the only valid one. They measure out everyone according to their own culture standards which for they think as superior ones. It also, like ethnocentrism, leads to prejudice and discrimination. Language can represent communication obstacle even if interlocutors speak the same language. The status and class differences have influence on different language use which can identify or exclude entire groups of people. Slang can have the same purpose.

4. PSYCHOLOGICAL OBSTACLES

Psychological obstacles refer to the individual and their mental and emotional state. People tend to hear what they want to hear, and to see what they want to see. Our filters and prejudices are very often the result of personal values and cultural origin. These problems can be avoided by cautious listening and reading. We are constantly "bombed" by so much information that we practically cannot process, so certain amount of selectivity is more than necessary. The rare ones succeed to deal with so many information and data and that is called framework of thinking. It is caused by: limited time and other resources during information collection, different expectations of the manager and others concerning criteria that determine the importance of information and, limited ability of understanding, processing and using huge amount of information. Perceptions are the ways by which we observe the world. Our perceptions can become the communication obstacles. It happens that we don't want to understand what is received in communication because even before the communication happened we had made the idea in our head that it is not important to us. We actually never lose what we have experienced by acting, listening, reading, smelling and touching. However, maybe we cannot reach those memories. If we want to become a successful communicator, we should learn and practice memory exercises. The key elements which enable better memory are: understanding, the knowledge width, active remembering, pre-learning and associations. Bad listening includes daydreaming, reading, listening to the other conversation instead of the one we are participating in, sightseeing and generally situations where we are not concentrated on listening. Some problems connected to listening are obvious – problems caused by external disturbances or lack of interest. However, there are more subtle ones: verbal struggle (It happens that, instead of listening and absorbing what the other person is telling us, we start to discuss ideas in our head.) and fact hunt (when we, instead of listening to the basic topic or the argument point, concentrate on detailed facts and because of that we don't realize the whole message). There are few types of listeners: fake listener (the one who seems to carefully listen, even transmits appropriate non-verbal signals, but is really somewhere else in their head), limited listener (partially pays attention to what we are speaking, concentrates on specific details or comments so they can misunderstand other messages), egocentric listener (only cares about their own point of view and all they want of us is to agree. They choose only the communication elements which can be used as the support for their point of view.), and positive or active listener (the one who absorbs and processes information that they receive, but also encourages the other person to speak). In order to be an active listener, we should develop the following skills: the ability to participate (it relies on careful listening, awareness and absorbing of told things), the ability to follow (not only mental, but physical indication that we are following what the speaker is talking about), and the ability to consider (we should think about the material so it could transfer from sensory to our short- term or long-term memory). Emotions can also represent obstacles in sending and receiving messages. When a person is angry, sad or frightened, their communicational abilities can weaken.

Positive feelings can be an obstacle too, for example, too much humor is going to make our message not so important and serious.

5. ORGANIZATIONAL OBSTACLES

Organizational obstacles refer to the organizational structure, culture, work model and communicational flows. The most common organizational obstacles are: information overload (direct approach to information gives people the feeling of overcrowding), message competition (the quantity of information that we receive every day forces us to choose between things that are important and things that we can ignore), information distortion (information can be wrongly interpreted or even intentionally be blocked), message filtering (by filtering or inspecting we can choose the communication which is worth paying attention), contradictory messages (they can ruin its credibility), communicational climate and status differences. We can solve organizational obstacles by observation, accuracy, credibility and likeability. We can mitigate the obstacles by lessening level numbers in organizational structure. Less number of links in communication chain contributes to better communication.

6. CONCLUSION

Business communication in English language in Occupational Health and Safety Education is very important for students. If they are good English language speakers, they tend to convince themselves that their business communication skills are also good and they usually make mistakes. They are mostly affected by sociocultural and psychological obstacles. The teaching experience has shown us that they mostly tend to think as a group, use stereotypes, have wrong perceptions and overuse their emotions. That is the reason why we have to take this matter more seriously and help them to reach better business communication skills as well as in English as in their mother tongue.

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A NOVEL TABULAR METHOD FOR ESTIMATION OF WATER FLOW RATE AT THE HYDRANT NOZZLE

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Abstract: *In order to estimate the flow rate of water at the hydrant nozzle, the standards such as SRPS Z.C1.050:1989 and DIN 14 440 cannot be applied to all types of nozzles that obey the requirements of reference standards SRPS EN 671-1: 2015 or SRPS EN 671-2:2015. In this paper the authors present tables that can be used for estimating flow in function of pressure and flow characteristic of hydrant nozzle with orifice diameter of 8 and 16 mm.*
Keywords: Hydrant nozzle, Flow characteristic of nozzle

1. INTRODUCTION

The most important numerical parameters for fire hydrant operation are: water static pressure, dynamic pressure and flow rate. During hydrant periodic testing, that is mandatory to be carried twice per year, static pressure is measured at each internal wall-mounted hydrant cabinet. Dynamic pressure is measured at the cabinet with the most unfavourable hydraulic position (where the lowest pressure values are expected, i.e. on the highest floor or the most distant form water source), while for other cabinets dynamic pressure is calculated. Flow rate at each cabinet can be determined by calculation or measurement. In paper [1], the procedure for determining the mentioned hydrant parameters is presented, as well as the procedure for determining the flow characteristics of hydrant nozzle. Standards [5] and [6], which are mandatory for application in Serbia according to the rulebook [3], define the minimum flow characteristic depending on the nozzle diameter and the minimum flow rate at pressures of 2.0 bar, 4.0 bar and 6.0 bar. In Serbia, the standard [4] is used to calculate the hydrant flow rate. This standard is practically a translation of the standard [8], in terms of text, equations and symbols that are identical, while the tables and nomograms are different. The difference is that in the standard [8] the flow rates resolution in tables and nomograms equals to 1 l/min while in the standard [5] it equals to 5 l/min. Please note that before the adoption of harmonized regulations [5], [6] and [7], the nozzle geometry and the procedure of nozzle manufacturing were standardized, but not the nozzle flow characteristics.
In a series of measurements that were carried out at the Centre for Fire Protection Engineering of the Faculty of Mechanical Engineering in Belgrade, it was shown that the flow characteristics of nozzles that are offered in Serbian market and that meet the requirements defined by standards [5] and [6] are significantly different from the flow characteristics that are obtained according to standards [4] and [8]. In paper [2], it was stated that for nozzles with a nozzle diameter of 12 mm, which are prescribed by regulation [3] for mandatory use when testing internal hydrant installations, the flow characteristic determined by measurement ranged from 76 to 83, while the flow characteristic determined by procedure given in standard [4] equals to 96 and by using standard [8] equals to 94. Hence, it can be

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concluded that tables and nomograms given in standards [4] and [8] are not applicable for hydrant nozzles that are present on the market.
In paper [2], tables are given in which the flow rates of water at hydrant nozzle with a nozzle diameter of 12 mm are shown as a function of pressure, for different nozzle flow characteristics. In this paper, tables will be presented in which the flow rates of water at nozzles with nozzle diameters of 8 mm and 16 mm can be determined as a function of pressure, for different nozzle flow characteristics.

2. DETERMINATION OF NOZZLE FLOW CHARACTERISTICS

The procedure for determining the flow characteristic of the nozzle is given in detail in other paper [1]. Here it will be presented briefly. For the standard hydrant nozzle, which is shown in Fig. 1, the water flow rate through a constant nozzle orifice is directly proportional to the square root of the water pressure value. The proportionality coefficient is called the flow characteristic of the nozzle (K). Therefore, the relation can be expressed as:

$$Q = K\sqrt{P} \tag{1}$$

Where,
P – pressure [bar];
Q – flow rate [l/min];
K – flow characteristics $[\,l/(\min\sqrt{bar})\,]$.

When determining the flow characteristic, a pressure gauge (manometer) is mounted between the hydrant nozzle and hydrant hose. The nozzle to be tested is directed outdoor or to a drainage pit. By adjusting the valve position at the hydrant cabinet, the pressure in the installation is controlled. The flow is measured with an ultrasonic flowmeter, which is placed at the water supply pipe to the hydrant cabinet. Pressure (P) is set at fixed values of 2.0 bar, 2.5 bar, 3.0 bar; 3.5 bar, 4.0 bar, 4.5 bar, 5.0 bar, 5.5 bar and 6.0 bar. The estimation of the value of the nozzle flow characteristic is determined by the application of the least squares method [1]:

$$K = \frac{\sum_i Q_i\sqrt{P_i}}{\sum_i P_i} = \frac{\sum_i Q_i\sqrt{P_i}}{36}. \tag{2}$$

Figure 1. Standard hydrant nozzle (orifice diameter 16 mm, hose connection flange Ø75mm - type B, length 410 mm, height 126 mm, weight 1.75 kg)
Source: https://tehnoprom.rs

3. TABLES FOR CALCULATING FLOW RATE AS A FUNCTION OF PRESSURE

In Table 1, results are presented for a nozzle with an orifice diameter of 8 mm. Such nozzles are used at the internal hydrant cabinets in accordance with the standard [4]. According to the rulebook [3], this type of nozzles can be installed on internal hydrant networks in residential and commercial buildings that have a maximum of 5 above-ground floors and the technological process category is K3, K4 or K5. For such hydrant installations semi-rigid hoses wound on a reel can be applied. Their advantage is that the maximum permitted distance from the point in the protected area to the hose connection in hydrant cabinet is 30 m, which is greater than the connections defined by the standard [5].

The water flow rate [l/min] is expressed as a function of the pressure (*P*) [bar] and the flow characteristics of the nozzle (*K*) as shown in Table 1. It was adopted that the pressure value should be regulated with step of 0.5 bar, which ensures an accuracy of 0.25 bar, because greater accuracy is not achieved even by measuring with standard manometers.

Table 1. Flow rate at nozzle [l/min] as a function of pressure *P* [bar] and nozzle flow characteristics *K* – for nozzle orifice diameter of 8 mm

Source: *original author's*

K/P	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5
28	40	44	48	52	56	59	63	66	69	71	74	77
29	41	46	50	54	58	62	65	68	71	74	77	79
30	42	47	52	56	60	64	67	70	73	76	79	82
31	44	49	54	58	62	66	69	73	76	79	82	85
32	45	51	55	60	64	68	72	75	78	82	85	88
33	47	52	57	62	66	70	74	77	81	84	87	90
34	48	54	59	64	68	72	76	80	83	87	90	93
35	49	55	61	65	70	74	78	82	86	89	93	96
36	51	57	62	67	72	76	80	84	88	92	95	99
37	52	59	64	69	74	78	83	87	91	94	98	101
38	54	60	66	71	76	81	85	89	93	97	101	104
39	55	62	68	73	78	83	87	91	96	99	103	107
40	57	63	69	75	80	85	89	94	98	102	106	110
41	58	65	71	77	82	87	92	96	100	105	108	112
42	59	66	73	79	84	89	94	98	103	107	111	115
43	61	68	74	80	86	91	96	101	105	110	114	118
44	62	70	76	82	88	93	98	103	108	112	116	120
45	64	71	78	84	90	95	101	106	110	115	119	123

In Table 2, results are presented for a nozzle with an orifice diameter of 16 mm. This type of nozzles are defined by regulation [3] for mandatory use when testing external hydrant installations. The regulation also define minimum dynamic pressure at the connection of the external hydrant network of 3 bar and the flow rate of 5 l/s.

As in previous case the pressure values from 2.0 to 7.5 bar in Table 2 are with step of 0.5 bar, which ensures an accuracy of 0.25 bar, because greater accuracy is not achieved even by measuring with standard manometers.

Table 2. Flow rate at nozzle [l/min] as a function of pressure *P* [bar] and nozzle flow characteristics *K* – for nozzle orifice diameter of 16 mm

Source: *original author's*

K/P	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5
170	240	269	294	318	340	361	380	399	416	433	450	466
171	242	270	296	320	342	363	382	401	419	436	452	468
172	243	272	298	322	344	365	385	403	421	439	455	471
173	245	274	300	324	346	367	387	406	424	441	458	474
174	246	275	301	326	348	369	389	408	426	444	460	477
175	247	277	303	327	350	371	391	410	429	446	463	479
176	249	278	305	329	352	373	394	413	431	449	466	482
177	250	280	307	331	354	375	396	415	434	451	468	485
178	252	281	308	333	356	378	398	417	436	454	471	487
179	253	283	310	335	358	380	400	420	438	456	474	490
180	255	285	312	337	360	382	402	422	441	459	476	493

181	256	286	314	339	362	384	405	424	443	461	479	496
182	257	288	315	340	364	386	407	427	446	464	482	498
183	259	289	317	342	366	388	409	429	448	467	484	501
184	260	291	319	344	368	390	411	432	451	469	487	504
185	262	293	320	346	370	392	414	434	453	472	489	507

4. CONCLUSION

In the former standards that were used before the adoption of harmonized regulations in Serbia in 2018, the geometry of the hydrant nozzle and the procedure of its production were standardized, but not the flow characteristics. In a series of measurements that were carried out at the Centre for Fire Protection Engineering of the Faculty of Mechanical Engineering in Belgrade, it was shown that the flow characteristics of the nozzles that are sold on Serbian market and that are in accordance with the harmonized regulations have lower flow characteristics than those for the nozzles defined by the standards [4] and [8]. Therefore, in this paper, tables are given in which the flow rate [l/min] through a nozzle with orifice of 8 mm and 16 mm in diameter is expressed as a function of the pressure [bar] and the flow characteristics of the nozzle. The use of these tables can significantly facilitate the work of engineers and technicians who carry out the initial and periodic testing of the performance of internal hydrant installations.

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SELECTION AND USE OF MECHANIZED EQUIPMENT FOR EXTINGUISHING FOREST FIRES IN ORDER TO INCREASE EFFICIENCY - METHODOLOGICAL APPROACH

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Abstract: *The choice of equipment and means for extinguishing forest fires is very often, along with the application of appropriate tactical extinguishing methods, important for the efficiency and success of extinguishing this type of fire. The use of mechanized forest firefighting equipment where possible can greatly help to improve firefighting efficiency and reduce firefighting time. In order to be able to use mechanized equipment, it is necessary to know the conditions on the ground and the possibility of its application. That is why it is always good to know certain legalities and according to them to choose suitable equipment for extinguishing forest fires. Where it is possible and economically justified, it is necessary to immediately use mechanized equipment for extinguishing forest fires, as this reduces the extinguishing time and the number of people needed for extinguishing.*
Keywords: forest firefighting equipment, forest fires, fire protection

1. INTRODUCTION

Fighting forest fires is a difficult and dangerous job. The choice of fire extinguishing equipment is very important when extinguishing and has a significant impact on the effectiveness of extinguishing. The use of mechanized equipment for extinguishing forest fires is very important, where it is possible to use this equipment primarily in reducing fatigue when extinguishing with manual equipment, and also in improving the speed during extinguishing and the efficiency of extinguishing.

2. MECHANIZED EQUIPMENT FOR EXTINGUISHING FOREST FIRES AND ITS INFLUENCE ON EXTINGUISHING EFFICIENCY

The use of mechanized equipment for extinguishing forest fires facilitates and accelerates extinguishing actions and prevents the spread of forest fires. Practice shows that after two to three hours of work on extinguishing forest fires using manual equipment, the efficiency of well-trained people drops significantly due to fatigue.

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Figure No. 1 shows the influence of fatigue on the efficiency of extinguishing using manual extinguishing equipment.

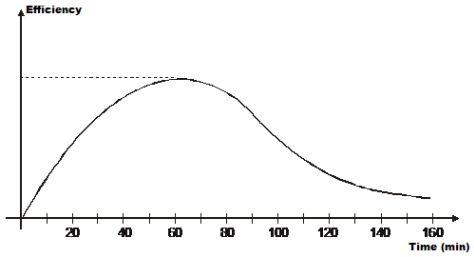

Figure 1. The influence of fatigue on the efficiency of extinguishing forest fires with manual equipment [1]

From the diagram (Figure 1), it can be seen that the efficiency drops significantly after 1.5 - 2 hours of work, so it is preferable to use mechanized equipment for extinguishing forest fires wherever possible.

The use of mechanized equipment for extinguishing forest fires can be made difficult by terrain conditions, such as: inaccessible and steep terrains, soft and unsuitable roads, unorganized and impassable forests, swampy terrains, economic reasons and the like.

The most important works that can be performed with mechanized equipment when extinguishing fires are:

- fire extinguishing with water,
- removal of combustible material in front of the fire, especially when forming fire lines,
- digging ditches, plowing and burying fuel material and the like and creating fire lines.

To extinguish and prevent the spread of forest fires, in addition to special firefighting vehicles and machines, machines for road construction, exploitation of forests, machines and tools for agricultural and other similar works are also used.

Mechanized equipment for extinguishing forest fires consists of:

- a wheeled tractor, with a simple or double plow, and a harrow for working on flat terrain,
- crawler tractor with plow,
- a grader (construction machine) on flat terrain, suitable for the construction and cleaning of fire protection lines,
- diggers and loaders for removing combustible material from the surface, transporting heavier pieces of combustible material (trees, branches, etc.).
- bulldozers for removing trees, pushing combustible material in front of the fire, laying fire lines when extinguishing fires of tall vegetation and the like,
- vehicles for water extinguishing (tanker trucks, combined vehicles, tankers with sprinklers and the like),
- vehicles for transporting personnel and equipment,
- vehicles for transporting heavy machinery to the place of intervention.

Figure 2. The creation of a blocked belt using a tractor with a plow

Table 1 shows the performance of mechanized equipment when extinguishing and preventing the spread of forest fires.

Table 1. Performance of mechanized equipment in preventing the spread and extinguishing of forest fires (1)

the name of the mechanized equipment	speed (km/h)	surface area (ha/h)	bandwidth, (m)
grader trailer: **д-20-А,д-20Б, д-165-А...** **д-241....**	 **1,0** **0,7**		 **4,5** **4,5**
auto graders: **д-144** **д-196**	 **1,0-1,25** **0,7-0,9**		 **4,5** **4,5**
bulldozers: **д-216** **д-157** **д-159**		 **0,4-0,7** **0,6-2,0** **0,6-1,2**	 **6,0** **6,0** **6,0**
tractor plows: **п-5-35, 5к-35...** **к-412-д...**		 **0,81** **0,6**	 **tractor speed** **4,8 km/h**

Setting up a barrier belt using agricultural machinery is the safest and most efficient way to stop the spread of fire along the edge. However, the application of these machines is limited by their slowness of movement, high weight, poor mobility and low maneuverability. Due to slow movement, mechanized equipment arrives late at the work area. Therefore, in order to transport these machines faster, it is necessary to provide vehicles for their quick delivery to the place of intervention (towing train, vehicle carriers, etc.).

The choice of vehicles for extinguishing forest fires cannot always be subject to some standardization, primarily because the problem of extinguishing forest fires is so diverse that common lines cannot be drawn in every case. The choice, construction and equipment of firefighting vehicles depends on terrain and topographic conditions, the type of predominant vegetation, the way and method of extinguishing and economic factors.

Terrain - topographic conditions impose the use of different types of vehicles. Tracked vehicles are more suitable for swampy, soft, uneven, rocky, hilly, and poorly accessible roads. Wheeled vehicles are more suitable for hard, flat, well-traveled terrain and with good roads.

The type of vegetation also requires the use of different types of vehicles, so lighter and faster vehicles are used for grassy terrain and maquis, and heavier and slower vehicles for forests and dense maquis.

Firefighting tactics determine the choice of vehicle, primarily depending on the application of direct or indirect firefighting methods. In the first case, more people and equipment are needed for extinguishing, so the vehicles must be adapted to those needs. In the second case, more heavy equipment and vehicles will be used for indirect extinguishing.

Figure 3 shows some dependencies when choosing a vehicle for extinguishing forest fires.

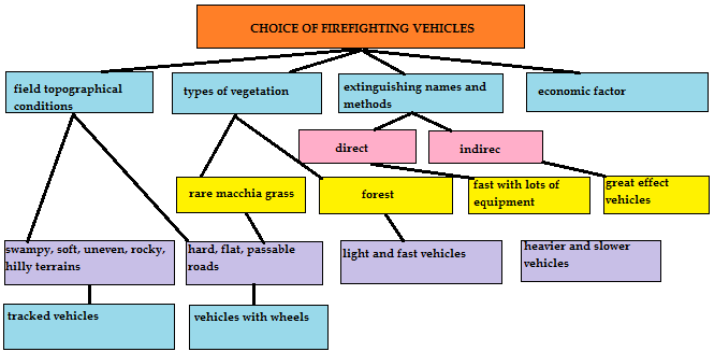

Figure 3. Scheme of selection of vehicles for extinguishing forest fires (1)

Before choosing, purchasing and equipping a vehicle, a thorough examination of the field conditions is necessary. It is necessary to work out the tactics of extinguishing forest fires in detail and include all this in the plans for suppressing and extinguishing forest fires.
Where the conditions allow it, it is necessary to use mechanized equipment when extinguishing forest fires, primarily due to the speed of extinguishing, reduction of fatigue of people, coverage of a larger area affected by the fire. By using this equipment, the risk can be reduced, and thus contribute to the increase in extinguishing efficiency. That's why in operational extinguishing plans, it is necessary to enter all the facts that are important for the use of mechanized equipment, such as the marked roads, the condition of the roads, the method of transporting the mechanized equipment, the type of vegetation, places for collecting and stationing the equipment, protective lines and the like.
Table 2 shows the time saved by using mechanized equipment compared to manual equipment for extinguishing forest fires.

Table 2. Time savings using mechanized equipment for extinguishing forest fires (1)

TYPES OF WORKS	1 man (minute)	the machine (minute)
1. Installation of a barrier belt with a width of 0.5 (m) using hand tools and machines	80 - 100	15 - 20
2. Installation of the obstacle belt using a tractor plow by five people	10 - 15	2 - 3
3. Placement of an obstacle belt using explosives at a distance of 1 m between the openings	100 - 120	
4. Installation of a barrier belt using chemicals, 1 m wide and consumption 0.5 l/m2	15 - 18	3 - 6
5. Extinguishing the edge of the fire using two jets of water with the treatment of a strip 10 m wide by six people	40	15

Table 2 shows that the time to extinguish forest fires using mechanized equipment is relatively shorter. This equipment should always be used in forest firefighting when field conditions permit.

3. EFFECTIVENESS OF APPLICATION OF FOREST FIRE EXTINGUISHING EQUIPMENT - METHODOLOGICAL APPROACH

Table 3. Efficiency of the use of mechanized equipment for extinguishing forest fires in relation to the possible area of application

Extinguishing area with mechanized equipment (%)	Extinguishing efficiency
The possibility of using mechanized equipment on 70% or more of the surface	Excellent and extremely effective
The possibility of using mechanized equipment from 50 to 70% of the surface	Extremely good
The possibility of using mechanized equipment from 30% to 50% of the area	Good
The possibility of using mechanized equipment from 10% to 30% of the area	Good as an auxiliary shutdown method
The possibility of using mechanized equipment on less than 10% of the area	Satisfactory as an additional extinguishing method

Table 4. Efficiency of the use of mechanized equipment and the choice of vehicles for extinguishing forest fires depending on the terrain and topographical conditions

Type of terrain	Choice of vehicle	Efficiency
Wetlands with softer ground, hilly terrains	Crawlers and tracked vehicles	Very good
Wetlands with softer ground, hilly terrains	Wheeled vehicles	Not recommended due to the possibility of jamming
Wetlands with softer ground, hilly terrains	Four-wheel drive vehicles	Good
Wetlands with softer ground, hilly terrains	Vehicles without four-wheel drive	Not recommended
Hard and flat, with good and passable roads	Wheeled vehicles	Very good
Hard and flat, with good and passable roads	Tracked vehicles	It can be good, it is limited by slower and heavier transport
Hard and flat, with good and passable roads	Vehicles for transporting people	Good

Table 5. Efficiency of the use of mechanized equipment and the choice of vehicles for extinguishing forest fires depending on the type of predominant vegetation

Type of predominant vegetation	Type of vehicle	Efficiency
Predominant vegetation: grass and low vegetation	Lighter and faster vehicles	Very good
Predominant vegetation: grass and low vegetation	Heavier and slower vehicles	Good but the performance is lower due to greater slowness (longer shutdown time)
Forest and dense vegetation	Lighter and faster vehicles	Good, but depends on access (good and passable roads are required)
Forest and dense vegetation	Heavier and slower vehicles	Good because of greater passability, but requires a longer extinguishing time due to slower action

Table 6. Efficiency of the use of mechanized equipment for extinguishing forest fires depending on the way and method of extinguishing

Extinguishing method	Type of vehicle	Efficiency
Indirect extinguishing method	High-speed vehicles are used with great effect in the installation of barrier belts and tracks	Very good
Indirect extinguishing method	Heavier and slower vehicles with good performance in placing barrier belts and tracks	Good
Indirect extinguishing method	A combination of high performance fast vehicles and heavier slower vehicles with good performance	Extremely good
Direct extinguishing method	Fast vehicles with more equipment	Good
Direct extinguishing method	High speed vehicles and medium speed vehicles with water fire extinguishing equipment	Extremely good
Direct extinguishing method	Fast vehicles for transporting personnel and equipment	Good

Table 7. Mechanized equipment for extinguishing forest fires with water and efficiency in relation to the intensity and speed of filling with water

Charging speed (minutes)	Efficiency
Up to 15 minutes	Very good
Up to 30 minutes	Good
Up to 60 minutes	It depends on several factors (intensity of fire, speed of spread, influence of wind, etc.)
Over 60 minutes	Not recommended

4. ECONOMIC JUSTIFICATION OF THE USE OF MECHANIZED EQUIPMENT FOR EXTINGUISHING FOREST FIRES IN RELATION TO THE AMOUNT OF MATERIAL DAMAGE CAUSED BY THE FIRE

Although this aspect is often overlooked and not taken into account, the actual costs of extinguishing forest fires are often high and exceed the damage caused by the fire itself. The question is often asked whether it is justified to make large material costs using a large amount of equipment and hiring a large number of people if this exceeds the damages caused by the fire itself, unless the fire creates a danger to people and material goods. It is often not possible to draw an exact line between all the parameters because there are many of them, and one must also take into account the environmental hazard factor, which is often immeasurable.

Table 8. shows the economic justification of using mechanized equipment for extinguishing forest fires in relation to the damage caused by the fire itself.

The amount of damage caused by the fire and the material costs of extinguishing it with mechanized equipment	Justification
If the use of mechanized equipment for extinguishing forest fires does not exceed 30% of the material damage caused by the fire	Very justified
If the use of mechanized equipment for extinguishing forest fires ranges from 30% to 50% of the material damage caused by the fire	Justified
If the use of mechanized equipment for extinguishing forest fires ranges from 50% to 80% of the material damage caused by the fire	Justified if there is a greater threat to people and material goods
If the use of mechanized equipment for extinguishing forest fires exceeds 100% of the material damage caused by the fire	It is not justified, it is necessary to use other methods

5. CONCLUSION

The use of mechanized equipment for extinguishing forest fires where possible is desirable and its application can compensate for many of the shortcomings and problems that arise from the use of manual equipment for extinguishing fires. Where the conditions allow and where the use of mechanized equipment is justified, mechanized equipment should be used because it reduces the extinguishing time and reduces the number of people needed for extinguishing, and its application can increase the efficiency of extinguishing. The very possibility of using mechanized equipment for each area should be determined based on the parameters that condition the use of this equipment and entered into the maps of applicable equipment for extinguishing forest fires.

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PREVENTION OF OCCUPATIONAL RISKS IN TRANSPORT AND INSTALLATION OF CONCRETE PRESTRESSED T-GIRDERS ON PROJECT IVERAK-LAJKOVAC

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Abstract: *With a gantry crane located on the plateau, the precast T-girder is lifted and loaded onto the transport vehicle. Placement of the girder in a precisely determined and pre-prepared place is done with two truck cranes with a load capacity of up to 70 tones or with one truck crane with a load capacity of up to 200 tones. Due to their size and mass, precast concrete elements pose a significant risk to everyone who works with them and persons in the immediate vicinity. The process of lifting and mounting the girders belongs to the group of high-risk jobs. Transport, lifting and installation of girders is a demanding and complex process in construction site. In the construction phase, occupational safety management is a critical segment that must be addressed in order to maintain the health and safety of employees while promoting productivity. During the preparation of technical documentation, engineers must take into account occupational safety and health as well as costs, so that the Plan of preventive measures foresees adequate preventive measures in the execution phase. In the future, alternative methods such as working with a launching gantry or working on scaffolding should be used.*
Keywords: prestressed concrete girder, truck crane, launching gantry, protective measures, technical documentation

1. INTRODUCTION

The construction of the high-speed road Iverak - Lajkovac represents a transverse link in the road network of the Republic of Serbia and connects parts of the Republic of Srpska, i.e., Bosnia and Herzegovina with the E-763 road (Belgrade - South Adriatic) and Corridor X. The technical characteristics of the terrain through which the section of the state road passes is plain. The total length of the section is 18.25 km.
Based on the hydrological analysis of the "Jaroslav Černi" Water Institute, carried out for the hydraulic calculation of the high waters of the Kolubara River for the relevant 100-year high water level, the route was placed on the bridge structure in the zone of immediate influence of the Kolubara River, in a length of 4 km. Crossing 1 has a total length of about 185 m (six fields), Crossing 2 has a length of about 930 m (33 fields) and Crossing 3 has been increased to 580 m (20 fields) [1]. Bridge constructions are semi-integral, they consist of segments with spans usually of 30 m. The upper part of the structure consists of 6 prefabricated prestressed girders connected to each other by a road plate. At Crossing 2 (the bridge over the Kolubara River), where there are 33 fields, a total of 348 prefabricated concrete girders have been prepared for installation. In the assembly phase, the girders are of the static simple beam system, and the span of the girders is 24.40 m, 29.40 m, and 35.40 m.
In the paper are presented method used for lifting and mounting T-girders, alternative methods, determination of safe methods and procedures, monitoring of the entire work process, analysis, and improvement of protection measures during the performance of work activities on the assembly of T-

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girders. The aim of the paper is to analyze the construction, transport, and installation methods of the ginders, identify existing hazards and circumstances that may threaten the occupational safety and health of employees. To implement adequate measures, a risk assessment is needed that includes an analysis of the current state of safety. It is important to raise awareness among all participants about the importance and role of safety, as well as the impact on the behavior of employees during the performance of work activities.

2. CONCRETE PRESTRESSED GIRDERS CONSTRUCTION PROCEDURE

Prefabricated components are previously concreted and confined on the prefabrication platform in the immediate vicinity of the building (bridge). After the concrete has hardened and the appropriate stress has been achieved in accordance with the project documentation for the construction of the bridge, they are transported as finished elements and mounted on the bearing beams. Before mounting the girders, the contractor will control the position and height of the bed on which the mounting supports will be supported and seek the approval of the supervisory authority. Installation is done with truck cranes. During assembly, the supports must be secured in terms of the designed position and secured from reaching such a position in which stress conditions occur that are unfavorable in relation to the quantity provided by the project.
After the concreting process of one girder and formwork dismantling, as well as after the completion of the first phase of the prestressing process (tighten of the lower cable), the girders are placed in the designated place for storage. Gantry cranes are used to move the girders, which are placed on the platform for the prefabrication of girders. On the plateau there are two cranes with a capacity of 60 tones, which are used for lifting the finished girders and two cranes with a capacity of 10 tones for lifting the formwork. The girders are raised three times in different stages. The first time with gantry cranes in the storage phase, when the girder is moved from the base (foundation) where it is concreted to the storage area. The second time with a gantry crane when the girder is placed on a transport vehicle that is used to transport it to the place of installation. The third time, the girders are lifted by truck cranes and placed in the intended place in the bridge structure itself (bearing beam). Figure 1 shows the method of lifting a T-girder with cables using a gantry crane [2].

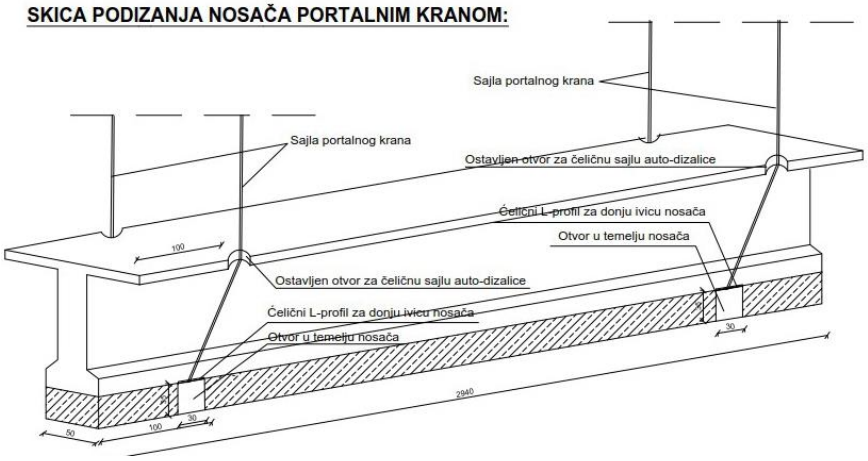

Figure 1. The method of lifting T-girders with a gantry crane with cables [2]

The gantry crane located on the plateau lifts the prefabricated T girder and loads it onto the transport vehicle with a payload of 100 t and the girder is transported to the location of the bridge. On the bridge, the longest T-girder is 35.40 m, and the weight is about 60 t. Placement of the girder in a precisely determined and pre-prepared place is done with two truck cranes with a load capacity of up to 70 t or with one truck crane with a load capacity of up to 200 t. The required number of truck cranes depends on the plan for lifting the girder in the specific field of the bridge, the access and working field of the truck cranes, the access road of the transport vehicle, the terrain conditions at the construction site, the height of the girder lifting, the presence of the river and electrical lines. Figures

2 and 3 show a graphic representation of the mounting of the girder with one truck crane of the right and left bays of the bridge.

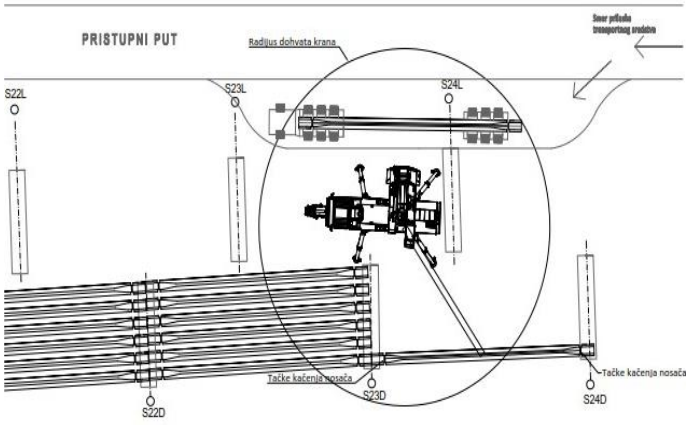

Figure 2. Mounting of the right field with one truck crane [2]

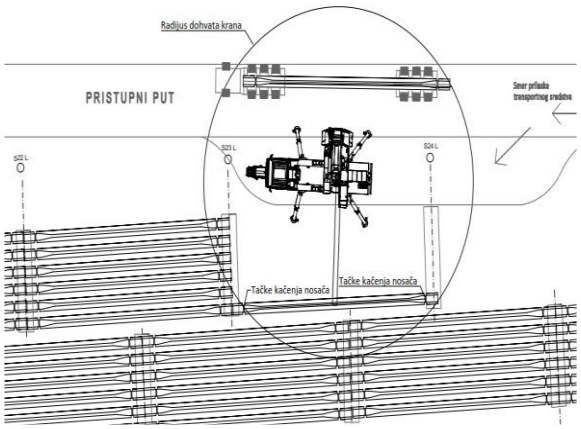

Figure 3. Mounting of the left field with one truck crane [2]

When the terrain and access is such that it is possible to place two truck cranes and a transport vehicle with a girder can approach the working field of the cranes, lifting and placing the girder is performed with two truck cranes, whose load capacity is up to 70 t. Figures 4 and 5 show a graphic representation of the mounting of the girder with two truck cranes.

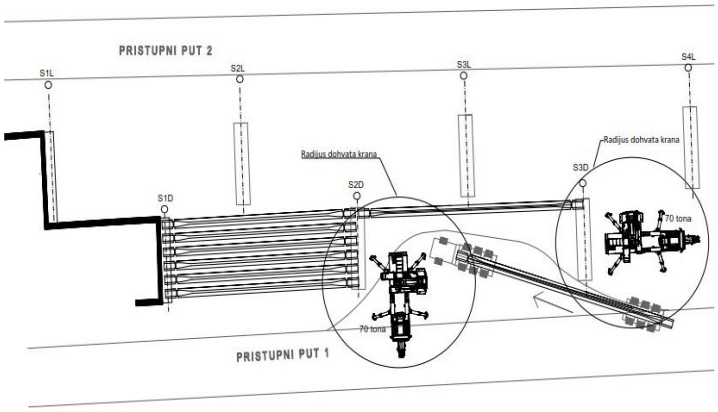

Figure 4. Mounting of the right field with two truck cranes [2]

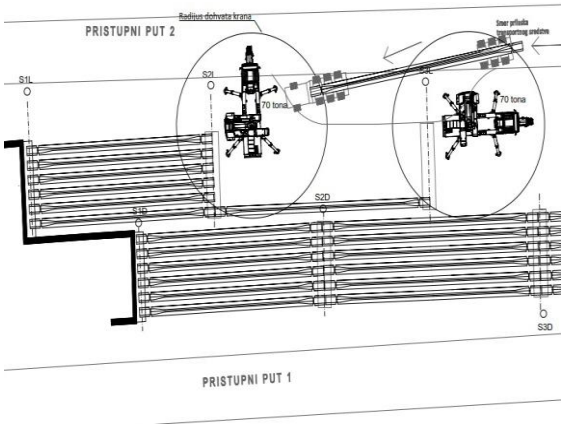

Figure 3. Mounting of the right field with two truck cranes [2]

Testing of the load bearing capacity of soil of the transport roads and platforms for lifting the girders are carried out before the start of the process of transporting prestressed concrete girders. Bearing capacity is satisfactory if it is more than 40 MPa. The test is carried out on the transport road itself, then on the platform where the girders are loaded onto the transport vehicle, as well as in the places where truck cranes are planned for lifting and mounting the girders. The examination is carried out in the presence of the supervisory authority and is carried out by an accredited laboratory.

2.1 Hazards and critical points identification

The previously described method of lifting the girders, using truck cranes, is the simplest, fastest, and cheapest method. Using this method has several disadvantages, namely critical points from the aspect of occupational safety and health. Disadvantages observed during work with truck cranes relate to compaction of the soil and stability of the cranes, access to the place of work and installation of the girders and movement after the completion of the lifting of the girders. The ground on which the stabilizers from the truck crane rest, must be adequately compacted and tested. In certain situations,

near the pillars, the material settles because the compaction guidelines are not respected in the places where the truck crane is placed in the initial lifting position. The stability of the crane is compromised, and it may tip over (Figure 6). Access to the place of work is provided so that employees can come with lifting platforms and after that they make preparations on the bed beams before lifting the girder. The work zone on the bearing beams during the assembly of the girder is narrow and the space for manipulation is narrowed also. The employees are between the reinforcements that are woven and follow the girder that is lifted with truck cranes and the installation in the designed position (bed), where even the slightest lack of concentration and movement can lead to injuries during work (Figure 7). After finishing lifting and mounting the girder on the bed, it is necessary to untie the cable and move to the next field and place yourself in the initial position. Getting out of the initial position from the bearing beam to the girder, untying the cable and moving on the girder after the installation riskier positions in the lifting and mounting phase (Figure 8).

Figure 6. Stabilizers of truck crane

Figure 7. Access and working area of mounting the girder

Figure 8. Getting out of the initial position

In addition to the mentioned method, there are other systems that can be applied when building structures from prestressed concrete, such as the method with a launching gantry or work on scaffolding and other temporary structures. A girder launch is generally a designed and built machine used for precast post-tensioned bridge structures. It consists of a lifting device and a supporting structure for lifting girders and prefabricated bridge segments into the assembled position. A launch girder usually consists of a main truss (″girders″) and lifting devices that would move horizontally along the truss when hanging/lifting the precast girder, bridge segment and/or assembly work platform [3]. The method of the launch gantry crane is divided into the shuttle method, the one-way method and the side feeding method according to the overstressed girder supply method. The construction method of the launching gantry crane enables the construction of bridges with overstressed girders in difficult conditions by delivering materials (girders) to the construction site with vehicles for transporting girders [4]. Figures 9 and 10 show the mounting methods of the carrier with the launching gantry.

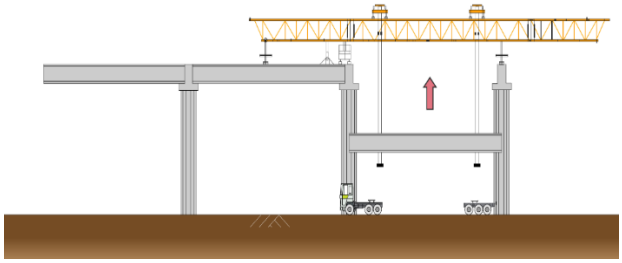

Figure 9. Installation of the carrier from the transport vehicle [4]

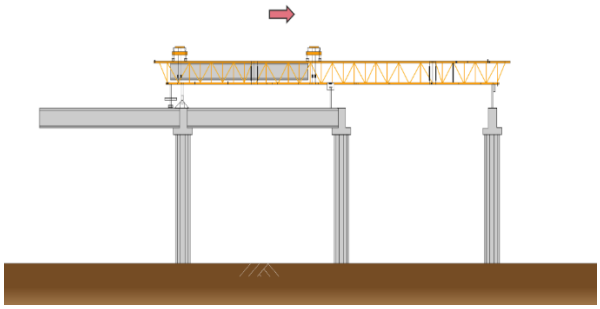

Figure 10. Installation of the carrier using lateral method [4]

From the preparatory work on the installation of the portal for the launching gantry grid method, there are hayards that require the application of protection measures during the process of mounting the elements on the bed. As with the method of lifting with cranes, it is necessary to pay special attention to the movement of employees on the girders after assembly.
Scaffolding consists of straight and angular connections (supports) that are installed and assembled from the bottom surface to the level of the bridge base (fixed scaffolding). Steel scaffolds can be formed manualy or in special forms made in factories [5]. Work on the scaffolding includes complete concreting and prestressing of one field and is done according to the "field by field" principle.

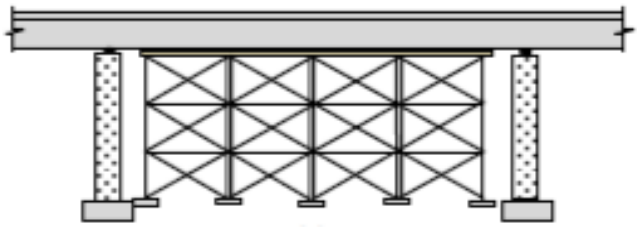

Figure 11. Method of construction on a fixed scaffold [4]

Scaffold assembly and disassembly work requires sufficient soil compaction to prevent settlement. During the preparatory work, it is necessary to comply with the requirements from the scaffolding project and the application of special protection measures when performing work at height. The scaffolding method requires a lot of time for assembly and disassembly and higher costs.
There were no reported work-related injuries on the project during the lifting and installation of the girders, but in this regard, it should be noted that the method with the launching gantry is safer compared to the method used with truck cranes.

2.3 Technical documentation, risk management and protection measures

Technical documentation contains textual, numerical, graphic attachments, technical characteristics of the object, the way, and methods of building the object and the construction works. It is created as a: general project; conceptual solution design; project design; project for building permit; project for construction work; project of the constructed object [6]. Through the justification study, the spatial, ecological, social, financial, market and economic justification of the investment is determined. During the preparation of technical documentation, designers must consider occupational safety and health, so that the Plan of preventive measures foresees adequate preventive measures of protection in the phase of construction works. In the stage of planning and preparation of technical documentation, it is necessary to anticipate costs related to safety measures. Defining and determining safety costs is very important to accurately calculate safety costs and establish a safety management system during construction.
Due to their size and mass, precast concrete elements pose a significant risk to everyone who works with them and employees in the immediate vicinity. Persons carrying out work must manage occupational safety risks, including consultation, cooperation and coordination with others. Employees and their representatives must also be involved when identifying and assessing risks and when deciding how to eliminate or minimize risks [7]. In a construction safety management system, identifying safety risks is one of the most important things to do. Risk identification is necessary to improve workplace safety, as the first step to prevent accidents by knowing the risk factors that contribute to accidents [8]. Based on the perceived dangers in the process of lifting, transporting, and mounting the girders and the analysis of the work activities performed, the works are classified as high-risk and risk control measures must be taken. Figure 12 shows the risk analysis during the lifting and mounting of the T-girders.

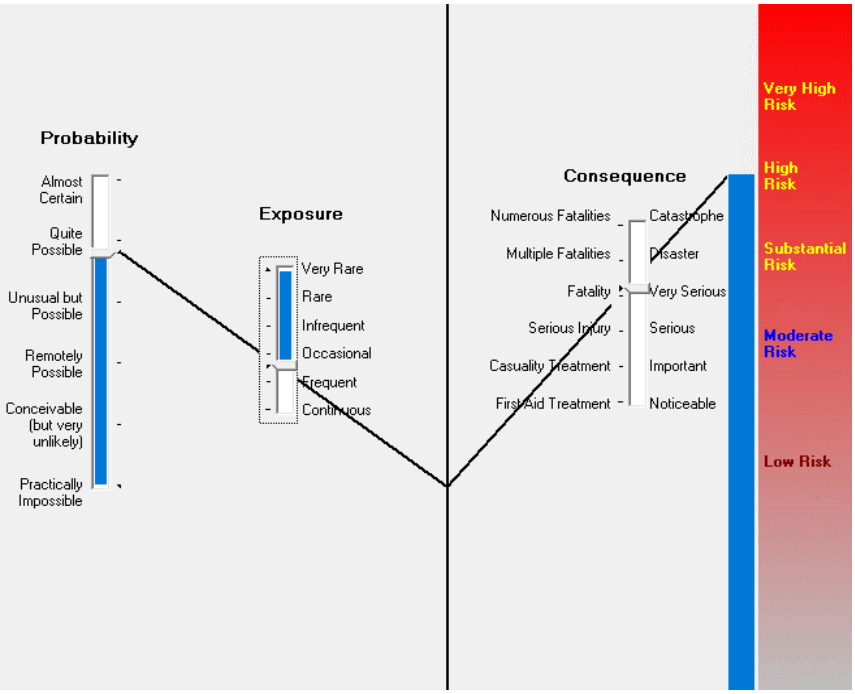

Figure 12. Lifting and installation of the T-girder risk analysis

Based on the identified and established hazards during the transport and installation of T-girders, it is necessary to apply appropriate protection measures. The goal is to eliminate/reduce recognized risks by applying measures and to reduce the possibility of accidents, to the extent that injuries at work are prevented. Figure 13. shows the hierarchy of prevention and control measures.

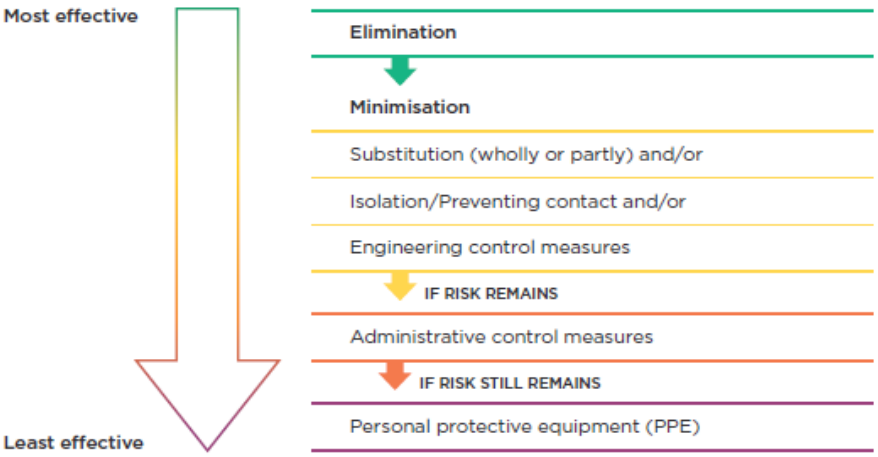

Figure 13. Hierarchy of prevention and control measures [7]

During the construction works, it is necessary to respect the safety measures that have been defined and that the participants in the project adhere to them. For access to the workplace and work zone, it is necessary to set up work platforms that will allow employees safe access to perform work activities. To prevent settlement on the platforms where the truck cranes will be installed, it is necessary to prepare the terrain and sufficiently compact the material. Respect the guidelines from the methodology and carry out continuously for each field test on the transport road itself, on the platform where the girders are loaded onto the transport vehicle and in the places where the installation of truck cranes for lifting and mounting the girders is planned. The aim is to create safe conditions for smooth operation to place the crane stabiliyers on a solid base to avoid the cranes tipping over during the lifting of the girder. A horizontal fall protection system must be provided for exiting the working position and moving on the support. By connecting a portable steel cable or reinforced nylon rope to a series of portable anchors or poles, employees can work safely and efficiently at heights without

compromising mobility or range of motion. When used in conjunction with personal protective equipment, a fall protection system can arrest a fall, limiting the amount of force transmitted to both the employee and the poles [9]. The system must be placed on a platform before being transported to the installation site. In addition to technical protection measures, it is very important to carry out additional training (education) of the direct executors of the work and familiarize them with new methods and procedures for mounting concrete girders, as well as protection measures.
The most effective measure of risk control is the elimination of danger or the replacement of a dangerous process with a less dangerous one, which is more practical, simpler, and cheaper to define in the design and planning phase than to manage risks in construction works.

3. CONCLUSION

Transport, lifting and installation of girders is a demanding and complex process in the building construction phase. The method of lifting and installation the T-girders with truck cranes carries with it dangers that may endanger the safety of employees during the work, therefore alternative methods (launching gantry or scaffolding) should be considered and used. The process of lifting and installation the girders belongs to the group of high risk works. In the construction phase of facilities, occupational safety management is a critical segment that must be addressed to maintain the health and safety of employees while promoting productivity. A well-crafted project that complies with regulations and a method that is safer can result in a significant reduction in costs, injuries, as well as improving the health and well-being of employees during the construction phase.

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ENVIRONMENT AND SUSTAINABLE DEVELOPMENT. MECHATRONICS. OCCUPATIONAL SAFETY AND HEALTH AND FIRE SAFETY. SMART MANAGEMENT SYSTEMS. GRAPHIC ENGINEERING. DESIGN. TRAFFIC ENGINEERING. BIOTECHNOLOGY AND HEALTHCARE. MECHANICAL ENGINEERING. ECOTOURISM AND RURAL DEVELOPMENT.

Student paper

"NEAR MISS" EVENTS IN THE TPS ZEMUN RECONSTRUCTION PROJECT: A Research and Analysis

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Abstract: *The construction sector is a vast and constantly evolving field characterized by a multitude of uncertainties. All construction projects involve numerous stakeholders and a variety of risks. Effective safety management in this industry requires a tailored and flexible approach. Traditionally, efforts to improve health and safety at construction sites have focused primarily on analyzing indicators collected after work-related incidents, illnesses, or fatal accidents. However, statistical data from the Occupational Safety and Health Administration show that the number of occupational accidents in the construction industry is increasing at an alarming rate despite extensive legislative measures. The main objective of this study was to explore the potential application of corrective measures for "near miss" incidents as a proactive approach to effective safety management in construction projects. The aim was to improve outcomes and overall safety performance. The study was conducted in an organization that had implemented a system for reporting "near miss" events. The study provides a deeper understanding of real-life situations on construction sites, and the willingness and understandings of employees to report unsafe acts and conditions. This prerequisite is crucial to ensure that this tool adds significant value to the safety performance of projects.*
Keywords: Near miss, Safety, Construction

1. INTRODUCTION

The idea of collecting data that would serve to create preventive measures specific to each construction project, through the reporting of "near miss" events, is not new in the world and is part of the indicators that are rated as leading in the field of project management from the aspect of safety and health at work. This relatively free tool is important for collecting data that could not be obtained in any other way and is important for taking preventive measures adapted to the construction project being carried out, but also for the construction industry in general.
Avoided events are well known for providing a major source of useful information for security management. These events occur statistically more often than accidents, and their causes could potentially lead to an accident under slightly different circumstances. Despite the importance of this type of feedback that can be obtained by analyzing the collected data, there is little knowledge about the characteristics of avoided events and the use of this information in the management of occupational safety and health in various fields.

2. NEAR MISS CONCEPT OVERVIEW

A "near miss" refers to an unforeseen incident that, although it did not cause any harm, illness, or damage, had the potential to do so. It was only due to a fortunate chain of events that injury, death, or damage was averted. Additionally, a "near miss" encompasses any unintentional occurrence or

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sequence of events in which injury or damage to property, infrastructure, or equipment is avoided solely by chance.
A broader definition that encompasses not only the negative aspects of near misses, but also their positive impact on system functioning, characterizes a near miss as an occurrence, series of events, or observation of an unusual incident that has the potential to enhance the operability of a system by reducing the risk of any disruption. Some of these disruptions could result in significant damage or injury. A near miss presents an opportunity to enhance environmental, safety, and health practices, based on an incident that could have had more severe consequences. It is viewed as a chance for improvement, where positive experiences motivate employees to report such incidents rather than conceal them. This definition also includes any operational issues or disturbances, some of which may lead to serious damage, while others may cause inconvenience or downtime, resulting in inefficiencies [1].
Alternative phrases for these occurrences are often referred to as a "close call" or, when it involves objects in motion, a "near hit". Additionally, a "near miss" can be defined as any instance in which an employee perceives being in an unsafe situation due to factors such as circumstances, equipment, or their own actions that had a significant likelihood of causing harm. However, by a fortunate chance, the employee remains unharmed. The specific definitions of a "near miss" can differ and may encompass incidents resulting in damage or injury, excluding fatalities [2].
Near-miss is also defined in the literature as a chance to improve practices related to safety and health at work and environmental protection based on working conditions or an event/incident that has a high potential to produce a serious consequence [3].

3. ELEMENTS OF RESEARCH

The purpose of this study: is to examine the perspectives of the workers regarding the implementation of this tool as a means of safeguarding against workplace injuries in the construction site. Additionally, it aims to gauge their comprehension of the incidents classified as "near misses" and determine the essential elements that need to be reported to ensure the tool's effectiveness. Efficiency in this context refers to the thorough examination and collection of all relevant data about potential undesirable incidents at a construction site. These incidents may not be readily apparent to occupational safety and health professionals during their site visits or when reviewing the documentation. By being aware of potential hazards and risks that are not immediately visible, professionals can take proactive measures to prevent injuries and damages from occurring. Moreover, this practice empowers employees to actively contribute to enhancing the safety culture within the organization. They can do so by suggesting measures to improve safety and health at work based on reported "near miss" events. The ultimate objective of this practice is to engage all employees in the organization in the process of establishing a secure work environment. This, in turn, fosters the development of a robust and well-recognized safety culture within the organization. This culture is evidenced by satisfied employees, a minimal number of work-related injuries, and the absence or low incidence of professional and work-related illnesses. Employees' engagement involves actively comprehending the nature of potential incidents or hazardous practices that necessitate reporting, the reporting process, the need for timely reporting, and ultimately, the decision to report. Consequently, to arrive at a conclusive outcome, it becomes imperative to establish sound research hypotheses that align with the research subject and objectives.
The null hypothesis: H_0 - *It posits that the level of comprehension regarding the reporting of "near miss" incidents significantly influences the decision to report such incidents, consequently reducing work-related injuries.*
Technology of research: The study involved gathering questionnaires from participants and analyzing the data using Microsoft Excel software. In addition to this, descriptive and inferential statistics were employed to examine the data, and the findings were summarized using a chi-square test to evaluate the null hypothesis. The data was thoroughly analyzed, and the results were visually presented through pictures, graphs, and tables. Following an assessment of the variables at various

levels of trust, the study concluded and offered suitable recommendations to enhance the organization's management.

To gather data for our research, we opted for the survey research technique on the construction project called "TPS Zemun". Since there are no standardized research techniques available for our specific research problem, which is stated in the subject of this paper, we developed a research questionnaire. You can find the questionnaire attached as Attachment No. 1 in this paper. The research questionnaire was designed as a tool to collect data using surveying as the research technique. By analyzing the responses received from the questionnaire, we were able to uncover relevant facts about the phenomenon under investigation in this paper. Specifically, the questionnaire assessed the respondents' levels of agreement regarding the implementation of the "near miss" concept on the selected construction project, which directly relates to the subject matter of this paper.

Research sample: For this research, the survey was successfully completed by 60 employees at the "TPS Zemun" construction site. Of that, 65% are male and 35% are female. Most respondents at the construction site were men, which agrees with the data of the survey conducted by the International Labor Organization in Serbia in 2018, which was used for this survey to review and compare the data. Most survey participants fall within the age bracket of 30 to 40 years, which aligns with the findings of a study conducted by the International Labor Organization in Serbia back in 2018. This study was utilized for our research to evaluate and compare data. Among the participants included in our research sample, the highest number of respondents had accumulated work experience ranging from 15 to 30 years in the construction industry. This indicates that our sample is representative and suitable for the intended research objectives.

4. RESULTS AND DISCUSSION

The variables used in this research were divided into those that can be associated with the elements of the organization's safety culture based on the idea shown through the Bradley curve (Figure 1) and those that do not belong to those elements.

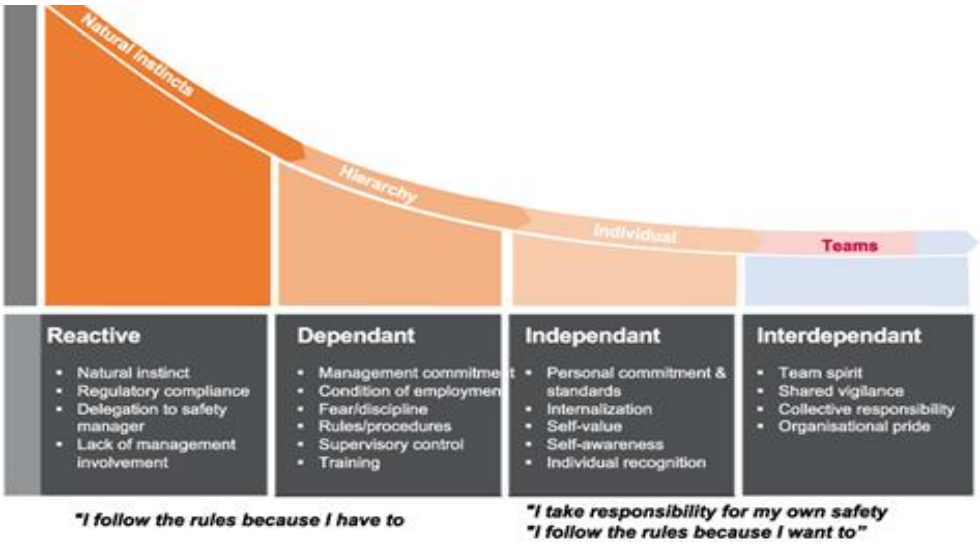

Figure 1. Bradley curve, Du Pont
Source: Du Pont official coaching material

This division was made for the purpose of giving recommendations to the employer regarding the improvement of the Safety management system. The Dupont Bradley Curve is based on DuPont's experience and expertise in safety management, which dates to 1802 when the company was founded as a gunpowder manufacturer [1]. It illustrates the relationship between accidents and corporate culture. Next figures show that the elements of corporate culture are essentially important for participation in terms of reporting and contributing to "near miss" reporting tool among the employees.

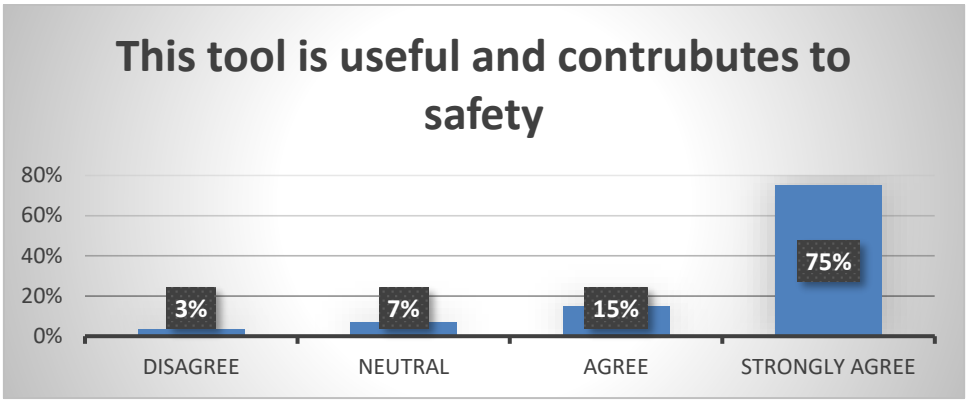

Figure 2: Questionnaire results
Source: *original author's*

To the question "I think reporting "near miss" events is useful and contributes to safety on the construction site, which was designed in the form of a Likert-type scale, as many as 75% of respondents answered that they completely agree with this statement and 15% that they mostly agree (Graph 1), which represents a significant number of respondents who have no doubt that the concept of reporting "near miss" events is something that contributes to their safety and the safety of their colleagues on the construction site.

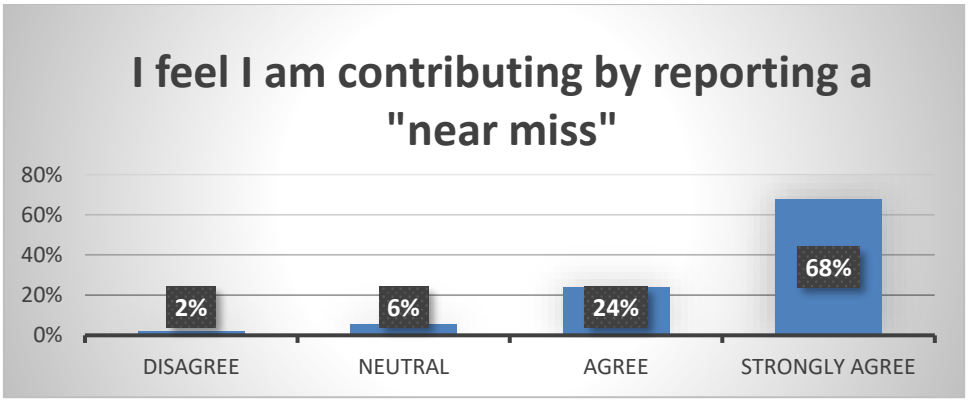

Figure 3: Questionnaire results
Source: *original author's*

To a slightly lesser extent, respondents agreed with the statement that they feel useful and as if they contributed to safety when they reported an unsafe event (Graph 2). This again indicates a very positive attitude towards the concept of reporting and recognizing "near miss" events.
The questionnaire and the whole research are available in the Master Thesis Paper available at the library of Belgrade Polytechnic [5].

In the following part it will be presented what were the results of testing the research hypotheses.

H_1 - There is a significant association between employee gender and willingness to report a near miss event.

Given that the calculated value of Chi-square is 1.68 less than the critical value of Chi-square, we can conclude that there is no statistical association between the gender of employees and the willingness to report a "near miss" event. It is therefore concluded that **H_1** is ***NOT ACCEPTED***.

H_2 - There is a significant association between the simplicity of the near miss event reporting system and the decision to report the event.
Given that the calculated Chi-square value of 8.81 is greater than the critical Chi-square value, we can conclude that there is a statistical association between the simplicity of the near miss event reporting system and the decision to report the event. It is therefore concluded that **X_2** is ***ACCEPTED***.

H_3 - There is a significant association between perceived usefulness and contribution to safety and the decision to report a near miss.
Given that the calculated Chi-square value of 5.10 is greater than the critical Chi-square value, we can conclude that there is a statistical association between the sense of usefulness and contribution to safety and the decision to report a near miss. It is therefore concluded that **H_3** is ***ACCEPTED***.

H_4 - There is an association between an employee's job loss concern and willingness to report a near miss event.
Given that the calculated value of Chi-square is 2.84 less than the critical value of Chi-square, we can conclude that there is no statistically significant relationship between the fear of job loss and the willingness to report a "near miss" event. It is therefore concluded that **H_4** is ***NOT ACCEPTED***.

H_5 - There is a statistically significant association between years of work on a construction site and willingness to report a near miss event.
Given that the calculated value of Chi-square is 2.06 less than the critical value of Chi-square, we can conclude that there is no statistically significant relationship between years of work at the construction site and willingness to report a "near miss" event. It is therefore concluded that **H_5** is ***NOT ACCEPTED***.

H_0 - It is assumed that the degree of understanding of the concept of reporting a "near miss" event has a significant impact on the decision to report a "near miss", and therefore on the reduction of injuries at work.
Given that the calculated Chi-square value of 6.59 is greater than the critical Chi-square value, we can conclude that there is a statistical association between the sense of usefulness and contribution to safety and the decision to report a near miss. It is therefore concluded that the zero hypothesis **H_0** is ***ACCEPTED***.

After thoroughly examining the relevant literature, previous studies conducted in this field, gaining valuable insights from the construction site, and concluding this research, it is concluded that: the primary objective and intention of this study were to explore the possible utilization of "near miss" incidents within an occupational health and safety management system in construction projects, to enhance outcomes and overall performance. In contrast to a conventional management system that relies on analyzing data from accidents with and without lost time, this approach offers a more comprehensive understanding of the current situation on-site in terms of risks, the safety culture among employees, and ultimately the number of work-related injuries that have transpired during project execution. The primary objective of this study is to specifically examine employees' comprehension and willingness to actively contribute their firsthand safety observations to such a management system. Notably, extensive research has demonstrated the effectiveness of this system in enhancing safety and health performance across various industries and operational frameworks. It has been demonstrated that the comprehension of the concept, the perception of usefulness, and the ease of implementation of the avoided event reporting system have a direct impact on the frequency of reported events by employees. Considering that these factors are integral to the safety culture, it becomes evident that concerted efforts must be made to enhance the overall safety culture within the organization. This will ensure that reporting avoided events becomes ingrained in the cultural practices observed at construction sites. Conversely, it is observed that variables such as gender and years of experience among employees do not influence their willingness to report a “near miss”. Hence, it becomes imperative to focus on fostering a comprehensive safety culture within

organizations and leverage all the documented information obtained through the safety protocols implemented at construction sites. This approach ensures that our precautionary measures align with the primary hazards prevalent in the environment. By employing this distinctive methodology tailored to individual construction sites, we can guarantee the identification, management, and eradication of potential hazards.

The present study possesses certain constraints associated with the fact that it solely focuses on a single endeavor pertaining to railroad reconstruction. Consequently, the outcomes cannot be extrapolated to encompass all construction projects. Moreover, the investigation primarily elucidates the safety and health protocols implemented by a foreign corporation, which cannot be directly correlated to the safety and health standards prevalent in the Republic of Serbia. In this context, it is worth noting that the adoption of such an approach is not obligatory in Serbia.

5. CONCLUSION

In the construction industry, it is crucial to take numerous preventive and proactive measures before accidents occur, while gathering valuable insights from employees who face risks daily. Encouraging employees to embrace a safety-focused mindset and actively report dangerous situations and behaviors is pivotal for the effective implementation of management systems. Rather than harboring shame, it should be ingrained in individuals as a core value they continually strive for, ultimately ensuring the success of these systems. Developing a safety culture based on each employee's independence in being aware of, contributing to and caring for a safe and healthy work environment, not only for themselves but also for others, is key to reducing work-related injuries and striving for "zero" fatalities as the highest value we strive for as a society.

To my mentor dr Marta Trninić: Accept my most sincere appreciation to you, for being a **mentor** *and a friend.*

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Belgrade, 15th December 2023

ENVIRONMENT AND SUSTAINABLE DEVELOPMENT. MECHATRONICS. OCCUPATIONAL SAFETY AND HEALTH AND FIRE SAFETY. SMART MANAGEMENT SYSTEMS. GRAPHIC ENGINEERING. DESIGN. TRAFFIC ENGINEERING. BIOTECHNOLOGY AND HEALTHCARE. MECHANICAL ENGINEERING. ECOTOURISM AND RURAL DEVELOPMENT.

Student paper

RESEARCH AND ANALYSIS OF PROFESSIONAL STRESS ISSUES AMONG EMPLOYEES IN SECURITY ROLES

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Abstract: *In today's increasingly complex work environment, professionals from various sectors face challenges related to workplace stress. This issue particularly affects security workers, whose daily responsibilities include maintaining safety and security in both public places and private organizations. The focus of this study is on identifying key stress factors among security workers and exploring their impact on stress levels and employee well-being. More precisely, this study aims to provide a deeper understanding of the stress issue among security workers, investigate the specifics of the organization in which the research was conducted, and offer guidelines for improving working conditions and stress prevention. The study presents the results of research on professional stress conducted on a sample of 70 security workers in the "Securitas Services" organization.*
Keywords: professional stress, security workers, identification of stress factors

1. INTRODUCTION

Security personnel, defined as individuals with the appropriate license for performing private security duties, often carry out their responsibilities within the premises of other employers or service users. This places them in situations that significantly impact their safety, further contributing to the existing professional stress. Service users, on the other hand, can be legal entities, entrepreneurs, or individuals who rely on private security services to protect their property interests. Understanding the specific working conditions and the relationship between security personnel and service users becomes crucial for comprehending the stress experienced by these professionals during their work routines.
Previous research indicates that working conditions such as night shifts, shift work, the risk of violence, and poor working environments (noise, inadequate lighting, etc.) are key factors contributing to professional stress among security workers. For example, the risk of violence can be present in their daily tasks, leading to psychological and emotional stress. Studies have also highlighted how night shifts and shift work can disrupt the circadian rhythm, leading to sleep disturbances and an increased risk of health issues. These specific issues have been the focus of investigation in this study.

2. METHODOLOGY

The research was conducted in August 2023 at the company Securitas Services Ltd., which employs over 4,000 individuals. All respondents are security personnel. The research employed a quantitative research method, which involves collecting quantitative (numeric) data and analyzing this data using statistical methods. The instrument used in this research is a questionnaire consisting of several sections. The first part of the questionnaire pertains to basic information about the respondents, such as gender, age, level of education, length of employment in the current company, and other relevant information, as presented in diagrams 1-6.

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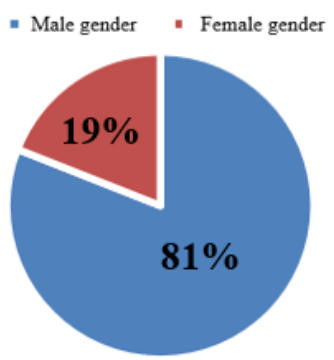

Figure 1. The structure of respondents by gender

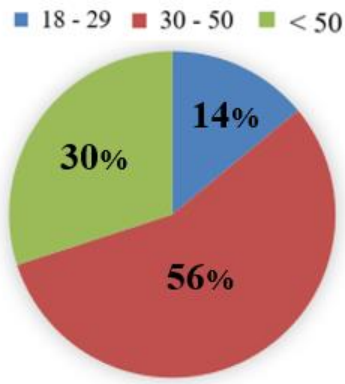

Figure 2. The structure of respondents by age

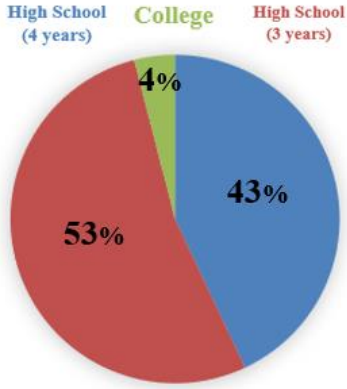

Figure 3. The structure of respondents by qualifications

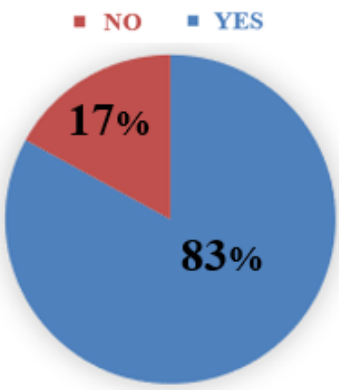

Figure 4. The structure of respondents by shift work

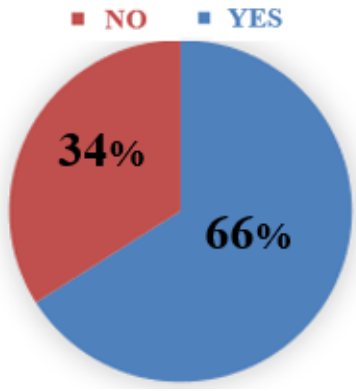

Figure 5. The structure of respondents by night shift work

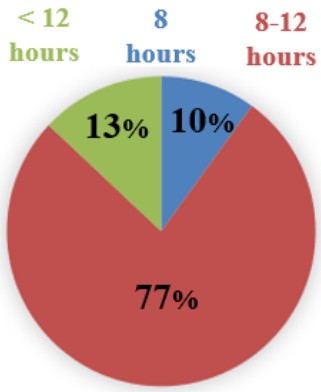

Figure 6. The structure of respondents by the length of their working hours

These data can reveal whether certain demographic groups tend to experience higher stress levels compared to others. Understanding the specific needs of different groups can help allocate resources where they are most needed.

The second part of the questionnaire contains questions about workplace conditions, workers' experiences with violence or conflicts, and the impact of working hours (shift work, night shifts) on their emotional state. The final part of the questionnaire is about workplace stressors, which consists of selected 10 stressors, and respondents' answers about their experience of each stressor were evaluated using Likert scale ratings: 1 (not stressful at all), 2 (rarely stressful), 3 (sometimes stressful), 4 (stressful), and 5 (extremely stressful). The total sample size consisted of 70 security personnel, including 57 males and 13 females, who worked in different sectors. The sample was stratified by different sectors and genders, meaning that the sample included 20 security personnel from industrial complexes, banks, and shopping centres, as well as 10 security personnel employed at the airport, who were selected by random sampling.

Data were collected using the following methods: *frequencies* (f) and *percentages* (%), which show how often certain responses occur and the percentage of workers supporting specific statements. Descriptive statistical methods were used, including measures of central tendency (mean and median), which show where the majority of workers position themselves about specific stress factors.

3. RESULTS AND DISCUSSION

Within the research on professional stress among security workers, the responses of 70 security personnel from various sectors, including banks, shopping centres, industrial complexes, and airports, were analyzed. By examining their responses to key questions, insights were gained into their

experiences and perceptions of workplace stress factors. In response to the question "Do you have enough time to rest after a night shift", 40% of the respondents claim they do not have enough time to rest after a night shift. The majority of these respondents are employed in industrial complexes and shopping centres. Indecisiveness proved significant, with 32.86% of respondents, the majority of whom work in banks. Only 20% of respondents believe they have enough time to rest after a night shift, while 7.14% strongly disagree with the statement.

Regarding the question "Shift work/night work affects the quality of your sleep and rest", the results show that 45.71% believe that shift work/night work affects the quality of their sleep and rest. Most of these respondents work in industrial complexes and shopping centres. In contrast, 37.14% of respondents claim that this is not the case, with the majority working in banks. Indecisiveness is present in 12.86% of respondents, while 4.29% believe that shift work/night work significantly affects the quality of their sleep and rest.

Regarding the question "Do you have the opportunity for professional development and education at work", 40% of respondents believe they do not have this opportunity, with the majority working in shopping centers and industrial complexes. Conversely, 24.29% agree that they have this opportunity, with banks and airports being the most significant sectors. Indecisiveness is present in 18.57% of respondents, while 17.14% believe they have complete opportunities for professional development and education. The results of these questions are presented in diagrams 7, 8, and 9.

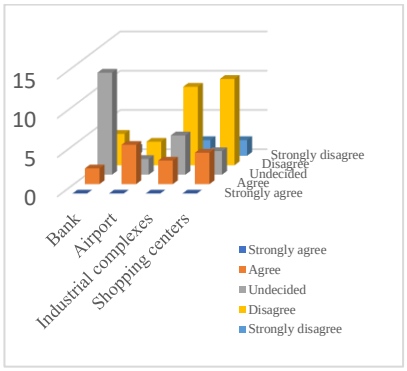

Figure 7. The structure of respondents by shift work
Source: *original author's*

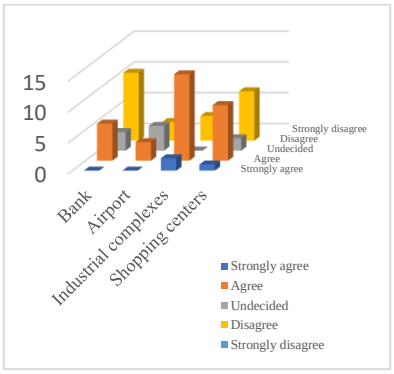

Figure 8. The structure of respondents by night shift work
Source: *original author's*

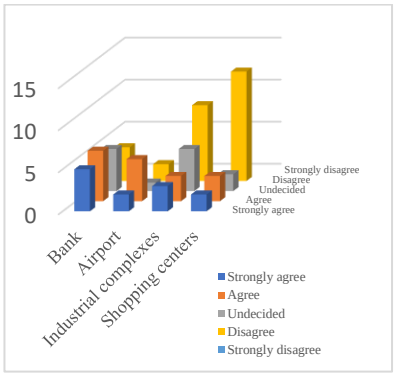

Figure 9. The structure of respondents by the length of their working hours
Source: *original author's*

These research results indicate the diversity of perceptions and experiences of security workers regarding workplace stress factors. Different groups from various sectors have different views on rest time after night shifts, the impact of shift work on sleep quality, and opportunities for professional development. These results highlight the need for further research and consideration of how working conditions for security workers can be improved, with a particular focus on sectors where issues are more pronounced.

To gain a deeper understanding of the attitudes and needs of security workers, an open-ended question was posed to the respondents: "What would be the most important change that could be implemented immediately to improve the work of your profession?". This question allowed respondents to express their personal comments and views on possible improvements in their professional environment. The results displayed in diagram 10 show that a significant number of respondents (72.86%) emphasized an increase in salary as the most important change that would improve their professional status. This may indicate that many feel inadequately compensated for their work, which can affect their job satisfaction and motivation. Additionally, the results show an interest in more days off (5.71%) and the elimination of overtime work (10%). This may indicate the importance of work-life balance for security employees. 11.43% of respondents did not provide an answer, which may suggest that respondents were not willing to share their opinions.

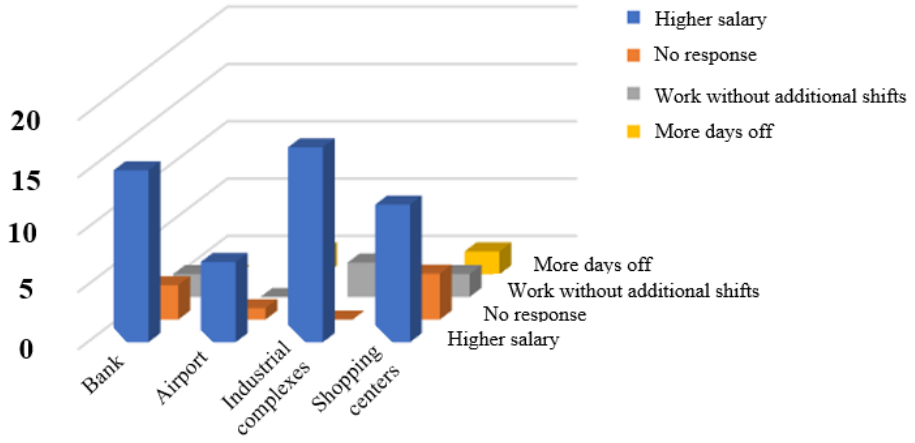

Figure 10. Analysis of the open question
Source: *original author's*

These results point to the need for further research and consideration within organizations employing security workers to explore specific measures to improve their working conditions and well-being. Salary increase is just one possible step in that direction, while considering other aspects, such as working hours and benefits, is also crucial for creating satisfaction and motivation among these workers.

To gain a deeper understanding of stress factors and highlight differences in stress perception among male and female security workers, an analysis of the stressors that workers rated as most pronounced was conducted. Through this analysis, we gain a deeper insight into the challenges faced by security workers, which will help in forming a more comprehensive understanding of their work experience.

Among male respondents, the highest values for stress factors were related to overtime work, lack of rest, and violence or threats from visitors. These factors were rated as the most stressful, while long and monotonous work activities, as well as daily unforeseen situations, were rated as less stressful.

On the other hand, among female respondents, the highest values for stress factors were related to overtime work, lack of rest, and limited advancement opportunities, and the lowest for communication with superiors. Graph 11 shows the stress factors causing the most stress in both genders to understand the difference in stress perception between the two genders.

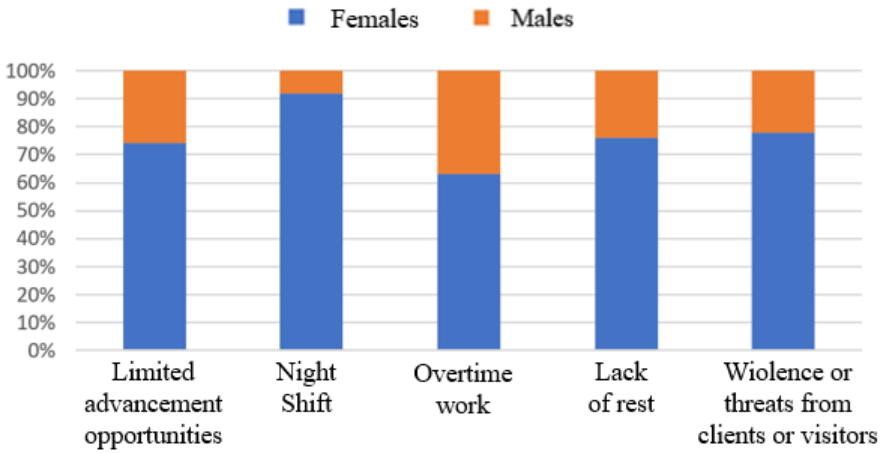

Figure 11. The Difference in stress perception between male and female workers
Source: *original author's*

So, female respondents rate the mentioned factors as more stressful compared to male respondents, with a significant difference in percentages. These results suggest the need for a targeted approach to stress management and support depending on the gender of security workers to improve their working conditions and well-being.

4. CONCLUSION

Research on stress among security officers represents an important aspect of working conditions in this professional field. The results of this study point to significant challenges that security officers face in their work environment. Stress factors such as night shifts, overtime work, and violence or conflicts with visitors are significant challenges that can impact the physical and emotional health of workers and can have important implications for managers and organisations employing security officers, emphasizing the need for the development of programs and measures to help manage stress and support a healthy work environment. The results also indicate differences in stress perception between men and women. However, the inequality in the number of participants may affect the interpretation of the results, so future research should address this imbalance in sampling to arrive at more reliable conclusions regarding stress perception among security workers. The results of this study also suggest the existence of a statistically significant relationship between stress factors and stress levels among security officers, leaving room for further research to further confirm this relationship.

In summary, this research represents an important step in understanding the issue of stress among security workers and provides a foundation for designing programs and measures to enhance the quality of work and the well-being of workers in this sector. Continuous monitoring and analysis of stress factors and stress perception in the security sector remain a necessity to ensure ongoing support and improvement of working conditions.

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Student paper

THE IMPACT ANALYSIS OF STRESS ACCUMULATED OUTSIDE THE WORKPLACE ON THE OCCUPATIONAL SAFETY AND HEALTH OF EMPLOYEES IN INSTITUTE OF NUCLEAR SCIENCES „VINČA"

Lazar Milićević[1], The Academy of Applied Technical Studies Belgrade
Novak Milošević[2], The Academy of Applied Technical Studies Belgrade

Abstract: *In the process of researching literature on the term, causes, effects and consequences related to professional stress, the authors noticed that vocational publications in this area primarily direct protection engineers in the field of risk assessment regarding this professional phenomenon to exclusively consider incidents that can or already have taken place in the workplace itself, without reference to the process of stress accumulation, the source of which is most likely to manifest itself outside of the workplace. The authors believe that non work related stress has equal importance for health and safety at work as much as work related stress. As proof for the previously stated position authors will include in this paper, part of the research that analyses the impact of non work related stress on health and safety at work in one of the units of the Institute of Nuclear Sciences "Vinča" (Centar Operativa 300/200).*
Keywords: professional stress, non work related stress, stress accumulation.

1. INTRODUCTION

The fast-paced lifestyle is the most common reason for often unrealistic demands, which a person sets for himself on a personal and business level. The reaction of our body to this artificially created pressure can be very different and depends on the type of stressor and its intensity. A naturally innate defence mechanism, which protects the human body from an excessive reaction to a stressor, which could have serious consequences, is called stress [1].
The phenomenon of professional stress is ubiquitous when implementing technological processes and other work tasks in the daily lives of employees. This psychological phenomenon is a direct consequence and the "price" that modern society pays due to the unfathomable and often irrational speed of technological development.
One of the major problems in the field of studying professional stress, which is currently very difficult to solve, is directly related to the "modern" way of life and the fact that workers come to work with an already significant amount of accumulated stress. Therefore, ***one of the goals of this paper is to draw the attention of the experts in the field of protection engineering to the fact that professional stress should not be seen as a source of harm, which can only manifest itself in a working place.*** It is much more likely that the manifestation of this professional phenomenon at work is only a trigger, for accumulated stress, which source is actually directly linked to the employees and the time they spend outside of the workplace.
The "battle", that protection engineers lead every day, against such currently "stronger opponents", inevitably leads to an increase in the number of incidents and accidents at work. One of the reasons for the difficulties in the fight against the observed occupational harm can be **the very approach** of the profession, which is concentrated exclusively on stressors, that are manifested in the technological processes at the workplace. In the opinion of the authors, ***this approach is***

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fundamentally wrong, because the process of identifying professional stress is based on actions, which are oriented towards the trigger, and not the source, of the future accident. Based on the previously stated conclusions, authors deem pure necessity to suggest change and diversification of stress through the national professional literature into "work related stress" and "non work related stress", as well as to equalize their importance, when assessing occupational risk at the workplace.

2. THE NEED TO PROBLEM RESEARCH

The starting point in stress management is the fact, that it is impossible to completely eliminate it. It is only possible to control its effects when they manifest themselves at work and take a series of preventive measures to eliminate stressogenic factors. A very important component of stress management, when eliminating risks that may arise due to the presence of stressors at work, is **the way** professional experts manage this psychological phenomenon. Stress management at the workplace is possible through interventions and activities on an organizational and individual level. The best preventive measure in the event of stress occurring in the workplace is to adapt the working conditions for employees to their individual physical and mental capabilities [2].
The results of many researches indicate that the accumulation of stress, which takes place at the workplace, is to a large extent directly related to the working conditions at the observed workplace. Similarly, people's feelings when they are not at work are largely conditioned by events that take place outside the workplace. Stress, which occurs at the workplace, as well as stress, which occurs outside the workplace, are associated with physical and mental effects on the health of employees. ***Excessive demands at work or stress in one part of private life can have a serious effect on the life of employees in another.*** Such a "conflict" between private and business works equally in both directions. When such a situation occurs, the amount of accumulated stress in the human body begins to increase, because there is a **joint effect**, which acts as an **additional source of stress**, and in this way, a **synergistic effect on the health of employees occurs**. When viewed together, both types of stress are divided according to the place of origin, it is possible to conclude that the effects and consequences of one type of stress can easily spill over to a part of life, where another type of stress from the analyzed division is present [3]. So, ***the manifested effects of stress that people feel at the workplace are not only a reflection of the problems and events that took place at work, but a very important variable in looking at the entire problem is the private life of the respondent, as well as his "personal problems".***
The practice has shown that it is not enough to adapt only the workspace and technological operations, so that they do not cause a significant increase in the accumulation of professional stress, because even after the implementation of all the foreseen "anti-stress" measures in the field of the health and safety at work, there is still a manifestation of incidents and accidents directly linked to this psychological phenomenon. **It is of the utmost importance**, based on previous conclusions, that **protection engineering implements** in the design of modern programs and tools for the promotion of health and safety at work and stress detection tools, **an idea which insists** that it is an absolute necessity, that **all types of tools for measuring professional stress** are adjusted so that they **equally detect the accumulation** of this psychological phenomenon **in the workplace** itself, **as well as outside it**. To implement this idea in the most efficient possible way, the first step is to **conceive and organise multidisciplinary research** on the topic of stress accumulated outside the workplace, to determine the starting points for the creation of professional "tools", which would help employees who work at high-risk workplaces. The second step is to implement these professional "tools" in the work process in that way, employee that works in high-risk workplaces must solve tests, before the start of their "high risk" works, which would establish the precise amount of already accumulated stress in their bodies. The employee population after the test, according to the level of risk of manifesting the effects of accumulated stress, would be divided into three groups: benign, neutral and threatening part of the population. The next step is to distribute the tested workers based on the rotation of jobs so that: the **neutral part of the population** work task starts with easier duties, the **benign part of the population** with the most difficult, while the

threatening part of the population for the day would be assigned to work tasks, where there is no risk of manifesting the effects of professional stress.

3. METHODOLOGY

Research of the impact of external stress on health and safety at work when employees are exposed to this psychological phenomenon, part of which is presented in this paper, was conducted by surveying 29 employees at the Institute of Nuclear Sciences "Vinca". It was done in the form of non-experimental research, through a survey of the population of employees in the Centar - Operativa 300/200. The research technique used is based on written communication and consists of questionnaires for the employees. When selecting the population units that will participate in the research, the random sample method was applied, which in itself guarantees that the research result is representative. Based on the number of respondents who participated in this research, it can be concluded that the results are adequate. Work assignments in the Centar - Operativa 300/200, consist of various types of maintenance work within the Institute. Due to the nature of working assignments, present in this part of the organization, it was not possible to organize group testing. Workers filled out the survey individually and at their workplaces.
The sample includes employees from several workplaces of the Centar - Operativa:

- Operation and maintenance (the sample includes two workers from the boiler room and one housekeeper),
- Design Bureau (the sample includes Institute architect and architectural technician),
- Center for engines and vehicles "CMV" (the sample included five drivers and one housekeeper),
- Product testing and certification department (two employees participated in the survey),
- HSE department (two HSE officers participated in the survey),
- Fire protection (five firefighters participated in the survey),
- Electrical services (three electricians participated in the survey) and
- Computer networks (three employees participated in the survey).

The employee questionnaire was filled out by the director, business secretary and driver from the Centar - Operativa, as well as one employee from the legal department of the "Vinča" Institute. The structure of respondents in relation to their gender, age, qualification and work experience at the current workplace is shown by descriptive statistics, that is, in the form of frequency or percentage in diagrams 1-4 [4].

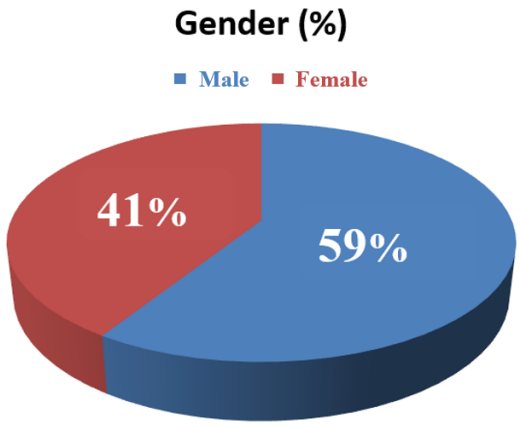

Figure 1. The structure of respondents by gender
Source: *original author's*

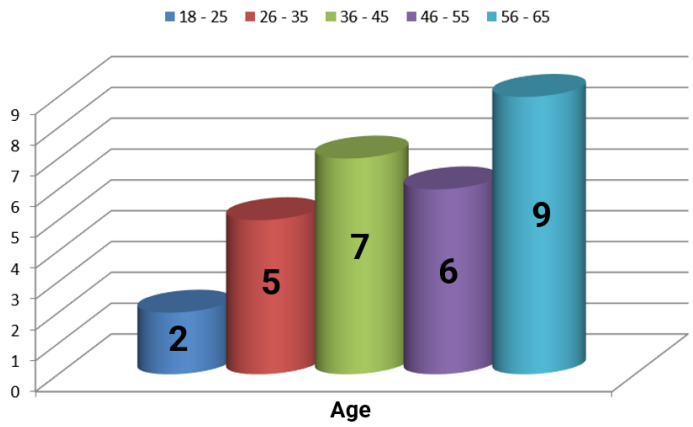

Figure 2. The structure of respondents by age
Source: *original author's*

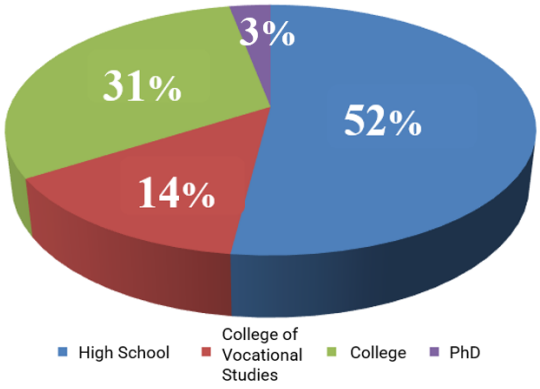

Figure 3. The structure of respondents by qualifications
Source: *original author's*

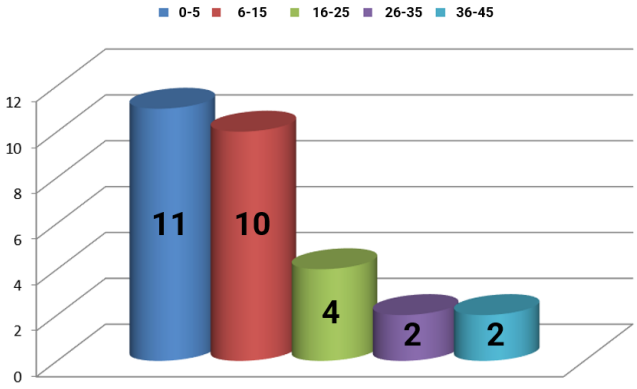

Figure 4. The structure of respondents by work experience at the workplace
Source: *original author's*

The data obtained from the questionnaire were processed with the help of descriptive statistics, i.e. using counting measures (frequency (f) and percentage (%)), to determine and analyze the impact of "external stress" on the health and safety at work of employees in the observed institution. This way of data processing enables the distribution of research results to be displayed in an overview [5].

4. RESULTS AND DISCUSSION

The most important goals of this paper are [4]:

- To devise, redefine and publish a new categorization in professional publications for psychological phenomenon - stress;
- To ensure the introduction of the concept of "external stress" in national by-laws, through amendments to the regulations;
- To precisely determine the probability of the impact of stress outside the workplace as a factor on the health and safety of employees in work organizations;
- To determine the frequency of the manifestation of stress outside the workplace, as a risk that cannot be avoided in work organizations;
- To determine the severity of the consequences that can be caused by non work related stress,
- That "external stress" and its impact on the health and safety of employees in work organizations be implemented as an unavoidable variable in the risk assessment in relation to the harms associated with the psychological phenomenon of stress;
- To design and create modern "tools", which would ensure the accurate measurement of the presence of "external stress" in the worker's body, before starting work;
- To ensure an increase in the level of health and safety at work in work organizations, through the mandatory implementation of "tools" for measuring "external stress" and corrective measures in case of the presence of this psychological phenomenon.

Table 1. shows the opinion of employees in the Centar - Operativa 300/200 and their attitude towards the manifestation of the effects of accumulated external stress at the workplace, as well as their attitude about the impact of this psychological phenomenon on health and safety at work, shown in the form of frequency and percentage. In the part of the questionnaire for employees presented in the paper, on a Likert-type scale, respondents were required to enter a + sign next to each question, depending on how they assess the level of agreement or disagreement with a certain statement, on a scale of 1-5. Whereby the level of agreement of the respondents was assessed as: **1 - I do not agree at all; 2 - I do not agree; 3 – I partially agree; 4 - I agree; 5 - I completely agree** [4].

Table 1. Results of the employees attitudes at the Institute of Nuclear Sciences „Vinča"
Source: *original author's*

QUESTION		1	2	3	4	5
Manifestation of accumulated external stress at the workplace						
It happened to you that you **"spend"** non work related stress at work.	Frequency	14	10	3	1	1
	Percentage	48	34	10	4	4
It happened to you that you **felt calm and satisfied** after **successfully completing a work task**, even though you **came to work nervous or in a bad mood**.	Frequency	3	3	6	8	9
	Percentage	10	10	21	28	31
You often **feel the need to complain to colleagues** that you are under stress because you are not satisfied with the support provided by your partner and/or family.	Frequency	20	9	/	/	/
	Percentage	69	31	/	/	/
It happened that you **experienced an unpleasant situation due to a conflict with colleagues**, which you consider to be **caused by non work related stress**.	Frequency	17	7	4	1	/
	Percentage	58,5	24	14	3,5	/
It happened that **you needed to cause a conflict with one of your colleagues**, due to a stressful situation you experienced outside the workplace.	Frequency	21	6	1	1	/
	Percentage	72	20	4	4	/
You often **feel difficulty in using work equipment,** because of the stress you have accumulated outside the workplace.	Frequency	21	6	2	/	/
	Percentage	72	20	8	/	/
It happened to you **that you forgot to apply** health and safety measures at work, due to stressful situations that happened to you outside the workplace.	Frequency	18	8	2	/	1
	Percentage	62	27,5	7	/	3,5
You feel reluctance to implement health and safety measures at work because **you often think about stressful situations**, that happened to you outside the workplace.	Frequency	19	7	2	/	1
	Percentage	65,5	24	7	/	3,5
It happened to you that **you feel that the work you do is too difficult or monotonous** because you **felt the effects of stressful situations** that you experienced outside the workplace.	Frequency	13	8	7	/	1
	Percentage	45	27,5	24	/	3,5
It has happened to you/you know that it happened to someone, **to get injured at work**, due to the **presence of non work related stress**.	Frequency	14	7	4	3	1
	Percentage	48	24	14	10	4
QUESTION		**1**	**2**	**3**	**4**	**5**
The impact of non work related stress on the health and safety at work						
In your opinion, stress accumulated outside the workplace **has an impact on the health and safety** of employees in work organizations.	Frequency	6	3	11	5	4
	Percentage	20,5	10	38	17,5	14
You believe that **it would be desirable** that one part of the **basic theoretical training in health and safety at work** be devoted to **non work related stress and its effects** on the health and safety of employees in work organizations.	Frequency	5	2	9	5	8
	Percentage	17,5	7	31	17,5	27
You feel that it would be desirable to introduce **mandatory testing of employees** for the **presence of accumulated stress**, immediately before starting work on high-risk jobs.	Frequency	1	3	11	6	8
	Percentage	4	10	38	21	27
In your opinion, **testing employees for the presence of accumulated stress** would lead to a **reduction in the number of injuries at work**.	Frequency	4	2	10	8	5
	Percentage	14	7	34,5	27	17,5
You think that **testing employees for the presence of accumulated stress would save part of the money**, which the employer spends on health and safety at work.	Frequency	4	7	7	4	7
	Percentage	14	24	24	14	24

Through this research on "external stress" in work organizations, two effects of **social significance** can be promoted. The social importance could first be presented through improving **the mental health of employees**. Preventive tests that detect the presence of external stress among workers could also improve the early detection and diagnosis of mental disorders and mental health in the earliest stages of their occurrence [4].

The next effect on the social importance of this research is reflected in the **savings of employers' resources**, which they can redistribute to some other very important parts of the work process in their organizations. This saving would be realized after the complete implementation of this research into professional streams because then the preventive nature of amendments to legal regulations and procedures related to the effects of "external stress" on work organizations would come to the fore. The money, which was once spent on preventing and eliminating the consequences of this psychological phenomenon, would now be left to employers to use to eliminate some other dangers or harms associated with the activities they are engaged in [4].

5. CONCLUSION

When analyzing the first statement from this part of the questionnaire, four fifths, or 23 respondents, believe that doing their work assignments, allows them to at least partially "spend" the stress they accumulated outside the workplace and thus improves their state of calmness and satisfaction. Respondents have an opposite opinion in the case of the statement: ***It happened that you*** *experienced an unpleasant situation due to a conflict with colleagues****, which you consider to be*** *caused by non work related stress.* The vast majority of respondents, as many as 82.5% of them, expressed a negative attitude towards the analyzed claim. A significant majority of respondents, 72% of them, **do not know that someone has been injured at work**, due to the **presence of accumulated stress**. Despite the position expressed in the previous two statements, **the employees** of the Institute of Nuclear Sciences "Vinca" still ***believe that the presence of "external stress" in the workplace has an impact on health and safety at work***. The processed and analyzed result of this conclusion is very important because it is a confirmation of the author's position on non work related stress. Respondents also believe that it would be desirable to implement a part in basic HSE training, which refers to non work related stress. An important conclusion is the affirmation of the idea that it would be desirable to introduce a mandatory test, which would preventively measure the presence and level of stress accumulated by the employees.

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Student paper

RESEARCHING THE HARMFUL EFFECTS OF COOLING LIQUID ON EMPLOYEES

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Abstract: *During the processing of metals and other materials, there is a need to cool the work process. Depending on the composition of the cooling system, it can hurt humans or the environment. To reduce the negative impact, several procedures are undertaken. The work aims to determine the level of information and training of employees during work with the chemical substance. After the survey, it was concluded that the knowledge of the employees should be improved to prevent injuries or illnesses.*
Keywords: Cooling liquid, chemicals, toxicity, health and safety.

1. INTRODUCTION

With the development of metal processing, the problems of overheating of tools and workpieces appeared. In an attempt to solve that problem, the workers began to experiment using water, then water enriched with soapy water, and so even today by mixing various substances, cooling agents are obtained. These cooling agents have different chemical properties and sometimes hurt humans and the environment. The health and safety department at works to reduce such risks to the lowest possible level. Due to the use of chemical substances, accidents often occur. It is important to react properly so that they do not happen or, if they do, to reduce the consequences in the best possible way and to learn from such situations. The best way to handle a chemical is with a safety data sheet. To improve the new safety of employees who handle the chemical substance, research was carried out through a survey on the level of awareness of employees about the chemical substance they work with. Through the survey, it was concluded at what level is the knowledge of the employees about the dangers and harms they are exposed to. Based on the answers, measures were proposed to improve knowledge.

2. COOLANTS

Coolants are a type of liquids used to cool and lubricate in specific processes like metalworking [1]. Their main use is to regulate the temperature of a system and workpiece, and secondary uses are to lubricate and prevent corrosion on tools, machines, and workpieces. Use is widespread due to the constant growth of the metalworking industry.
Their main characteristic is high thermal capacity, low cost, and low viscosity, which helps with the cooling and distribution of the fluid. Ideally, they should be non-toxic, corrosion-inhibiting, and chemically inert. Their freezing point must be lower than the minimal temperature at which the fluid will be used. From a safety standpoint, they need to be non-flammable and non-explosive. Many

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substances fulfill the cooling and lubricating requirement, but for them to be used they must also fulfill requirements in terms of toxicity, flammability, and price. Its effect on the human environment and law regulations is also an important factor.

3. MEASURES FOR SAFE WORK WHILE USING CHEMICAL MATTERS

While working with cooling fluids proper implementation of safety measures is important. These are modern training, social, organizational, technological, ergonomic, and health measures, prescribed by the occupational health and safety law [2]. Preventive measures must call for law regulations. Preventive measures are measures that have been taken before an accident or occupational-related sickness happens. For their proper implementation, it is important to properly understand all hazards and dangers inside the workplace. If the workplace contains chemical matters it is important to note the safety data sheet content which contains identification properties of the chemical, its characteristics, way of use, preventative measures, and supplier information [3]. It is important to have the safety data sheet in the native language that the workers understand so they will be able to understand named risks and preventive procedures. The starting point for prescribing preventative measures is the eleven principles of environmental protection [4]. When assessing the risk it is important to note the presence of chemical matters and take them into account [4]. While using chemical matter designed for the cooling of the work process it is important to pay attention to specific and general limit concentration in substance so the limit concentration can be evaluated over which its use affects human health and the environment [4]. It is concluded that the risks while using this liquid are high. Measures for reducing the risk of hazards and dangers are numerous technical and organizational solutions. Both types of solutions can be individual and collective. Based on all the information presented, it is clear that ensuring safe and healthy handling of chemicals is crucial for protecting both human lives and the environment. It is the responsibility of both employers and employees to take necessary measures to ensure safe and healthy work practices are followed [5].
It is also important to adhere to the principles of prevention, where it is expected from the employer to nullify the risk from work-related illnesses and accidents or at least to reduce it to the lowest level possible. The principles are:

- Planning and organization of work;
- Providing adequate clothing and personal protection equipment for working with chemicals;
- Implementation of proper maintenance system;
- Reducing the number of exposed workers to a minimum;
- Reducing the time and intensity of exposure to workers;
- Implementation of proper hygienic measures;
- Reduction of chemical matter presence in the workplace to a minimum;
- Implementation of proper procedures including use, handling, storage, and maintenance of chemical fluids and disposal of waste fluids.

4. ACCIDENTS

Production and consumption of hazardous matters are in constant growth. Transport and storage of hazardous matters is done for the needs of production processes which exposes the environment to constant danger of accidental and unwanted contact. Every day in the world around 35 chemical accidents of different scales. Hazardous matters can pollute the environment in two ways. The first one is daily from different means of constant pollution (spills, leaks, etc.). They are hard to spot and show only after years or decades of constant pollution. The second way is sudden and happens almost instantly, then it is a chemical accident. Chemical accidents can happen due to human error, failure of various systems, breakdowns, traffic accidents, etc. The consequences in this case are the release of large amounts of chemical substances which can cause large-scale pollution over a large area. All types

of chemical accidents cause human harm, loss of lives, and often loss of livestock and material goods. Chemical accidents threaten human safety and prosperity. All these accidents need good organization, planning, evacuation, and a large amount of funds for decontamination and loss mitigation. When working with hazardous substances, it is important to implement safety measures to ensure a healthy work environment.The key to accident prevention is well-made assessments of risk and environmental protection [6].

5. DATA ABOUT THE LIQUID USED FOR COOLING IN THE PROCESS OF MANUFACTURING CASINGS

From the safety sheet for the substance can be concluded that the fluid is intended for mixing with water to create water-oil emulsions (cutting fluid), industry use, transport, handling, and disposal [7].

Table 1: Information on ingredients
Source: *Safety data sheet [8].*

Chemical name	%
Distillates (petroleum), hydrotreated light naphthenic; Baseoil - unspecified	20- <40
2-(2-butoxyethoxy)ethanol; diethylene glycol monobutyl ether	1- <5
2,2'-(methylimino)diethanol; N-methyldiethanolamine	1-<5
Alcohols, C16-18 and C18-unsatd., ethoxylated	1-<5
Amides, C12-18 and C18-unsatd., N-(hydroxyethyl), ethoxylated	1-<3
2-Pyridinethiol, 1-oxide, sodium salt	0,1-<0,25
Other components below reportable levels	60-<100

It is identified that in contact with human skin or eyes can cause damage and irritation of second category harmfulness to human health. Contact with the environment can cause environmental damage. Can cause damage to the water world of the third category if it gets into it.

Table 2: Risks and mitigations.
Source: Safety data sheet [8].

Vulnerable body part	Risk mitigation measures and PPE
Eyes	Glasses with side protection or other adequate eye protection equipment.
Hands	Adequate gloves are intended for protection against oil or chemicals.
Breathing organs	Adequate ventilation inside work and storage spaces. If ventilation is not available breathing masks with adequate filters are needed. Filters must protect against the aforementioned chemicals.
Skin	Adequate clothing.

Common ways to come into contact with chemicals:

- Breathing – prolonged inhalation of chemical vapors can cause damage to breathing organs and related illnesses;
- Skin contact – according to relevant data it is not possible to classify the type and level of possible skin damage;
- Contact with eyes – causes hard irritation and temporary or permanent damage to vision or vision loss;
- Ingestion - according to relevant data it is not possible to classify the type and level of possible damage but poisoning and esophagus and stomach damage are probable.

6. SURVEY RESULTS AND DISCUSSION

The data collected through the anonymous survey was processed. The survey contains eighteen questions, eight of which are shown in the results discussion. The survey aims to determine the level of employees' ability to work while using the cooling agent.

Table 3: Questions and answers
Source: Author

Questions	Answers:	Percent:
Are you acquainted with the safety sheet for the chemical matter with whom you come into contact every workday?	Yes	75%
	No	25%
Is there always available a copy of the safety data sheet in the Serbian language or in a language that the employee understands at the workplace?	Yes	87,5%
	No	12,5%
Are you familiar with all the dangers and harms to which you are exposed in the workplace as an operator of a machine for the production of chanchet?	Yes	50%
	No	50%
Are you informed about the data obtained based on the act on risk assessment and informed about the amendments and additions to the Act on risk assessment that are carried out if there is a significant change in the work process?	I am	62.5%
	I am not	37,5%

Based on the answers provided to the four questions, it can be concluded that employees have some knowledge of the properties, dangers, and harmful effects of the cooling agent. To minimize the risk of injuries and illnesses, it is crucial to have a safety sheet that contains all the necessary information in a language that the employees understand. It should be made available at the workplace where chemical substances are used. It is also important to educate the employees about the safety data sheet and its contents.

Table 4. examines the general knowledge of employees about the asset and how to handle it.

Table 4: Questions and answers
Source: Author

Questions:	**Answers:**	
Does the liquid meet the limit value of 8% ?	Yes	Percent:
Does the liquid meet the limit value of 8% ? Is the chemical stored at a safe distance from incompatible materials?	No	50%
	I do not know	33,3%
	Yes	16.7%
Is the chemical stored at a safe distance from incompatible materials? Are you familiar with what means of extinguishing a fire if there is a fire on that production line?	No	75%
	I do not know	25%
	Yes	0%
Are you familiar with what means of extinguishing a fire if there is a fire on that production line? To what extent do you think appropriate hygiene measures were applied? (hygienic measures include access to technical water, hand washing pastes, and availability of brooms and brushes intended for maintaining hygiene at the workplace)	No	75%
	Not at all	25%
To what extent do you think appropriate hygiene measures were applied? (hygienic measures include access to technical water, hand washing pastes, and availability of brooms and brushes intended for maintaining hygiene at the workplace)	Little bit	12,5%
	Satisfied	37,5%
	Very satisfied	25%

Based on the answers provided by employees, it has been concluded that they have varying levels of knowledge and awareness when it comes to preventing injuries or illnesses. To address this, it is important to identify the reasons behind their responses and attitudes. Once this is done, suitable training sessions should be conducted to remove any misunderstandings or doubts that employees may have, thereby minimizing the risk of injuries or illnesses in the workplace.

7. CONCLUSION

During the preparation of the paper, the topic of cooling agents and their characteristics, which are required by the market and legal regulations, was covered. It also investigated what measures should be taken for safe and healthy work, what legal regulations do they refer to and how does it look in practice. It explains how to act after various accidents and how they can occur if chemical substances are used. Through a survey, employees' knowledge of the dangers and harms of the fluid and information about how to handle the fluid were examined. Based on the processed data, it can be concluded that the employees have different levels of knowledge and training. Such results indicate to us that injuries or illnesses may occur due to a lack of information or negligence. To prevent such situations, it is necessary to talk with employees to determine inconsistencies in the answers. It is also necessary to educate employees. Education must be carried out regularly and properly to minimize the risk as much as possible.

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Student paper

EMPLOYEE SAFETY DURING PLASTIC DEFORMATION METAL PROCESSING

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Abstract: *Working in the metal industry carries with it a certain risk. The level of risk is largely influenced by the human factor, which is very important. The goal of this work is to determine the level of risk for the workplace operator on the machine for the production of casings and to prescribe preventive measures for safe and healthy work. To determine measures to reduce risk, a survey of the current state of occupational safety and health at the mentioned workplace was carried out. During the observation of the work process to assess the risk, the processing of metal by plastic deformation and the technical-technological procedure of the production of casings were observed.*
Keywords: Safety, workers, plastic deformation, production line, metal

1. INTRODUCTION

It is important to always be up-to-date with the latest laws and regulations, as well as advancements in occupational safety and health, to continuously improve workplace safety. Also, it is important to implement it all in practice. The awareness of the importance of said measures has to be lifted to a high level so the workers will accept their implementation. Respecting preventive measures is mandatory in workplaces with physical and chemical hazards. When doing research on work-related accidents and their causes, work-related health issues, or after the implementation of new production techniques or production equipment 1 the human factor is often disregarded although it is one of the most important factors in the occupational safety and health sphere.

2. HUMAN FACTOR IN THE OCCUPATIONAL SAFETY AND HEALTH SPHERE

Adaptation is important in the worker–work area interaction. Work equipment and work protocols must be adapted so that errors can be brought to a minimum. Workers must be qualified for safe work, which is enabled by schooling, courses, and training so the minimization of human errors is enabled too. Single factors or personal factors that affect work health and safety can be defined as any state or characteristic of an individual that can influence a worker to act less safely. They can be of a physical, cognitive, or psychological nature. Single factors include motivation, training, attitude, and human error and their interaction with the physical, mental, and perceptive ability of an individual[1]. Typical single factors include:

- Personal interests in bonuses and pay increases;
- Bad / damaged hearing;
- Bad eyesight;
- Language barriers or problems in communication;
- Physical health;

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- Experience;
- Competency;
- Personality and attitude;
- Age;
- Place in the hierarchy of the organization;
- Training.

After all large problems can be caused by language and communication barriers. The presence of foreign workforce and national minorities causes them. Training must be adjusted to different groups and the ability of workers to communicate in that group should be considered [2].
Negative factors that can affect workers are:

- Low level of skill and competency;
- Psychophysical exhaustion of colleagues;
- Disinterest of colleagues;
- Personal health problems;
- Dissatisfaction with repetitive tasks and lack of training to increase work/advancement availability;
- Lack of experience, especially in young workers;
- Peer pressure to conform to a group, or to accept their views on how "work should be done".

These factors have a great influence on operational health and safety, and some of them are unchangeable because they are caused by personality traits. Changeable factors also are important as are motivation, perception, attitude, and skill, and they can be changed through training, courses, and similar measures [3].

3. METAL PROCESSING BY PLASTIC DEFORMATION

In the production of brass casings, several hazards are present during metal processing by plastic deformation. These hazards affect the level of the risk, which has to be evaluated, and safety measures prescribed for risk mitigation. Plastic deformation is a complex process that starts as a consequence of the forced and permanent displacement of atoms in the crystalline structure of metals. Plastic deformation can be cold and hot. Cold plastic deformation happens at temperatures below the temperature of recrystallization while hot deformation happens at temperatures larger than the temperature of recrystallization which decreases the resistance of metals to deformation and increases plasticity. Both hot and cold deformation are used in different types of industries to produce metal parts [4].
The benefits of processing metal by plastic deformation compared to other methods are:

- Simpler machines;
- Increase in mechanical properties of deformed part;
- Room for automatization and mechanization of processes;
- High utilization rate of material.

Some of the downsides of plastic deformation are:

- Economic justification of process only for a large number of parts;
- Large deformation forces so the machines are bulky and heavy;
- Expensive tools.

4. PREVENTIVE MEASURES

While working it is important to properly implement preventive measures. These are modern social, organizational, technological, ergonomic, and health measures prescribed by the law of health and occupational safety [5]. Preventive measures must call on law regulations. Preventive measures are measures that are taken before an injury or illness happens. Their purpose is to decrease the risk or if possible, eliminate it. For proper implementation of preventive measures, timely identification of

hazards and dangers in workplaces is important. While creating preventive measures it's important to dedicate to the content of the safety data sheet which contains identification cards of chemical matters, data about its characteristics, way of use, way of disposal, dangers and hazards, measures for risk reduction and prevention, and supplier dana [6,7]. The basis for creating preventive measures is the eleven laws of environmental protection where in industry the accent is on prevention and precaution. The safety data sheet needs to be made in the native language of workers so they can understand all dangers and safety procedure [9]. While using chemical matter designed for the cooling of the work process its important to pay attention to specific and general limit concentration in substance so the limit concentration can be evaluated over which its use affects human health and the environment[10].

5. TECHNOLOGICAL PROCESS OF CASING PRODUCTION

For the production process of creating brass casings at „Valjaonica bakra Sevojno AD“ brass sheet is used as raw material. The raw sheet is made by passing a brass block through a series of rollers which decreases its thickness increasing length and width thus creating a sheet. The sheet is then cut to a specific width needed by the machine and tools used. The sheet is transported via a console crane and with a forklift to a roll feeder. The sheet is fed into feed rollers and then into the tool inside the machine. The sheet then goes through a multi-stage tool that transforms the raw sheet into casings. The first step is the stamping of the blank workpiece, and the second step is deep drawing to form the casing. The stamping speed of the machine is 100 – 115 strokes per minute. Using 2 stage tools and having multiple nests per tool the machine can produce from 600 up to 920 casings per minute (Figure 1.). The used sheet exits the machine and is collected and recycled (Figure 2.) Formed casings are at this point collected and transported to a rotational barrel degreaser to remove coolant oils from them. They go through a series of degreasing baths followed by a hot water bath, powder degreasing, and air drying which gives clean casings of corresponding shine, cleanliness, and quality. The finished product is then packed into wooden crates lined with oil paper. In the production of these casings cooling liquid must be used, most commonly oil–water emulsions which at the same time function to cool the tools and to lubricate them. Emulsions are created in a tank capacity of 600-800 liters, with a 5% oil concentration, and its own cooling and purification system. Coolant tanks are cleaned every two to three months. Because of its properties, emulsions pose a hazard and are harmful to human health and the environment.

Figure 1. Finished product
Source: Authors gallery

Figure 1. Leftovers
Source: Authors gallery

This process of creating casings produces a lot of heat which needs to be mitigated by the use of cooling liquids (emulsions).

6. RISK ASSESSMENT

The 5×5 method is used to assess the risk level according to the current situation and prescript corrective measures. Risk assessment takes into consideration work tools, work processes, work organization, raw materials, personal protection equipment, and other elements that can increase work-related accident risk, health deterioration, and sickness of worker [12].

Table 1. Risk matrix

Risk matrix							
Formula P=L*C		Level (L)	Probability of accident (B)				
			Minimal	Low	Probable	High	Sure event
			1	2	3	4	5
Accident consequences (C)	Very unlikely	1	1	2	3	4	5
	Unlikely	2	2	4	6	8	10
	Possible	3	3	6	9	10	15
	Likely	4	4	8	12	16	20
	Very likely	5	5	10	15	20	25

Table 2. Risk assessment.
Source: Author

Code	Hazard/harm	Probability	Weight	Risk	Evaluated risk
10	Probability of slip or fall (slippery floors)	4	3	12	Medium
21	Chemical hazards	3	2	6	Low
22	Noise	4	4	16	High
22	Vibrations	2	2	4	Very low
24	High/low temperatures	4	4	16	High
28	Hazards from dangerous materials present in production, transport, storage etc.	4	4	16	High
31	Non-physiological body posture	5	3	15	Medium
32	Psychological tiredness - monotony	4	4	16	High
33	Using adequate skill/knowledge.	3	3	9	Low
34	Shift work	4	4	16	High
34	Night shifts	4	4	16	High

By the assessment of risk using the matrix 5×5 method it can be concluded that a workplace of a machine operator for a casing production machine is the workplace with considerable risk, therefore measures for risk mitigation are to be prescribed. Table 3. shows evaluated risks and measures for their mitigation.

Table 3. Safety measures
Source: Safety sheet data [11]

Hazards/harms	Measure for mitigation
Slip or fall (Slippery floors)	Non-slip shoes and slippery (wet) floor signs.
Noise	Hearing protection.
High or low-temperature	Work clothing made for high/low temperatures. Climate conditioning. Air-conditioned rest areas. Access to cool water fridges during work shifts.

Hazards of using dangerous matters in work, transport, etc.	Adequate clothing/gloves. Adequate training on specific dangers. Safety data sheets.
Non-physiological body posture (standing for long durations).	Access to chairs near the workplace for resting. Adjusted work and rest time intervals.
Psychological tiredness - monotony	/
Shift work	/
Night work	/

7. CONCLUSION

During the preparation of the paper, the current state of safety and health was processed using risk assessment for workplace "Operator on the machine for casings production". Measures for risk mitigation are prescribed. The risk assessment shows that the workplace of the "Operator on the machine for casings production" is a workplace with increased risk. Therefore, it is necessary to post a prescribed notice of danger, to increase the awareness of the employees, and to use prescribed means and equipment for personal protection to reduce the risk to a satisfactory level. To implement risk reduction measures in practice it is necessary to properly educate employees about the dangers and harms and how new preventive measures can be used to reduce the risk of accidents or illnesses at the workplace. Based on the prescribed measures, instructions for safe and healthy work were written.

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Student paper

CHEMICAL HAZARDS IN HORTICULTURE FROM THE ASPECT OF OCCUPATIONAL SAFETY AND HEALTH

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Abstract: *Over the years in the horticulture industry, the use and distribution of chemicals on the market have escalated more and more. The main cause of this phenomenon lies in an increasingly diverse assortment of plants, which has led to a sudden increase in the need for pesticides to ease and speed up the production process. The usage of these chemicals can be seen in the context of significant concern and difficulty from the side of occupational safety and health and the natural environment. In this paper, we analyze the application of these chemicals in horticulture, hazards, and damages, as well as the measures of protection at work during the technological process.*
Keywords: chemicals, risk, hazards, damages, protective measures

1. INTRODUCTION

Horticulture, as one of the branches of agriculture, has to do with plant cultivation and maintenance, such as flowers, fruits, vegetables, and other plants. Although this activity provides various benefits, such as aesthetic landscaping and food production, it also brings significant challenges from the aspect of occupational safety and health. In recent years, we have witnessed an expansion of interest in horticulture due to an increasingly diverse assortment that has become easily available in terms of a simpler way of importing plants from other countries. As the number of plant species arriving from other countries increases, so does the need for new technologies to create artificial environmental conditions that imitate the original environment of the plant's origin. In this regard, the increased need for the wide usage of chemicals to protect plants by controlling pests and weeds carries countless unwanted results when it comes to the safety and health of the person engaged in this activity.

2. DESCRIPTION OF THE APPLICATION OF CHEMICALS IN THE TECHNOLOGICAL PROCESS

The most demanding but also the primary job of an employee who performs plant maintenance involves treating plants with different chemicals depending on the need. Frequently used solutions to treat plants belong to a group of pesticides, i.e. fungicides, selective herbicides, and the most harmful, i.e. insecticides.

1. Within the industry, fungicide is often used to protect plants right after their delivery from any fungal diseases and conditions potentially present in the new environment. This chemical agent for suppressing the growth and destruction of fungi, i.e. for protecting plants and animals, including humans, from the causative agents of fungal diseases and disorders (mycosis), includes many effects harmful for humans and the environment, such

as flammability, acute toxicity, environmental hazard and sensitization of respiratory organs.

2. Selective herbicides are chemicals used to control a specific type of weed that prevents the plant from developing properly. Their intentional effect on the weed plant targets specific growth processes or metabolic pathways. Production-wise, it is a useful tool in agriculture and gardening because it can ensure complete control of weeds without damaging crops or other plants. Although these chemicals offer many benefits, they still contain many, in terms of occupational safety and health, harmful properties, such as flammability, corrosiveness, sensitization of respiratory organs, and danger to the environment.
3. Insecticides are chemicals used to control insects that damage plants by feeding on their leaves, flowers, fruits, or roots. Although they are used less than fungicides and herbicides, they represent far more toxic and dangerous chemical compounds for the safety and health of people and the environment. Unlike selective herbicides that control only certain weeds, insecticides not only do not kill harmful insects but can also leave a negative effect on beneficial insects such as bees that pollinate plants. Therefore, improper use can potentially reduce the population of beneficial insects and affect the ecosystem. Moreover, the improper handling and disposal of insecticides can severely contaminate the soil, water, and air and accordingly cause harmful effects on plants, animals, and people that come into contact with these natural elements. Some of the properties of insecticides include toxicity, environmental hazard, corrosivity (corrosive substance), respiratory sensitization, and flammability.

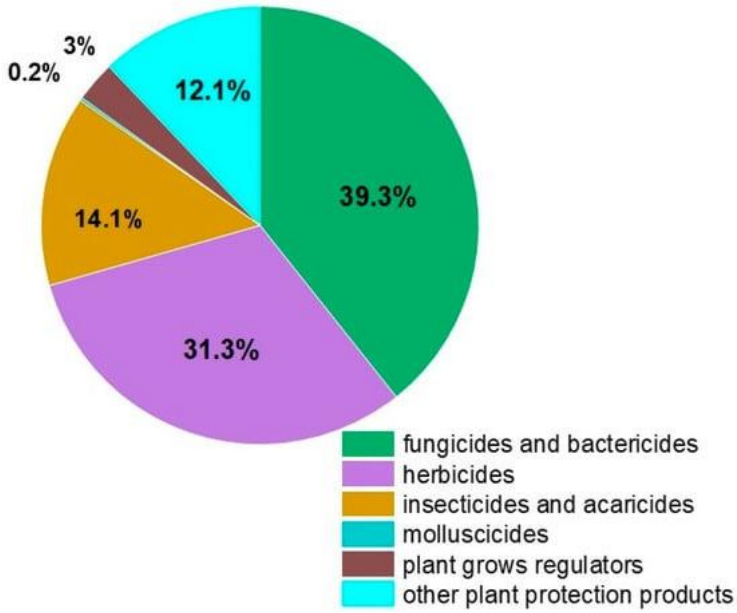

Figure 1. Categories of pesticide sales in the European Union in 2019
Source: https://shorturl.at/qxES4

3. HAZARDS WITH POSSIBLE CONSEQUENCES FOR WORKERS PERFORMING PLANT MAINTENANCE ACTIVITIES

Hazards are phenomena that endanger or may endanger employee's health and even life. Chemical hazards often take place in a short period, causing worker injuries that can be fatal, as opposed to damages that act over a longer period through long-term exposure to various harmful agents resulting from the technological process itself, causing occupational or work-related illnesses.

Depending on the type and level of exposure, exposure to chemicals can have a variety of negative health effects. The most common ones on the human body include:

1. Poisoning - chemicals such as pesticides, heavy metals, poisonous gases, and vapors originating from plants can cause acute or chronic poisoning in the body. Poisoning symptoms include nausea, vomiting, dizziness, damage to organs and nervous system, and even death.
2. Carcinogenicity - there is a wide range of carcinogenic chemicals that can cause different types of cancer such as cancer of the lungs, skin, kidneys, liver, and other organs. Susceptibility to cancer depends on many factors, such as body resistance, hereditary factors, and the length and frequency of exposure. Even so, the main risk catalyst can be still linked to the chemical exposure.
3. Respiratory problems - chemicals such as ammonia contained in artificial fertilizers or formaldehyde, also called an industrial fungicide, can cause numerous respiratory problems, such as airway irritation, allergic reactions, asthma, bronchitis, and other respiratory problems. Consequently, long-term exposure to these chemicals can lead to permanent lung damage.
4. Damage to the reproductive system - pesticides globally have very harmful effects on the reproductive system of men and women. They can cause decreased fertility, hormonal disorders, miscarriages, fetal deformities, and other reproductive health problems.
5. Neurological disorders - certain chemicals such as lead contained in insecticides, mercury used in the production of fungicides, or pesticides themselves can cause damage to the nervous system. Exposure to these chemicals leads to neurological disorders, the most common of which are memory loss, concentration disorders, depression, anxiety, tremors, epilepsy, and other problems.
6. Allergic reactions - sensitive people and people with reduced immunity are especially susceptible to allergic reactions to chemicals used in activities such as horticulture. The most common are surface reactions on the skin such as rash, itching, redness, and swelling. In addition, there are also respiratory reactions in the form of breathing difficulties, sneezing, coughing, and other allergy symptoms.

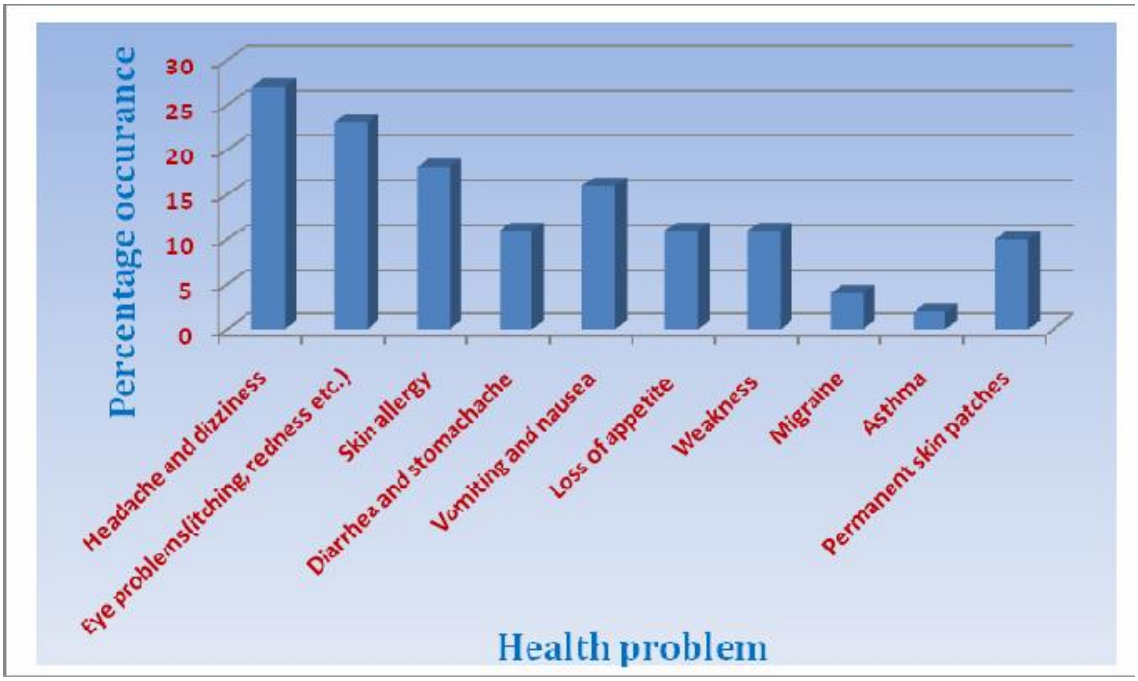

Figure 2. Negative health effects on farmers caused by pesticides
Source: https://shorturl.at/pxI37

4. PROTECTIVE MEASURES AT WORK AGAINST LONG-TERM EXPOSURE TO CHEMICALS

To precisely determine occupational protection measures against exposure to chemicals used in this activity, it is necessary to know the type of chemical, the length and method of exposure, the amount of dangerous chemicals present in the environment, and possible ways of chemical substances entering the body. There are four ways the chemical substances can reach the human body: absorption through the respiratory tract (inhalation), which is the most common case, absorption through the gastrointestinal tract (ingestion, i.e. swallowing), absorption through skin or eyes, and injection.

To avoid negative consequences for human health due to excessive exposure to chemicals, the Rulebook on preventive measures occupational safety and health when exposed to chemical substances ("Official Gazette of the Republoc of Serbia, no. 106/2009, 117/2017 and 107/2021) established occupational exposure limit value (OEL), as well as short-term exposure limit value (STEL). OEL is the average concentration of a hazardous chemical substance in the air at the workplace in the employee's breathing zone, under normal microclimatic working conditions and with light physical work. It is calculated over a certain period, in relation to the indicated reference period. According to the general opinion, it is not harmful to the employee's health, if the employee works at a concentration of a hazardous chemical substance that is lower than or equal to the limit value of a hazardous chemical substance, eight hours a day, expressed in mg/m^3 or ml/m^3 [ppm]. STEL is the concentration of a dangerous chemical substance to which an employee can be exposed for a short period of time without risking health damage. Exposure to such a concentration of a hazardous chemical should last no more than 15 minutes and should not be repeated more than four times during working hours. There should be at least 60 minutes must elapse between two periods of exposure to it. Short-term exposure values are expressed in mg/m^3 or ml/m^3 [ppm];

Occupational safety measures are organized according to a previously established hierarchy, first resorting to elimination and substitution measures, through engineering and administrative measures, all the way to the application of personal protective equipment measures. They can also be applied in combination.

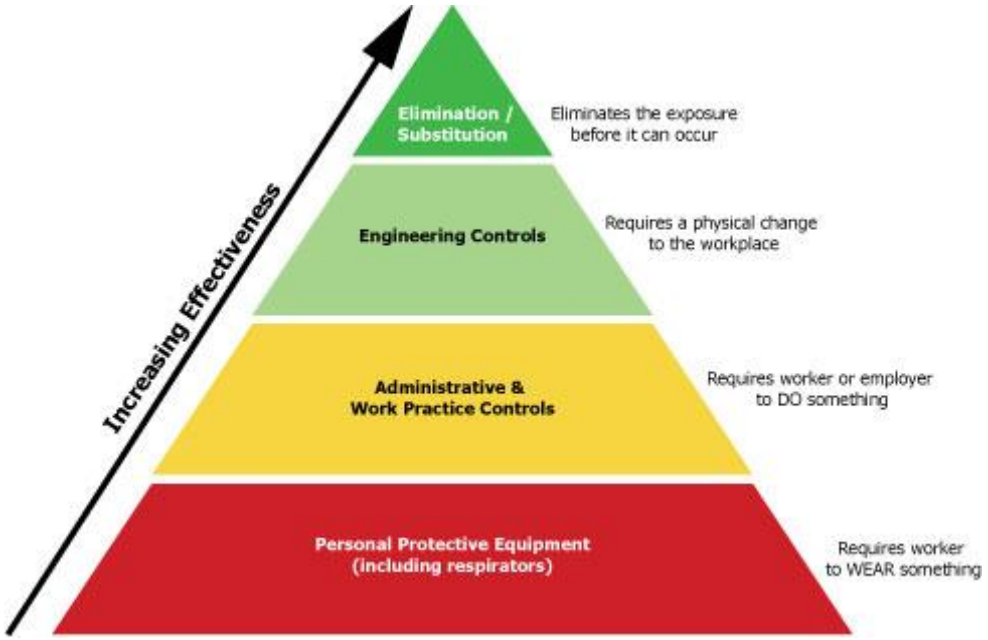

Figure 3. Hierarchy of measures for safety and health at work
Source: https://shorturl.at/ciqS1

1. Elimination and substitution refer to the elimination or replacement of hazardous chemicals by less hazardous ones. In this regard, we can mention a recent year's example of substituting the herbicide for destroying weeds called "Total 480 SL" by using completely safe agro textile mats. It is widely known how harmful the mentioned chemical is to the safety and health of both humans and animals that come into contact with it, but also how progressive and permanent the decontamination of the treated soil is, as the ban on the use of this chemical in the EU countries indicates. Nowadays, there are much safer alternatives for this type of problem, among which are agro textile mats made of woven polypropylene.
2. Engineering measures refer to physical changes in the work environment to reduce exposure to chemicals. Examples would be installing ventilation systems, establishing air drainage and filtration systems, or using closed chemical handling systems.
3. Administrative measures involve establishing organizational procedures to reduce exposure to chemicals. The most important administrative measures aimed at reducing the exposure of workers to dangerous chemicals are instructions for safe and healthy work when using hazardous substances, limiting the exposure time and rotation of workers, especially when plants are treated with insecticides and when high temperatures are present in greenhouses, providing access to safety data sheets for each dangerous chemical, monitoring the presence of dangerous chemicals using concentration detectors. They also include signs, signals and alarms to indicate permitted chemical concentration limits.
4. Personal protective equipment is used as the last line of defense when other measures are insufficient. This measure includes wearing gloves, safety glasses, face masks, respirators, protective suits, and other types of equipment that protect against exposure to chemicals. It is essential for personal protective equipment to be properly selected, used for its purpose, and regularly maintained.

5. CONCLUSION

In the field of horticulture, in addition to chemical hazards, there are also many other damages and hazards that additionally complicate finding a compromise solution. However, chemicals represent a major challenge for occupational health and safety engineers.
These are some essential measures for safe and healthy work during plant maintenance activities under exposure to chemical hazards:

1. Procurement of adequate personal protective equipment, such as disposable masks and gloves and their obligatory use during work. Non-disposable personal protective equipment must be regularly cleaned and maintained, especially after using harmful chemicals for plant treatment.
2. Using more frequent and shorter breaks when working in the greenhouse during the summer when the temperatures are above 35 °C, providing enough mineral water and air-conditioned rooms where the employee can spend time during breaks.
3. Mandatory previous and periodic medical examinations once a year.
4. Providing training courses and educating workers on how to properly use hazardous substances during plant maintenance activities.

What should represent a key aspect and good practice of every organization in the field of occupational safety and health primarily is the proper introduction of preventive measures, since they can significantly reduce the possibility of injuries, illnesses, and occupational diseases in the workplace. Preventive protection measures can bring the best results primarily through the direct cooperation of employees, employers, and persons in charge of occupational safety and health. Only a healthy and satisfied worker can ensure his maximum in the work process and contribute to himself and his employer accordingly.

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Student paper

POTENTIALLY EXPLOSIVE ATMOSPHERES IN FLOUR PRODUCTION

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Abstract: *Dusts of organic origin often appear in processes in the food industry. In addition to other hazards related to potential damage to the health of employees, there are also risks of creating explosive atmospheres of organic dust and air. The paper analyses the possibility of creation of an explosive atmosphere because of flour dust that is occur in the technological process of flour production. Important factors influencing the creation of an explosive atmosphere were studied.*
Keywords: flour production, dust, explosive atmosphere, explosive limits

1. INTRODUCTION

In the current practice of explosion protection, the greatest attention is paid to the analysis of electrical devices as a source of ignition of an explosive atmosphere. However, in addition to the creation of an electric spark, a spark can also occur due to other causes such as a mechanical spark (impact, friction), hot surfaces, hot gases and flames, static electricity, ionized radiation, ultrasound, shock waves, self-ignition of dust, etc. Flour dust is a common by-product in the production process, consisting of fine particles of flour and bran. As such, when it is found in a higher concentration, it represents a danger of explosion because there is enough oxygen for combustion, and in combination with certain factors, it represents a potential risk for explosion.

2. EXPLOSIVE ATMOSPHERES

An explosive atmosphere is a mixture of air and flammable substances in the form of gases, steam, fog, or dust, under atmospheric conditions in which, after ignition, combustion spreads to the entire unburned mixture [1]. An explosive atmosphere can be caused by:

- Inadequate ventilation resulting in the accumulation and deposition of flour dust and a truly explosive atmosphere.
- Equipment that generates heat, static electricity, or friction (this can create sparks that can ignite flour dust).
- The human factor (due to improper maintenance and non-observance of safety procedures can also increase the risk of flour dust exposure).

The hazard of explosions and fires from combustible dust is present in industrial plants where materials are crushed and/or there is present of finely divided solid particles. A characteristic of a dust cloud explosion is the high speed of the flame front. The strength of a dust explosion is influenced by the following factors:

- maximum explosion pressure (P_{max}) - the greatest amount of pressure and maximum amount of damage that dust can cause in an confined space;
- maximum rate of pressure rise $(dP/dt)_{max}$ - maximum rate of pressure rise, before an explosion runs out of oxygen and fuel.

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The product of the volume of test vessel (V) and the maximum rate of pressure rise (dP/dt) is expressed through the relation:

$$K_{st} = (dP/dt)_{\max} \times V^{1/3} \text{ [barms}^{-1}\text{]}$$

K_{st} (dust deflagration index) is a dust constant, therefore normalising maximum rate of pressure rise in a 1 m^3 vessel. K_{st} is characteristic of the material not the test vessel size [2]. Depending on the K_{st} classes, the classification of dust is given in Table 1.

Table 1. Classification of dust [2]

Dust class	**K_{st} (barms^{-1})**	
St0	0	Does not explode
St1	1-200	Weak explosion
St2	201-300	Strong explosion
St3	>300	Very strong explosion

3. COMBUSTIBLE DUST EXPLOSION

The term explosion means a rapid chemical reaction of oxidation or decomposition of an explosive substance, followed by a significant release of energy in a very short period, which causes shock waves in the surrounding space. Detonation and deflagration are distinguished according to the method and speed of propagation of this phenomenon through the reducing material. Deflagration is defined as a very rapid burning of material from the surface to the interior. Burning speeds are in the so-called subsonic range (burning speed is lower than the speed of sound - less than 340 m/s). Detonation is an almost instantaneous combustion explosion followed by the formation of high pressure and temperature. The speed of the explosion can reach 10 km/h [3].

If the right conditions are created, an explosion of very high intensity can occur. For the burning process to occur and take place, three conditions are necessary: fuel, enough thermal energy needed to heat the fuel to a certain temperature, ignition, and the presence of oxygen. Dust explosion needs two additional elements – confined space and dispersion of dust particles in right concentration, as shown in Figure 1. A dust explosion is often the result of the swirling of accumulated explosive dust, which, together with oxygen from the atmosphere, creates an explosive environment. Its initial ignition leads to the transfer of heat from particle to particle (when one grain burns, it lights up nearby grains like a chain reaction), and with the influence of dust turbulence, a primary explosion occurs, which is generally of lower intensity. It represents the main shock wave that promotes the further swirling of deposited dust, because the pressure lifts the deposited dust, which triggers a secondary explosion that is far more intense and far more dangerous. Accordingly, it is understood that all the bigger explosions are the result of a chain reaction - a domino effect (Figure 2).

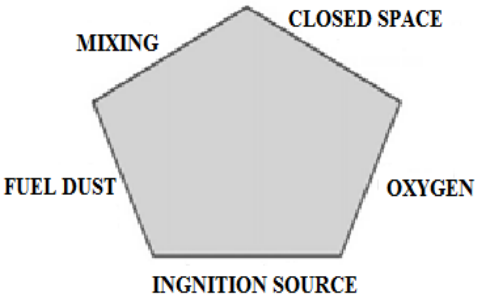

Figure 1. Dust explosion pentagon [4]

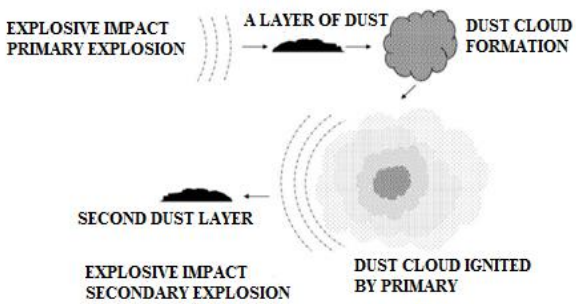

Figure 2. Dust explosion domino effect [4]

The explosive nature of flour is based on the fact that its particles are so small that they burn instantly. The energy thus released in the form of a flame can flash through the dust cloud with explosive force. When flour particles are suspended in the air and when the substance is present in powder form it offers a greater surface area exposed to oxygen per unit weight, compared to bulk materials, therefore flour dust clouds are much more flammable than bulk material, they can ignite in the presence of heat, burn instantly and transfer heat relatively quickly to nearby particles.
Flour and wheat, although are not classified as dangerous substances, under certain circumstances can exhibit dangerous properties. Flour is highly flammable as well as explosive in nature. This is because its main component is starch, a type of carbohydrate. Any hydrocarbon when it meets oxygen and heat undergoes combustion and burns to produce carbon dioxide gas and release water.
Flour and other sugar particles, when suspended in the air as dust, become explosive. Even a very small amount, is sufficient to ignite in the presence of a heat source. Almost all flour mills have flour handling systems such as transfer bins, bucket elevators, hammer mills, and bags. They provide the necessary containment and pressure, and ultimately, increase the risk of explosion. This type of explosion is known as a dust explosion [5].
Dust is defined "a small solid particle in the atmosphere that settles due to its weight but remains in the atmosphere as a dust/air mixture". The appearance of dust in industry is a consequence of the presence of raw materials and products (e.g. flour) or as a waste product (e.g. iron dust). Another definition of dust from the aspect of fire protection is that dust is a dispersed system in which one dispersed phase consists of particles of solid matter, and the other is air or another gas - the carrier gas [3].
The explosiveness of dust is primarily influenced by its chemical composition. Accordingly, dust can be defined in the following groups:

- organic (food dust, grain dust, cotton, wool, wood, coal, plastic and rubber dust, pharmaceutical and cosmetic dust, etc.);
- unbranched (dust from metals and various alloys, carbides, oxides, etc.);
  mixed (their composition can be different, and various dust mixtures occur in various ratios, eg calcium - carbonate, graphite - aluminium, polyester, etc.) [3].

In Table 2., the values of the lower explosive limit (LEL) for certain types of dust are given.

Table 2. Lower explosive limit for various dust [3]

The name of the dust	**LEL u g/m^3**
Al in powder	58
Potato starch	40,3
Tea	32,8
Flour	**30,2 – 63,00**
Hay	20,2

Ignition and combustion of dust take place within the explosive limits. Certain gases, vapours, and dust together with air can form explosive mixtures that explode under certain conditions. The minimum amount of flammable gases, vapours, or dust at which such a mixture can explode in contact with an ignition source is called the lower explosive limit. Above this limit value, the mixture is still explosive, but up to a certain concentration, when it stops being explosive. This limit value is called the upper explosive limit.
For many dusts, it is not possible to precisely determine the upper limit of explosiveness. For many dusts, the lower limit of explosiveness ranges between 20 and 60 g/m^3, while the upper limit of explosiveness ranges from 2 to 6 kg/m^3. The most favourable size for explosive combustion of dust is of the order of molecular size. As the particle diameter increases, the value for the lower explosive limit decreases. Table 3. shows the characteristics of some of the food dusts [3].

Table 3. Examples of combustible food dusts [6]

Product	Explosible?	P_{max} (bar)	K_{st} (barm/s)	MIE (mJ)	MIT_{cloud} (ºC)	MEC (g/m^3)
Corn	Yes	6.5	112	45-100	390-400	73
Wheat	Yes	7.4	87	50-100	370-380	67
Oats	Yes	7.2	43	> 500	420-430	30
Barley	Yes	6.3	100	50-100	360-370	73
Soy Beans	Yes	9.2	110	50-100	600-620	80
Starch (rice)	Yes	10.0	220	> 30	460-470	60
Starch (wheat)	Yes	9.1	156	10-30	470-480	30
Sugar	Yes	9.0	138	< 30	470-480	60

MIE - indicating the lowest electrical energy stored in a capacitor which upon discharge is sufficient to effect ignition on a dust cloud
MIT_{cloud} - lowest temperature of a hot surface capable of igniting a combustible dust cloud;
MEC - indicating the minimum amount of dust, dispersed in air, required to spread an explosion

4. FACTORS AFFECTING DUST EXPLOSION

Numerous factors affect the dust explosiveness, and to assess the risk of explosion, it is necessary to determine these factors, namely:

- dust concentration,
- oxygen concentration,
- size of dust particles,
- dust ignition temperature,
- minimum ignition energy,
- dust turbulence,
- presence of flammable gases,
- dust ignition source.

Dust concentration. A dust explosion occurs if the appropriate concentration of dust in the atmosphere is established. There is a range of dust concentrations. The lower explosive limit for most combustible dusts ranges from 50 g/m^3 to 100 g/m^3. The explosive concentration range of a dust cloud is not only a function of the chemical composition of the dust, but the limits vary depending on the size and shape of the particles in the dust cloud [4].
Oxygen concentration. As oxygen is a key factor in the triangle of fire (Figure 3), there is a limit to the minimum concentration required to cause an explosion (known as the threshold oxygen concentration). As stated in the dust explosion pentagon, the necessity of oxygen appears, which is characterized by the presence of air and its content of 21% oxygen. An oxygen concentration above 21% tends to increase the rate of the combustion reaction, but for a concentration lower than 21%, the rate of combustion decreases.
The consequence is that the rate of dust combustion decreases with the decrease of oxygen content in the atmosphere, thus the combustion may decrease or if an explosion occurs, it will be of lower intensity and the probability of a domino effect is very small. Burning is maintained only if the concentration of oxygen in the air is greater than 10% [3].

Figure 3. Fire trianle

Size of dust particles. The size of the dust usual ranges from 0.1 to 500 μm. [4] From the aspect of explosion protection, the most dangerous are dust particles smaller than 10 μm, the so-called floating - respirable dust. One of the most important properties of dust is that the smaller size of the dust particles means that they have a larger surface area in relation to the weight of the particle itself, thus enabling the speed of the particle's reaction with free oxygen in the air [3], Figure 4.

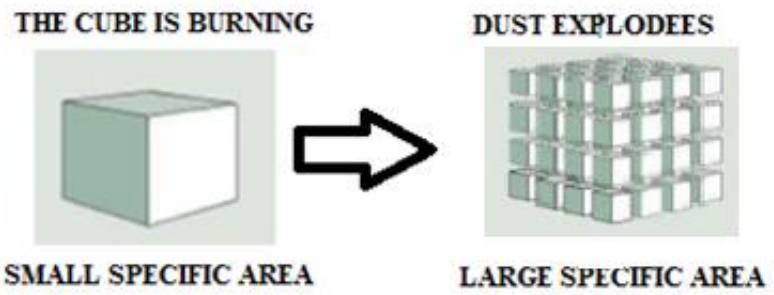

Figure 4. The surface of a dust particle

Dust ignition temperature. The ignition temperature represents the lowest temperature at which matter in the form of an aerosol or dust mixed with air can ignite. In the case of combustible dust, it is important to know:

- The minimum ignition temperature, ie the lowest temperature at which a certain thickness of the dust layer can be ignited on the heated surface;
- The ignition temperature of deposited dust, which represents the lowest temperature of the surface of the heated substrate leads to the ignition of a 5 mm thick layer of deposited dust. The ignition temperature decreases with the increase in the thickness of the dust deposits;
- Minimum temperatures of swirling dust, which is defined as the temperature at which the swirling dust of the most flammable concentration ignites.

The ignition temperature decreases with increasing dust fineness, in normal conditions of grain size of 50 to 100 mesh, the ignition temperature is 650°C, while with dust fineness over 270 mesh, the ignition temperature is 400°C [3].

Minimum ignition energy. The minimum ignition energy is the smallest energy of an electric spark, which can ignite finely distributed dust particles in the air. This energy depends on the concentration of the oxidizing agent in the combustible mixture, the type of combustible material, and the concentration of flying dust. A dust with a fineness of 50 μm can be ignited by a spark of energy 10-50 μJ, while dust with a fineness of 5000 μm only ignites when the energy reaches the level of 1.3 to 2.5 μJ [3].

5. REDUCING DUST EXPLOSION RISKS IN FLOUR PRODUCTION

The possibility of the creation of explosive atmospheres in the flour production process depends on many factors, primarily on the physical and chemical characteristics of the dust that is created and on the effectiveness of protective measures. Particularly important characteristics of dust refer to the size of the particles in the air of the work area. The distribution of the particles has a significant impact on the parameters of the wheat flour dust samples - smaller particles exhibit higher explosion parameters [7].

The aim of the protective measures is to minimize the creation of dangerous concentrations of flour dust in the air as much as possible, that is, to prevent the creation of high dust concentrations. The most effective way is to change the technological process so that the generation of flour dust is reduced to the smallest possible extent. Sufficient capacity ventilation and dust removal systems should be designed in accordance with the specifics of each technological process, as well as in accordance with the characteristics of the working space (space volume, equipment arrangement,

etc.). Maintaining the hygiene of process equipment and space through appropriate cleaning practices, preventive equipment maintenance are mandatory protection measures.

5. CONCLUSION

A organic dust explosion can be expected in almost all branches of industry, but the greatest risk is in the food and wood industries. The flour production process can create an environment where all these elements come together. Under such conditions, flour dust acts as a fuel source when mixed with oxygen, which can cause a fire when confined in a confined space. Due to the occurrence of disturbances during technological processes (high vibrations, dynamic imbalance, belt slippage, bearing damage, bent blades, rough handling, changes in environmental conditions, dust deposition, occurrence of static electricity, etc.), the creation of a spark and the ignition of an explosive atmosphere can occur.

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SMART MANAGEMENT SYSTEMS

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INFORMATION SECURITY MANAGEMENT STANDARD AND PERSONAL DATA PROTECTION – PRACTICAL EXPERIENCES

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Abstract: *The basic standard for information security ISO 27001 declares the need to preserve the basic properties of information - confidentiality, integrity and availability - and defines a certain number of controls oriented towards technical, organizational and combined actions that should ensure this. A special issue relates to the protection of personal data, which is the subject of a special General Data Protection Regulation (GDPR), which was applied in the EU on May 25, 2018. and the special Law for the Protection of Personal Data of the Republic of Serbia, which came into effect on August 22, 2019. After a brief presentation of the new revision of the ISO 27001 standard, GDPR and the relevant law, the paper discusses practical experiences and challenges in the application of personal data protection.*

Keywords: Information Security, Personal data protection, General Data Protection Regulative (GDPR), Law on personal data protection

1. INTRODUCTION

Modern technologies have greatly facilitated our daily activities, but they have faced us with a problem that was present before, but not to that extent - information security. A particularly delicate component of information security is the personal data protection (PDP), because we are all sensitive to information about ourselves that we do not want to share with a large number of people.

In order to solve the problem of information security in a comprehensive and systematic way, the International Organization for Standardization (ISO) adopted the family of standards ISO 27000, which refers to information security management systems (ISMS). The main standard in this family, ISO/IEC 27001 [1] is a standard with ISMS requirements that are oriented towards preserving the basic properties of information - confidentiality, integrity and availability - with a set of controls of an organizational, technological or combined nature that should ensure this.

The issue of personal data protection is only partially regulated by the ISO/IEC 27001 standard, because at the European level it is the subject of a special General Data Protection Regulation (GDPR) [2], which began to be applied in the EU on May 25, 2018. and the special Law for the Protection of Personal Data of the Republic of Serbia, which began to be applied on August 22, 2019 [3]. That is why the paper presents the key elements of the ISO/IEC 27001 standard related to the protection of personal data, the essence of the provisions of the GDPR regulation and the Law on Personal Data Protection in the Republic of Serbia. Also, some practical experiences and challenges in the application of these documents are considered.

2. INFORMATION SECURITY MANAGEMENT STANDARD ISO/IEC 27001 AND PDP

The ISO/IEC 27001 standard represents a global framework for ISMS, because it systematically provides an overview of all the elements that need to be taken into account if we want to protect information and thus reduce the business risk that can arise if that information gets into the hands of

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those who are not favorable to us as an organization. The basic properties of information are protected - confidentiality, so that the information is available only to those who have the right to it, integrity, so that the information is complete and not changed without authorization, and availability, so that the information is available to those who has the right to it when he needs it. Among the other properties of information that are protected in practice, the most interesting is non-repudiation, so that the recipient cannot deny that he has received the information, especially if some of its obligations arise from it.

The standard itself was issued under the designation 27001 in 2005, the second revision was published in 2013, and the third in 2022 [1]. This standard is specific in relation to other management system standards in that the basic part of the standard is relatively small in scope, but it contains Annex A which is normative (mandatory) with a multitude of controls that more precisely define certain elements related to information security. Revision 3 of the subject standard [1] defines a total of 93 controls (in version 1 there were 133, and in revision 2 there were 114) which are grouped into 4 categories - organizational controls (37), people-related controls (8), physical controls (14) and technological controls (34). The number in parentheses represents the number of those controls. It should be noted that despite the trend of reducing the number of controls, they were not omitted, but were only regrouped in order to facilitate their operational application. A more detailed description of these controls is given in the standard ISO/IEC 27002:2022 [4].

Revision 3 of the ISO/IEC 27001:2022 standard [1] already in the name change expanded the emphasis from information security to cyber security and privacy protection, because part of the name "Information technology - Security Techniques ... " was replaced by "Information security, cybersecurity and privacy protection ...". When it comes to controls, the topic of personal data protection is most directly dealt with by organizational control A.5.34, which refers to privacy and protection of information that identifies a person (Personal Identifiable Information - PII). A certain number of other controls deal with this topic indirectly. Of the organizational controls, these are management of information assets - human information assets (controls A.5.9, A.5.10), access control - authentication (controls A.5.17, A.5.18), incident management for information security (controls A.5.25 to A.5.28) and ensuring business continuity (control A.5.29), as well as most people-related controls (controls A.6.1 to A.6.5 and A.6.8).

3. GDPR REGULATION

The General Data Protection Regulation 2016/679 (GDPR) [2] was adopted by the European Parliament and the Council on 27.04.2016, published on 04.05.2016, and began to be applied on 25.05.2018. The period of two years from the adoption to the application of the GDPR was filled with many doubts about its content and the possibility of its application, which is still present today. The regulation itself has a total of 88 pages, the first 31 of which contain a preamble with 173 items, which explains the basic elements contained in the regulation. Paragraph (7) of the Preamble, which states that "natural persons should have control over their personal data", should be especially emphasized, and this can be considered an essential reason for adopting the regulation. The regulation itself is presented on the remaining 57 pages, it contains a total of 99 articles that are grouped into 11 chapters, some of which have sections.

It is important to note that together with this regulation, directive 2016/680 [5] was adopted, which limits the application of the GDPR in cases related to the processing of personal data by competent authorities for the purposes of prevention, investigation, detection and prosecution of criminal offenses. The bottom line is clear - those who engage in criminal activities cannot invoke the protection of personal data in order to prevent investigations related to their crimes!

A more detail overview of GDPR is given in the literature [6]. In accordance with the GDPR, the key participants in the processing of personal data are the "Controller" and the "Processor" - the "Controller" determines the purpose and means of personal data processing, while the "Processor" processes personal data on behalf of the controller. One of the key institutions is the "consent" of the data subject to the processing of personal data, as any form of freely expressed will of the data subject

by which he or she, by statement or clearly affirmative action, approves the processing of personal data related to him or her. A key problem that arises in the processing of personal data is "Personal Data Breach", which is a breach of security that leads to the accidental or illegal destruction, loss, alteration, unauthorized disclosure or access to personal data that is transmitted, stored or processed on another way.

According to the GDPR, the processing of personal data takes place in accordance with seven principles - legality, fairness and transparency, purpose limitation, data minimization, accuracy, storage limitation, integrity and confidentiality and accountability ([2],[6]). The essence is clear - personal data can be collected and processed only in accordance with the purpose for which they are intended and in the smallest possible scope, while they must be protected from all forms of abuse. In simple words, we need to "find the right measure" in the processing of personal data, and we know how difficult this is in many areas of life. In addition, the GDPR regulation defines eight key rights of data subjects ([2],[6]) - the right to be informed about the processing of their personal data, the right to receive confirmation from the controller as to whether or not personal data has been processed, the right to correction, the right to erasure ("right to be forgotten"), the right to ask the controller to limit processing, the right to data portability, the right to object and the right not to be the subject of decisions based solely on automatic processing, including profiling.

Within the GDPR, very high penalties are foreseen for breach of the personal data security, in two levels [2] - an administrative fine of up to €20 million, or up to 4% of the annual income in the previous financial year, i.e. €10 million, or up to 2% of the total annual income in the previous financial year, which is more unfavorable for the perpetrator! In the first two years, there were several cases of fining operators (Google, British Airways, Facebook, Post in Austria, real estate company Deutche Wohnen in Germany, etc.) mainly for the loss of personal data or their unauthorized use for marketing purposes, with fines ranging from 565 thousand to 205 million € [6]. Recently, the most attention has been attracted by fines for Twitter in the USA of $150 million (end of May 2022) for providing data to advertisers, as well as for the company META (formerly Facebook) in Ireland (end of May 2023) of as much as 1.2 billion € due to the delivery of data on EU citizens to the USA.

It is interesting to analyze the relationship of the GDPR to the information security management standard ISO 27001. The analysis shows [6] that a correctly implemented information security management system according to the ISO 27001 standard is still not sufficient for compliance with the GDPR. Although there are many similarities between these documents, there are also significant differences. First of all, these documents differ in their character - the GDPR is a legally binding document, the non-implementation of which entails certain penalties, while the implementation of the standard is voluntary, until the organization opts for it.

In addition, many institutions that exist in the GDPR do not exist within the ISO 27001 standard. This primarily refers to consent to the processing of personal data (Articles 7 and 8 GDPR), the right to erasure, i.e. "to be forgotten" (Art. 17 GDPR), the right to limit processing (Art. 18 GDPR), data portability (Art. 20 GDPR) and the right to object (Art. 21 GDPR), while the international transfer of personal data from Art. 46 of the GDPR partially exists in the ISO 27001 standard, but primarily refers to business data. On the other hand, the standard contains details on maintaining the level of information protection, which do not exist in the GDPR.

4. THE LAW ON PERSONAL DATA PROTECTION OF THE REPUBLIC OF SERBIA

In November 2018, a new Law on Personal Data protection of the Republic of Serbia - LPDP [3] was adopted. The constitutional basis for passing the Law in question is contained in Art. 42 of the Constitution of the Republic of Serbia, which proclaims that the protection of personal data is guaranteed, that the collection, storage, processing and use of personal data are regulated by a separate law, that everyone has the right to be informed about the collected personal data and has the right to judicial protection in case of their abuse. The reasons for the adoption of the new LPDP lie both in internal needs and in the context of joining the European Union. In the first segment, it refers to the need to upgrade the legal system to better ensure the protection of personal data, because the previous

law was passed in 2008 and was not able to fulfill what is required in this area. In the second segment, the adoption of this Law represents part of the state's international obligations and obligations to comply with EU legislation in the process of European integration. The need to amend this Law was stated in 2016 as part of the report on Serbia's progress in the EU accession process.

Table 1. LPDP structure vs GDPR
Source: *Raković R: Personal Data Protection – Framework and Challenges [6]*

Part	Part Title	Articles	GDPR Part
I	General provisions	1-4	I
II	Principles	5-20	II
III	Rights of the data subject	21-40	III
IV	Controller and processor	41-62	IV
V	Transfers of personal data to the thrd countries and international organizations	63-72	V
VI	Commissioner (Independent supervisory authority)	73-81	VI
VII	Remedies, liability and penalties	82-87	VIII
VIII	Specific processing situations	88-94	IX
IX	Penalty provisions	95	VIII
X	Transitional and final provisions	96-102	XI

The Table 1 shows the structure of LPDP [6]. The law essentially combines Regulation 679/2016 - GDPR [2] and Directive 680/2016 [5]. In comparison with the structure of the GDPR, sections VII "Cooperation and consistency" and X "Acts of delegation and implementation" are missing, which is a consequence of the fact that Serbia is not yet a member of the EU. Basically, the principles of LPDP and the rights of data subjects overlap to a significant extent in both documents. Nevertheless, there are certain additional differences between these documents, which are summarized in the literature [6] based on the wider literature:

- From the point of view of applicability, the GDPR has a significant advantage over the LPDP because it contains an extensive Preamble that accompanies the regulation itself and significantly contributes to its understanding through examples, explanations and the context of its adoption. The provisions from the Preamble were not included in the LPDP, and direct application of the GDPR is not possible because we are not a member of the EU, so in practice the provisions of the LPDP remain to be implemented in the spirit of other legislation.
- The law provides for the right to "complain" to the Commissioner, which is taken from the Law on Inspection Supervision, even though the GDPR provides for the right to lodge an objection - appeal. Lawyers are united in their opinion that the legal effect of a complaint and an objection - appeal is not the same.
- Violations of the Law are subject to fines ranging from 50 thousand to 2 million RSD for 32 cases, as well as 6 cases with a fixed fine of 100 thousand RSD. It is drastically different from the GDPR because the range of fines is from €430 to €17,000, which in a certain way contradicts the view that the penal policy should have a disincentive effect on the perpetrators. In the case of the Law, the amount of the fine is far below the damage that can be caused by violating the Law and the profit that can be made in that way, so the violators calculate it as a "cost" of doing business!

5. PRACTICAL EXPERIENCES AND CHALLENGES

In the practical application of the Law, there are many dilemmas, inconsistencies and challenges, of which only the most significant ones are listed below, summarized from the extensive literature in the reference [6]:

- The law imposed new obligations on the authorities and the Commissioner, but left a very short interval of 9 months from the entry into force of the LPDP until its implementation. In the case of GDPR, that interval was 2 years! The Commissioner asked for a postponement of the implementation of the LPDP, but this was not accepted.
- There is still insufficient awareness among people about the importance of personal data, people think that they are not important, that they have nothing to hide, etc. so they themselves in various forms (social networks, street polls, public places and public transport, etc.) give their personal data to others without any need.
- In the course of 2021 alone, more than 200 complaints about the violation of personal data were sent to the Commissioner, and 303 inspections were carried out [6].
- In the period from January 2015 to July 2020, the activities of the public prosecutor's office and the courts related to Art. 146 of the Criminal Code, which refers to the unauthorized collection of personal data. The results show [6] that in 14 of the 66 courts, there were a total of 28 cases related to that article, 4 acquittals, 2 convictions (both conditional), and the other 22 cases were rejected as unfounded, dismissed or suspended. In the same period, the Commissioner submitted 17 criminal reports, but none of them received an epilogue.
- Banks or hotels often ask for an ID card, which, instead of basic identification, is read, printed and placed in some binders without any need, or kept at the reception desk during the guest's stay with the explanation that they are being asked to do so by the Ministry of Interior Affairs. Similarly, during the registration and de-registration of employees, copies of identity cards are requested, in addition to the documents provided by the provisions of the law.
- By-laws did not resolve the issue of video surveillance in open and/or closed spaces (facial recognition technology), nor the use of photos on social networks.
- Within the unified IS in education and IS in health, there is a series of data in the form of a register of pupils/students, their parents or guardians, a register of teachers, etc. as well as an electronic diary system, as well as, patients, doctors, health records, laboratory results, etc. In practice, it happens that information leaks from these systems to the public, which should not be disclosed publicly under any circumstances.
- Companies carry out their activities based on the legal obligation to record the employment relationship, for the purpose of realizing the rights of employees and their family members or for the purpose of realizing the business and legitimate interest of the organization (eg employee references). In this sense, the principles of minimization (collecting only as much data as is necessary, no more and no less) and expediency, ie. that for each of the data there is a clear purpose for which it is collected and processed.
- In practice, there are many cases of abuse of personal data in order to discriminate against sensitive groups, e.g. women for whom, during employment, the employer asks for information that is not of interest to the job, such as information on marital status and family planning, etc.

Practical experiences of the application of personal data protection are illustrated by the example of the company Energoprojekt Entel p.l.c. from Belgrade, whose activity is design, consulting and engineering in the fields of energy, water, telecommunications and environmental protection. The organization has implemented an integrated management system (IMS) with five management standards ([6],[7]) – quality, environmental protection, occupational health and safety, information security and energy management, in accordance with the relevant ISO standards. The organization expanded its ISMS (defined by procedure EN-27P-01) with a special procedure EN-27P-02, which is dedicated to the issue of personal data protection. The subject procedure regulates the analysis (mapping) of personal data (data description, category, basis of processing, storage period, medium/location of storage, transfer to a third party, controller, processor and a more detailed description of the purpose of processing), assessment of the impact on the security of personal data, procedure in the case of endangering the security of personal data, giving and revoking consent to the processing of personal data, obtaining an employee's insight into the personal data that is collected and processed about him/her and deleting personal data. In addition to employees, this procedure

includes the collection and processing of personal data of potential employees (who apply for a job through the organization's website) and suppliers and other business partners.

6. CONCLUSION

The topic related to the protection of personal data is still new in our conditions. It is crucial to take measures of a preventive nature, and not to treat the consequences when problems arise. In practical application, there are many difficulties, considering that many elements are not defined by secondary legislation (use of unified number of citizens, video surveillance outdoors - traffic, parks, and indoors - shopping centers, etc.). The fact is that there is a lot of space for improvement.

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DEFICIENCIES AND ADVANCEMENT IN ORGANIZATIONAL STRATEGIC DECISION-MAKING

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Abstract: *Any organization is susceptible to make misperceptions which may bias own judgment and lead to weak strategic decision. This issue appears to be of a paramount importance for organizations striving excellence where the strategy is to be based on understanding needs of both stakeholders and external environment. Strategic decisions are never simple to make, and they sometimes go wrong due to human shortcomings. The prevalence of biases in company decisions is to some extent a function of habit, training, executive selection or organizational culture. However, biases are highly pervasive owing to human nature which is predominantly resistant to feedback. The paper is aimed to make an inventory of vices that are rather common in organizations of various sectors. At the same time, it proposes actions which are not only based on efforts to limit biases of personnel but also on organizing a decision making process that will confront different biases and restrict their impact.*
Keywords: strategy, excellence, organizational culture, quality

1. INTRODUCTION

Most top managers in companies would agree that skill to define strategy is the attribute of major importance for successful performance of their job. Following such position, a huge number of organizations spend a lot of time and resources in a formal and regular strategic-planning process which results in a series of business reviews with remarkable participation of top manager and his team. However, in real, a substantial minority of them truly accept that such time-consuming process pays off since they regard it to be fraught with politics offering a small amount of ideas. Instead to prepare management team to face strategic challenges ahead or to incite creative thinking about the vision of the organization or the route the organization is heading, the planning process frequently appears to be a mere ritual where no one is exactly sure why it is conducted but still nurturing a sort of mystical hope that something good will come out of it, [1].
Large organizations predominantly tend to separate operative work from strategic thinking ("hands" from "minds"). By doing so, they often sever the vital feedback between the two. For example, the person from the organization who identifies the customer with unmet need may gain the most strategic information in the whole organization. However, such information becomes useless if he is not in position to create a strategy in response or he cannot convey information to the person who is in such position or such transfer is meaningless since the response has already been formulated. [2]. Therefore, real strategies are rarely developed in paneled conference room. They are more likely to be cooked up in informal situations like: casual working groups, conversations in lobbies or even own reflections.

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2. STRATEGIC DECISION-MAKING: DISTORTIONS AND DECEPTIONS IN ORGANIZATIONAL SETTING

Whichever approach in strategy defining an organization inclines to, the organization is vulnerable to misconceptions and biases. The prevalence of biases in brought decisions is partly a function of habit, training, selection of managers, and organizational culture. But most fundamentally, biases are pervasive because they are a product of human nature – hard-wired and highly resistant to feedback, [3]. A group of wide-spread biases are cognitive biases we all possess as human beings. This sort of biases distort the way humans collect and process information and they may arise from interactions in organizational settings where judgement may be influenced by proper interest leading humans to commit (un)concious deceptions. One of frequent distorsion is overoptimism where people build their high expectation on something vague or unknown, what may result in underestimating technical chalenges in large projects or total time to complete them. However, humans that experienced losses more than gains in the past are susceptible to loss aversion which lead them to rather be inactive than to face even acceptable risks. Such an distortion have effects in scarcity of investment projects. Finally a distortion that is usually met among ambitious people is their overconfidence where excessive goal focus pulls to underestimation of challanges.

Also, strategic decisions made within an organizations result from interactions among senior executives. Usually, a manager proposes a decision (for some investment) and an executive committtee makes evaluation. In such an array, a conflict of interest between the manager, acting as an »agent«, and the organization (»principal«) on behaf of which he acts, may arise. Principally, this problem takes place when agent's intentions are not quite aligned with the interest of the organization what leads to intentional deceptions – conveying misleading information to other actors. When organizations make review and evaluation of proposed strategic decisions, three main conditions generating »agency problem« are encountered. One is the misalignment of time horizon between individuals and organizations where individuals are focused solely for time period for their curent position within organizational setting. Conflict of interest is avoided only if both parties are happy with short term impact.

Another problem that may result in harmful deception appears when career risks are perceived by individual and organization in different way. Very often managers are reluctant to risky project if they consider that if the project fails it wil ruin their reputation and have adverse effect to their future career. In such an consideration they rather incline not to propose an attractive investment (for the organization) particularly in situation when no penalty is expected for such an omission. The asymmetry between results based on action and inaction is refered to as »omission bias« which explains loss aversion behavior of managers.

Third sort of agency problem is encountered in situations where a subordinate is significantly more competent than his superior for a certain issue. Consquently, the manager doesn't make judgement on the ground of proposal merits but rather putting trust in the person (subordinate) who promotes it. At first glance, it is quite natural when managers believe to his closest associates. However, this leads to the tendency where the decision is grounded too much on a subordinates reputation, what in turn increases susceptibility to deception. This type of deception is known as the »champion bias«.

Almost opposite problem, but also grounded on exessive trust, may be encountered in large organization with authoritarian leadership. It is called »sunflower management« and denotes the inclination of people in organization to align themselves with leader's announced or even assumed viewpoint. If the readiness to pursue lider's decision is not based on personal attitudes but on pure obedience and supression of proper opinion the decision will be brouht under deception.

3. MANAGER'S FLAWS IN STRATEGIC DECISION-MAKING

Majority of top managers are reluctant to spend time on developing strategy for own organization. Out of many two reasons may be highlighted. First they see this job rather difficult in spite of the fact that most successful strategies have been created and led by pragmatic leaders who are capable

to consider alternative futures for their organizations, top managers are predominantly insecure on proper capability to generate credible and sustainable strategy. The other reason lies in perception that strategy development shall be in fade of their daily and most pressing issues. However, such attitude is not caused by personal misperception and shall be regarded rather as the result how the strategy is managed and developed in many organizations.

At the same time, classic term "strategic planning" should cover activities aimed to create opportunities for future organization growth. However, many have thought of endless form filling, request for additional information and fight to protect own budgets. Under a planning-led system top management team tends to initiate process with pre-defined growth that shall be attained in a certain period of future. Such process is usually led by finance department and performance trends are defined in terms of current trends with minor fluctuations. In such an approach top management discussions are limited to detailed budgetary issues. On the other hand, a strategy-led approach starts with a question what kind of business an organization is striving. The focus is on clarifications which are the best ways to win in the future and to determine what organization structure and size will be adequate to make it happen. Only upon such an alignment it is possible to determine key steps that will enable organization to move from the current position to the strategic future.

Generally, strategic planning and developing strategy approach are distinctly different. While strategy development is trying to find ways how to win on chosen market, planning seeks to identify best ways to achieve defined objectives within defined resource constraints. Planning requires a predefined timetable for proper allocation of resources, while strategy responds to the market issues and opportunities once they emerge. When metrics is concerned, planning deals with profit and loss, cash-flow budget and market share projections, whereas strategy development pays attention to innovation, customer satisfaction, brand strength etc. Finally, annual planning requires a central planning team, while strategy development needs the active involvement of business leaders. Therefore, to safeguard strategy development and increase chance for new opportunities an organization shall separate strategy development from annual planning process.

Planning-led approach provides incremental gains to an organization. However, if the changeover to strategy-led approach is conducted the success of such process will not be certain unless mindset of top managers is changed. Fleeing from risk to be wrong or even to be seen wrong in decision-making immobilizes top managers to propose some radical solutions that are directed to change existing business model or current strategy. The shift in mindset shall include declining from mere profit targets and moving towards a long-term goal that drive to new thinking and higher commitment to organizational ongoing success. The key issue for a top manager in setting goals is to be successful in suppressing ego and to have clear understanding on what are feasible options for the company once the top management team conducts necessary strategic and organization changes.

To be successful in strategic-led approach one should refrain from putting financial issues ahead of ideas due to the fact that developing business strategy relies on creativity and idea generation to higher extent than it is driven by analysis. Most business development successes emerged from small groups or individuals who possessed a strong will to change surrounding in some way. So far many books on business strategy have put stress on application of analytical methods and tools. No doubt that a certain level of analysis is inevitable to make business strategy successful. However, in the absence of fresh the efforts will result in very good understanding of the position an organization currently has on the market but with no guidelines how to drive new profitable growth in future. The table of comparison between analytical and creative approaches to strategy is given on Table 1, [4].

Many managers, even on senior level, do not feel the distinction between a vision and a strategy. Sometimes it is expected that once a vision defined it is a routine work to set out a strategy growth. Such expectations are ungrounded since a vision can merely inspire executives and employees but in fact the vision can not provide supportive information on where to focus their efforts in order to make your strategy embedded across the organization. In that regard, vision shall be understood as an inspirational overarching long term goal of an organization whereas strategy represents a

framework for directing decisions and actions across the organization to provide superior performance of the organization and the vision accomplishment.
Omission of top management to determine which are the key issues for an organization and which ones are of lower importance is the frequent reason for strategy failure. Once an organization fails to make proactive trade-offs it is quite unlikely that it will have a winning strategy or attain a leading position on the market. Very often top managers rely on competitive benchmarking excessively what results in trials to become a (pale) imitation of the leading organization on a particular market. The problem for such (imitating) organization lies in the fact that only market leaders can occupy the biggest part of customer's attention thus it is unlikely that new aspirants will be noticed addressing to the market in a repeated way. In other words, an organization should head in a way to identify what characteristics make it distinctive in its business environment, to ascertain whether there is something unique that would immediately be noticed by customers and last, but not least, to what extent the proposed business model will be difficult to be copied by rivals.

Table 1. Analytical vs. Creative Approaches to Strategy
Source: [4]

Analytical approaches	**Creative Approaches**
Focus on analysis of markets and performance	Focus on new ideas
Desktop assessments	Real-life experience
Follower	Leader
Problem solving	Innovation
What's happening	What if?
Dealing with the past	Focused on the future
Financial proof before action	Action before financial proof
Forecasts and long-term plans	Rapid learning action plans
Strategy teams staffed with analytical experts	*Ad hoc* strategy teams staffed with a mix of "thinkers" and "doers"

During strategy implementation almost no strategy can remain unchanged. By pursuing main organization objectives, implementing initial plans and taking actions, it is quite likely that some direction changes will take place. The results from the actions, as a feedback, will drive the strategy and rectify the way of future organization success. This is the core of Action-based Approach. In Traditional Approach many assumptions are made at planning stage and the plans are implemented regardless the assumptions were confirmed while in Action–based Approach a permanent trial-and-error and learning process yields opportunity for continuous strategy correction. Traditional Approach includes planning how to plan for months, whereas Action-based Approach means - act from day one, [5].

4. STRATEGY ISSUES IN ORGANIZATIONS PURSUING EXCELLENCE

Vision and mission in excellent organizations are implemented by developing a stakeholder focused strategy. Strategy is based on understanding both of needs and expectation of organization stakeholders, and internal performance and capabilities of organization. In gathering stakeholders' needs and expectation for the development of their strategy an organization striving excellence remains constantly alert to any changes. They also identify, understand and anticipate threats and opportunities based feedback from stakeholders and other external sources. To better define position in market environment they compare their performance with relevant benchmarks to understand own strength among competitors and areas for improvements, [6]. Such approach in excellent organizations principally reduces their vulnerability to misconceptions and biases, and particularly reduces susceptibility to deceptions due to intensive interrelation with key organization stakeholders.

Strategy and policies established for strategy implementation are regularly reviewed and updated. Organizations tending excellence identify and introduce key results to evaluate accomplished progress towards the vision and strategic goals. They also adopt mechanisms to create future scenarios on market and to manage organizational strategic risk. These mechanisms significantly contribute that risk aversion of their top managers is diminished. Regular keeping track of key results and key performance indicators enable such organization to identify advantages of its rivals thus to learn about the areas where the organization might excel, i.e. items that are supposed to draw significant customer attention that will result in future leading position of the organization on the market, [7].

Regular monitoring of business environment landscape furnishes relevant information to conduct analysis and understand external indicators and timely feedback from stakeholders thus creating a ground to establish a cycle of idea generation – action, learning and refinement. The critical aspect in this cycle is to learn as quickly as possible. It means that the ability of an organization pursuing excellence to generate its competitive advantage is directly proportional to its capacity to operate this cycle faster, more efficiently and more effectively.

5. BETTERMENT IN DECISION-MAKING PROCESS

Being aware of the fact that human nature may lead to some hardly explained decision, wise leaders in ambitious organizations will fortify their judgment when making important decisions. To cope successfully with this problem, they have to identify which sort of bias is most likely to affect decision. Predominantly large organizations suffer from excessive optimism, whereas excessive risk aversion is inherent to small organization where the decision-makers fear for potential losses to a higher extent.

Leaders in organizations play crucial role both in identification of prevalent biases and in use of adequate tools to create productive decision-making culture. At first place, they should consider which decisions are really strategic and where they are made. After targeting the crucial decision making processes, leaders shall examine them with two objectives: determining susceptibility of organization to human error and real problem assertion. It should be taken into account that a decision-making safeguard that appears useful in one setting may be counter productive in another.

Once an organization tackles the diagnostic process, it can introduce tools that limit risk of distortions and deceptions. To temper optimism it is useful to track the expectation of individuals against actual outcomes in order to examine process that support strategic decision. Once forecasts and results show strong departure, the organization shall review these processes.

Another way of avoiding overoptimistic decision is to provide an additional assessment from independent second source. It is usually done by assigning important decisions to committees. However, the effectiveness of such approach depends on willingness of committee members to challenge proposals and on validity of facts that are in front of them.

Loss aversion along with career induced self-censorship find roots in explicit and implicit organizational censorship. Regularly, lower-level managers are typically faced with more but smaller risks. To mitigate the problem, an organization can embed higher tolerance for them, for instance by using different criteria for the financial analysis of larger and smaller projects. Another technique is to request from managers that their investment recommendation include alternatives (second and third option). The approach yields two benefits: organization may calibrate the manager's risk aversion level and uncovers opportunities that a manager might consider insufficiently safe to present, [8].

Another approach to solve distortion and deception problem lies in fostering a culture of open debate within an organization. It should be noted that ultimate effectiveness is proportional to quality of the resulting discussions, and they may be effective only if organization already has a culture of open and objective debate. It is commendable to initiate constructive debate among top

manager and management team in order to reflect collectively on past decisions. A willingness to ask how the decisions emerged demonstrates that the organization is able to learn from mistakes.
Once it is decided that a group will be the decision-maker, the key prerequisite for good strategic decision-making is to "frame" conversation thus to ensure that right questions and answers are on the table. When a meeting has been called to reach a decision, framing the discussion includes understanding the criteria to reach it and being aware to what extent options can be expanded, particularly when the decision is important and unusual. In this way, a well-framed debate includes a set of proposed criteria for making the decision and, if applicable, an effort to demonstrate their relevance though examples and analogies.

6. CONCLUSION

Organizations that are deliberate to pursue successful strategy shall not lose from sight the influence of human factor in the process of making strategic decisions. Such organizations can greatly enhance their chances to make right decisions by raising awareness of the way cognitive biases can mislead them, by performing review of their decision-making processes and last, but not least by nurturing the culture of open and objective debate.

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CIVIL PROTECTION MANAGEMENT MODEL AT THE LOCAL GOVERNMENT LEVEL

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Abstract: *Resilience to crisis situations is built at the local level of the civil protection system. In the Republic of Croatia, 127 cities and 428 municipalities participate in the civil protection system at the local level, which represents many participants who have the obligation to develop capacities for prevention, preparedness, and response to crisis situations. Bearing in mind the available capacities and especially the crisis situation caused by the COVID-19 pandemic and the mitigation of the consequences of the earthquake in Zagreb, Sisak-Moslavina, Zagreb, Karlovac, and Krapina-Zagorje counties, local government units cannot carry out their duties independently. The existing Civil Protection System Act prescribes numerous obligations (prevention, planning, operational, financial) for local government units, and it is obvious that local government is faced with great challenges. The aim of the paper is to present a new civil protection management model that is based on research conducted with the purpose of collecting data from the level of local government units on the topic of the civil protection system. The civil protection model should be based on three main elements: citizens, operational forces, and local administration, and focuses on citizen education, prevention, and the development of a safety culture.*
Keywords: civil protection, local government, management.

1. INTRODUCTION REMARKS

Civil protection in the Republic of Croatia, as well as in other countries of Europe and around the world, represents the most complex subsystem of national security and connects together the planning, prevention, and operational capacities of a large number of participants from the national, regional, and local levels. The experience of the member states of the European Union shows the need to build risk management capabilities, develop a system of early warning and preventive action, and propose and implement risk reduction measures to avoid new risks and especially reduce existing ones. The civil protection system in the Republic of Croatia is organized on three levels (state, regional - counties and the City of Zagreb, and local including cities and municipalities). Cities and municipalities are obliged by the Civil Protection System Act to participate in the implementation of civil protection measures and activities, but in this process, they face numerous challenges (personnel, organizational, financial, etc.). Civil protection tasks represent the important obligation of local government that is also prescribed by the Constitution.

In 2022, the University of Applied Sciences Velika Gorica conducted research entitled "Civil protection in the local community". The goal of the research was to collect data on the challenges faced by local government units in the civil protection system and to propose improvements to the legislative framework and guidelines for the development of the civil protection system at the local level. The research technique used was an online questionnaire with 17 questions that were grouped by thematic areas (planning, preparedness, operations, and development). Out of 555 local self-government units (127 cities and 428 municipalities), 110 units filled out the questionnaire, which represents about 20 percent of the respondents. This tells us that the local government want to be an

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active participant in the process of revising the civil protection system and emphasis the problems they are facing and to propose improvements to make civil protection at the local level even better and more efficient.
The results of the research offered a basis for creating new proposals for the improvement of the civil protection system. The civil protection management model, which is presented in this paper, represents one of the proposals based on the conducted research, which aims to improve and connect all available capacities for civil protection management at the local level.
The main hypothesis of this paper is that all crisis situations begin and finish at the local level of the civil protection system.

2. BEST PRACTICES OF THE CIVIL PROTECTION SYSTEM

The civil protection system should be determined on clear and acceptable principles, agreeing with the political system, the material possibilities of the state and local communities, and the real needs to respond to existing and possible risks from sources that have the consequences of a crisis situation [1]. Civil protection is an important element of the national security system for action in crisis situations. The civil protection system in the Republic of Croatia is regulated by the Civil Protection System Act. The Act defines all segments of the system (participants, operational forces and citizens) with the aim of protecting and rescuing people, animals, cultural assets and the environment in major accidents and disasters.
The greatest advantage of the civil protection system, compared to other components of national/homeland security, is that it provides a coordination platform for the inclusion of all necessary participants throughout the country, and has the great advantage that it operates at all levels (state, regional and local). This enables all participants and operational forces to coordinate the implementation of civil protection measures (i.e. search and rescue, shelter, first aid, etc.) and other activities in crisis situations.
Organization of the civil protection system is based on risks that pose significant threats to the population, property, and environment. The principles of the civil protection system are humanity, prohibition of discrimination, sustainable development, solidarity, subsidiarity, and continuity of action. Subsidiarity principle is important to have in mind at the local level. It described the way to activate the system from the lowest to the highest hierarchical level by making decisions and implementing civil protection measures and activities by engaging a higher level, only when all the available resources of the lower level are exhausted. The first response to crisis situations occurs precisely at the local level with all available operational capacities (firefighters, police, emergency medical service, Red Cross, civil protection units, etc.) [3].
Civil protection headquarters play a very important role in the civil protection system as a professional, operational, and coordinating body for the implementation of civil protection measures and activities in crisis situations. The civil protection headquarters is established at all levels of the system (state, regional, and local) and manages the response of the civil protection system to crisis situations in its area. Civil protection headquarters of municipalities and cities in crisis situations are the first to be activated and start implementing the necessary measures and activities with the aim of mitigating the consequences of a specific crisis situation.
The mayor (city-level) and head (municipality level) play a very important role as the primary responders for the civil protection system in their area of responsibility. According to the Civil Protection System Act, the mayor and head of the municipality are required to undergo training within six months of assuming office and familiarize themselves with their rights and obligations in crisis situations [3].

3. MAIN CHALLENGES AND OPPORTUNITIES

In order to facilitate and operationally speed up the operation of the civil protection system, certain powers and responsibilities of administrative structures at the national level in most countries are

dispersed to local government, while respecting the specificities of the area covered by each local government, i.e. it is necessary to create an analysis of real threats which are characteristic of that local community [2].

Analysis and research play a crucial role in understanding complex systems like civil protection. Thorough analysis and research we can understand the nature, scope, and potential impact of the crisis. This understanding is fundamental in formulating an effective development strategy to implement best practices for the civil protection system.

Research conducted in 2022 by the University of Applied Sciences of Velika Gorica has shown that the biggest challenge at the local level is the lack of professional staff and the big obligations in the part of creating planning documents. 60% of those surveyed believe that the area of preparation of planning documents should be revised, that is, the obligations of local government should be reduced in that area. The challenge of lack of financial resources, as well as citizens' lack of interest in the issue of civil protection, is always relevant. Opportunity for development, except through the support of the state and the county through budget funds (30% of respondents), as many as 26.4 respondents believe that connecting with neighboring local government can improve civil protection capacities at the local level.

It is interesting feedback that in the part of investment in operational capacities, in addition to firefighting capacities, the largest investments should be made for the development of capacities for managing crisis situations (technical-tactical support) in the field.

Research has also identified the following areas for improvement:

- Reduce the burden on the level of local government in the part of obligations to prepare planning documents.
- Conduct trainings for the preparation of planning documents.
- Digitization of planning documents, application of documents in trainings, exercises, and real situations.
- Education of children through compulsory teaching programs in schools.
- Emphasize the creation of digital platforms for information management.
- Further investment is required: digital innovation for early warning systems, creation of strategic documents, education, and infrastructure.

Implementing above mentioned areas will enable local governments to make informed and better decisions, allocate resources wisely, communicate effectively (both internally and externally), and continuously improve their resilience, ultimately enhancing their ability to mitigate the impact of crises.

4. LOCAL MANAGEMENT MODEL 3x3

A simple and effective management model that covers various stages of the civil protection system: planning, prevention, preparedness, response, and recovery, is a must for local government. The model should be based on principles, priorities, and values that will ensure the implementation of civil protection activities at local level. We need to keep in mind that the model should be implemented to 555 local management units and therefore it should be developed like a “toolbox” where the local government will pick and implement solutions that are relevant for them, having in mind topography, demography, history aspect, identified threats, etc.

4.1. Cornerstones of management model

Three *cornerstones* of the management model are identified principles, priorities, and values of the civil protection. For each, three actions are identified as most relevant:

Principles

- *Flexibility*: refers to the ability of civil protection systems to adapt and respond effectively to a wide range of crisis situations. Given the unpredictable nature of the crisis, having flexible plans and frameworks in place is crucial for a successful response.
- *Self-sufficiency*: capacity of the necessary material and technical means (personal and collective equipment, including vehicles, water, food, etc.) with which the local level operates independently

at the location of the intervention in the response with the aim of achieving continuity of action and to have, as least possible, logistical requirements to regional and/or national civil protection authority.
- "*Light and fast*": refers to a strategy in crisis response that emphasizes swift, agile, and efficient actions to quickly provide aid and support to affected communities. This approach is particularly important in the initial stages of a crisis when rapid response on the local level can save lives and reduce the impact of the crisis.

Priorities
- *Prevention*: refers to the actions implemented to avoid or minimize the negative impacts of potential crises or disasters. It involves identifying potential risks, vulnerabilities, and hazards and taking proactive measures to mitigate these risks.
- *Education and exercises*: educate the public and operational forces about potential risks and how to prepare for crisis situations. This includes school programs, public service announcements, and community workshops. It is necessary to conduct regular exercises to ensure that the population and operations forces know what to do in case of the crisis situation.
- *New technologies*: digital solutions can facilitate and speed up the decision-making process in crisis situations through the establishment of interactive databases on risks and operational forces, modern early warning systems, and tools for reviewing the situation on the ground in real-time.

Values
- *Knowledge*: expertise and skill of methods for involving communities in crisis preparedness, response, and recovery efforts. Building community resilience through education, awareness, and participation.
- *Partnership*: essential for creating a collaborative and coordinated approach to crisis preparedness, response, and recovery. These partnerships involve various stakeholders, including local administration, operational forces, and citizens, working together to enhance the overall resilience of communities.
- *Trust:* crucial for ensuring the effectiveness of civil protection efforts and maintaining the well-being of communities during crises. Trust fosters cooperation and encourages compliance with directives and promotes a sense of safety in the public from actions taken by local administration and operational forces.

4.2. Main stakeholders of management model

In the context of civil protection, various stakeholders are involved to ensure the safety and well-being of communities during crisis situations. The main stakeholders of civil protection at the local level are local administration, operational forces, and citizens. For each, three actions are identified as most relevant:

Local administration
- *Infrastructure:* essential for responding to crisis situations effectively are local operations centre, communication systems, fire stations and firefighting/rescue equipment, police station, and medical facility, shelters, warehouses, and training facilities.
- *Early warning system:* establish systems that can provide early warnings to the population. This could be through sirens, text alerts, social media, or other communication channels that will provide in the fast way alerts and instructions to the population.
- *Legal persons:* who have the capacity to quickly and efficiently provide accommodation services (hotels and schools), transport in case of evacuation (transport companies), water and food (restaurants and hotels), sanitary support, and other types of services for the affected population.

Operational forces
- *Digital database*: A robust but single system to manage and organize critical information about risks, resources, and their capabilities. Such a database can significantly enhance the efficiency of civil protection activities and support decision-making process.

- *Single communication system:* involves integrating various communication technologies and channels into a unified platform. Such a system aims to facilitate communication and coordination among operational forces (firefighters, police, emergency medical service, civil protection units, Red Cross, etc.) involved in civil protection activities.
- *Modular equipment:* refers to an approach where equipment and vehicles are designed in a modular fashion, allowing them to be compatible and easily assembled, disassembled, replaced, or upgraded based on specific requirements or changing needs during civil protection operations.

Citizens

- *Safety culture:* collective awareness, attitudes, and behaviours of citizens within a community regarding safety measures and practices. A strong safety culture among citizens is essential for building resilient communities and mitigating the risks associated with the local community.
- *Vulnerable groups:* individuals or communities that are at higher risk during crisis situations due to various factors such as age, disability, socioeconomic status, health conditions, or limited access to resources and information. It is crucial to identify and address the specific needs of these groups to ensure their safety and well-being during crisis situations.
- *Commissioners of civil protection*: operate in their area (street, neighborhood, etc.) in preparing citizens for personal and mutual protection, provide information to citizens about the timely undertaking of civil protection measures, participate in the organization and implementation of evacuation, shelter, disposal, organize protection and rescue of members of vulnerable groups [3].

Effective collaboration and communication among these stakeholders are essential for a coordinated and efficient civil protection system at the local level. Each stakeholder group contributes with unique expertise and resources to ensure the safety and resilience in the crisis situations. Within the local administration office is necessary to have at least one employed person/expert that will cover the portfolio of civil protection that could be combined with wide security aspects like environmental protection, local infrastructure, urban security, etc.

Management model 3x3 that is appropriate for certain local administration units should be defined in detail in the local Civil Protection Response Plan that is adopted by the local administration council, and it is obligations defined by the Civil Protection Act.

5. CONCLUSION

The civil protection system ensures the implementation of measures and activities in complex crisis situations of interest to national security. The civil protection system should be flexible, logistically self-sufficient at the local level, the capacities of civil protection units should be strengthened. It is necessary to better define the role of legal entities/private companies from the local level that have capacities for transportation, nutrition, accommodation, sanitary support, etc., which proved to be crucial in caring for people during crisis situations. Further research can offer an objective picture of the current situation of civil protection and their results should be taken into account when thinking about improving the civil protection system. The paper confirmed the main hypothesis.

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ARTIFICIAL INTELLIGENCE AS SUPPORT FOR QUALITY 4.0: A REVIEW OF CURRENT APPLICATIONS AND FUTURE DIRECTIONS

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Abstract: *Quality 4.0 is a paradigm that focuses on the integration of advanced digital technologies, including Artificial Intelligence (AI), into quality management systems. AI has the potential to improve product quality, reduce defects, and optimize production processes. This paper provides a comprehensive review of the current applications of AI in Quality 4.0, including predictive maintenance, quality control, and data analysis. It also discusses future directions for the use of AI in quality management, such as the integration of AI with the Internet of Things (IoT) and blockchain technologies. This paper reviews the current applications of AI in Quality 4.0 and discusses future directions for research and development.*
Keywords: Quality 4.0, AI, Predictive Maintenance, Quality Control and Data Analysis.

1. INTRODUCTION

The journey of digital transformation has led us from Quality 1.0 to Quality 4.0 (Figure 1.). With each phase, advancements in technology have revolutionized quality management. From manual processes and inspection in Quality 1.0 to the integration of AI, IoT, and blockchain in Quality 4.0, organizations now have the tools to optimize quality, achieve operational excellence, and thrive in the era of the fourth industrial revolution [4,11,21].

Quality 4.0 is a transformative paradigm that emphasizes the incorporation of advanced digital technologies, particularly AI, into quality management systems. This paper presents a comprehensive review of the current applications of AI within Quality 4.0, highlighting its potential to enhance product quality, minimize defects, and optimize production processes [2,6]. Additionally, it explores future directions for leveraging AI in quality management, such as integrating AI with the IoT and blockchain technologies [20].

In the era of Industry 4.0, organizations across various industries are actively seeking innovative approaches to optimize their operations and improve product quality. Quality 4.0 emerges as a promising paradigm, leveraging advanced digital technologies to revolutionize quality management systems [3]. Among these technologies, AI stands out as a transformative force with its ability to analyze vast amounts of data, extract meaningful insights, and facilitate intelligent decision-making [8].

This paper explores the current applications of AI in Quality 4.0, highlighting its potential to drive advancements in predictive maintenance, quality control, and data analysis. Moreover, it delves into the future directions for AI in quality management, envisioning the integration of AI with the IoT and blockchain technologies.

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Figure 1. Digital transformation from Quality 1.0 to Quality 4.0
Source: [21]

2. RESEARCH METHODOLOGY

This research aims to provide a comprehensive review of the current applications of AI in Quality 4.0 and discuss future directions for research and development. To achieve this objective, the following research methodology is utilized:

- Literature Review
- Data Collection
- Analysis and Synthesis
- Future Directions

It is important to note that this research is based on a comprehensive review of existing literature and does not involve primary data collection or empirical studies. The primary focus is to synthesize and present the current state of AI applications in Quality 4.0 and provide insights for future research and development in this field.

2.1. Literature Review

A systematic and extensive review of existing literature is conducted to gather relevant information on the current applications of AI in Quality 4.0. This involves searching scholarly databases, journals, conference proceedings, and relevant industry reports to identify studies, articles, and case studies that focus on AI in quality management systems.

2.2. Data Collection

The collected literature is analyzed and synthesized to extract key findings, applications, and insights regarding the integration of AI in Quality 4.0. The data collection process involves extracting relevant information such as the types of AI technologies used, their application areas (e.g., predictive maintenance, quality control, data analysis), and the benefits and challenges associated with their implementation.

2.3. Analysis and Synthesis

The collected data are analyzed and synthesized to identify patterns, trends, and common themes related to the current applications of AI in Quality 4.0. This analysis will help in understanding the impact of AI on product quality improvement, defect reduction, and production process optimization.

2.4. Future Directions

In addition to reviewing the current state of AI applications in Quality 4.0, this research explores future directions and potential areas of research and development. This involves identifying emerging technologies, such as the integration of AI with the IoT and blockchain, and discussing their potential implications for quality management systems.

3. KEY FINDINGS

This study provides a comprehensive review of the current applications of AI in Quality 4.0 and also highlights the need for further research and development in this field. Also, the study summarizes the key findings derived from the review and outlines the implications for future research and development.

3.1 Improved Product Quality

AI plays a crucial role in augmenting product quality within Quality 4.0. Through advanced analytics and machine learning algorithms, AI enables proactive defect detection, early identification of quality issues, and real-time quality monitoring. By harnessing AI's capabilities, organizations can achieve higher levels of precision, consistency, and reliability in their products [13,16,18].

3.2 Defect Reduction

AI empowers quality control efforts by automating and streamlining defect detection processes. It can analyze vast amounts of data, identifying patterns and anomalies that may indicate potential defects. With AI-driven quality control systems, organizations can proactively identify and rectify defects, minimizing rework, waste, and production disruptions [10,14].

3.3 Optimized Production Processes

AI's integration into Quality 4.0 enables the optimization of production processes. Machine learning algorithms can analyze historical production data, identifying opportunities for process improvement, efficiency enhancement, and waste reduction [9]. By leveraging AI, organizations can achieve leaner, more agile manufacturing processes, leading to cost savings and improved productivity [15,19].

3.4 Predictive Maintenance

AI is a powerful tool for predictive maintenance, which involves monitoring and predicting the maintenance needs of equipment and machinery. By analyzing sensor data, performance indicators, and historical patterns, AI can anticipate equipment failures, allowing for timely maintenance interventions. This proactive approach reduces unplanned downtime, extends equipment lifespan, and enhances overall operational efficiency [11,14,17].

3.5 Data Analysis and Insights

AI enhances data analysis capabilities within Quality 4.0. Through sophisticated algorithms, AI can extract valuable insights from vast amounts of structured and unstructured data, enabling

organizations to make data-driven decisions and quality control (Figure 2.). By leveraging AI-powered analytics, organizations can uncover hidden patterns, detect emerging trends, and identify areas for continuous improvement [5,7,10].

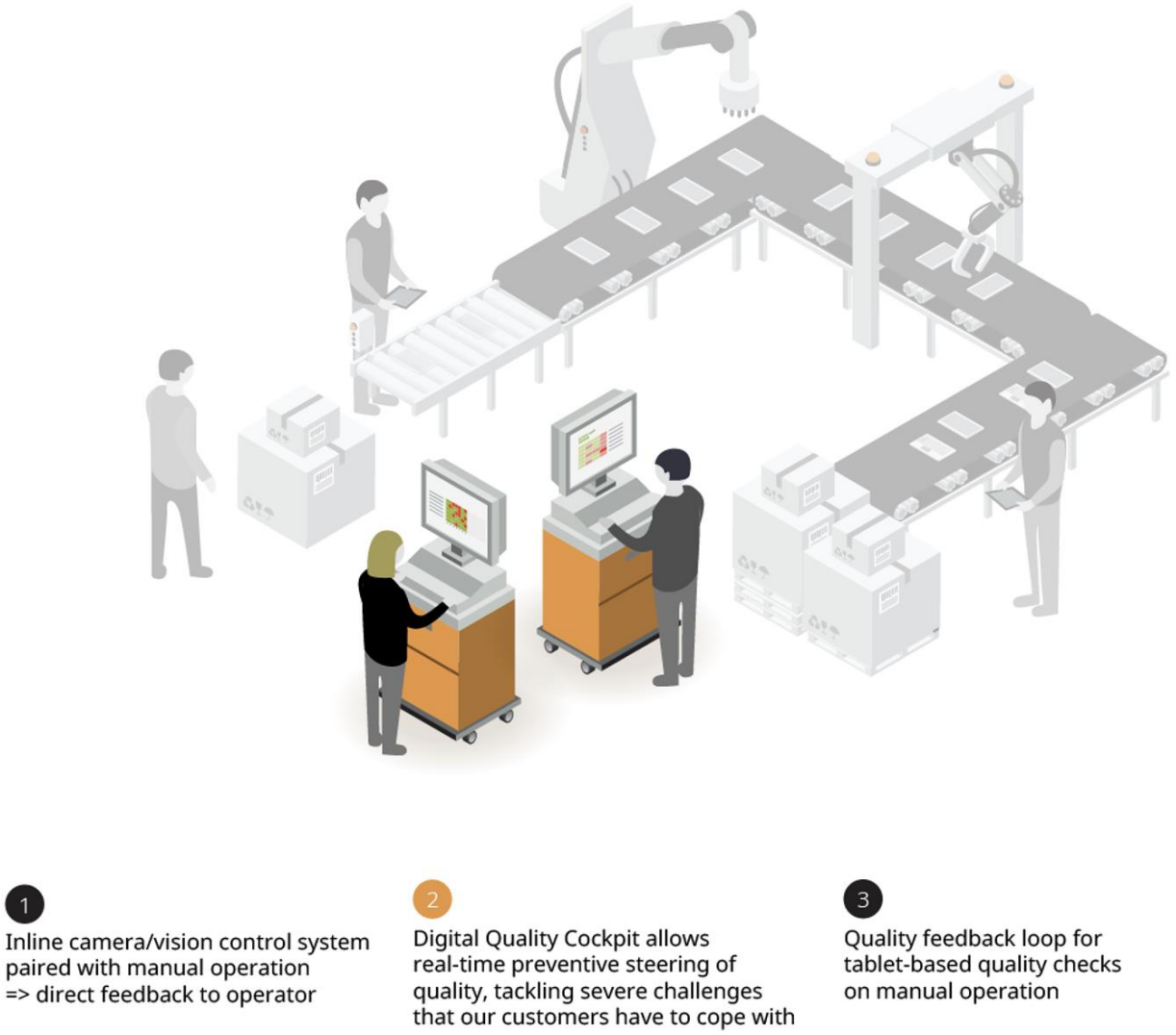

Figure 2. Quality control tower application interfaces
Source: [10]

4. DISCUTIONS AND FUTURE RESEARCH DIRECTIONS

The integration of AI with the IoT is a promising future research direction for AI in quality management. By connecting AI systems with IoT devices and sensors, organizations can leverage real-time data streams to improve quality control, enable predictive maintenance, and enhance decision-making processes.

Another future direction is the integration of AI with blockchain technology. Blockchain has the potential to enhance transparency, traceability, and trust within quality management systems. By utilizing the distributed ledger of blockchain, organizations can ensure immutable records of product quality, facilitate transparency across the supply chain, and streamline recalls, audits, and compliance procedures.

However, it is important to note the limitations of this study. The scope was limited by the databases examined, and the analysis focused only on English publications, excluding articles published in other languages. Future research should consider a broader range of databases and languages to provide a more comprehensive understanding of the topic.

The findings of this study offer valuable insights for organizations looking to harness the potential of Quality 4.0. By effectively implementing Quality 4.0 strategies based on these insights, organizations can align with their strategic objectives and gain a competitive advantage in the market. The incorporation of advanced digital technologies, particularly AI, into quality management systems is a key aspect of Quality 4.0, offering opportunities to enhance product quality, reduce defects, and optimize production processes.
So, the future directions for AI in quality management involve further exploration of its integration with emerging technologies such as the IoT and blockchain. This will enable organizations to unlock new levels of efficiency, transparency, and quality in their operations.

5. CONCLUSION

AI plays a crucial role in the realization of Quality 4.0, providing organizations with the capability to optimize their quality management processes and achieve exceptional product quality. The current applications of AI, including predictive maintenance, quality control, and data analysis, have already demonstrated their potential in driving substantial improvements. Looking towards the future, the integration of AI with the IoT and blockchain technologies, along with the emergence of autonomous quality management systems, holds immense promise for revolutionizing quality management practices [1, 3, 12]. As organizations embrace these advancements, they position themselves at the forefront of innovation, enabling them to adapt and thrive in the dynamic landscape of the fourth industrial revolution. Therefore, this study holds significant importance as it pioneers the examination of the impact of Quality 4.0 on organizational performance, achieved through the utilization of an integrative literature review.

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ADULT EDUCATION IN SERBIA AND COUNTRIES OF THE REGION

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Abstract: *Adult education is not new practice in education, but under the influence of contemporary environment it has gained importance over the last years. It prepares individuals for present and future jobs and roles in the society; has positive effect on health and well-being; reduces differences and diversities*; *improves productivity, innovation and creativity; raises the awareness about the importance of democracy; and it is necessary for implementation of national and international policies. Based on this importance, the paper explores the state of adult education in Sebia and countries of the region. Statistical data were collected from national sources of mentioned countries, as well as from European sources. By applying descriptive statistics actual situation is systematically presented. The findings could be interesting for individuals, educators, policy makers and present and future studies.*
Keywords: Adult Learning, Statistical Data, Croatia, Slovenia, Montenegro, North Macedonia

1. INTRODUCTION

Globalization, technological developments and demographic change have caused numerous challenges in the lives of individuals, organizations, governments and society. The ‘’new’’ context of working and living has required transformations in the way people work, new approaches to utilization of talents and diversity, better social protection for workers, update education, investments in workforce through training and learning [1, 2]. For these issues one thing is common – the necessity of continual ‘’adult skilling, reskilling and upskilling throughout person`s career’’ [3, pp.1]. In addition to previous, contemporary findings refer to the following: globally, 60% of the total employees were in informal employment in 2019 [5]; in 2020, 7.2% of workers lived in extreme poverty [5]; 1.3 billion people are overeducated or undereducated, and by 2030 this number will be increased to 1.4 billion [4]; 203 million persons have been unemployed in 2023 [5]; great number of organizations recognize the skills gap as the main barrier to business transformation, as well as the 44% of workers` core skills will be changed in the next five years [6]; ‘’600 million new jobs need to be created by 2030’’ [7]; differences have still existed in employment rate by gender, age and education level [6]; inflation and cost-of-living crisis have affected the most vulnerable groups [6]; the fastest growing jobs are technology-related roles, while the ‘’fastest declining roles are clerical or secretarial roles’’ [6].

Based on the previous data, it is clear that current knowledge and skill needs differ from those that will be demanded in the very close future. Besides the other actions, adult education could have a crucial role in overcoming these differences. The main idea of this paper is to present actual situation of adult education in Serbia and countries of the region. This is a review paper and it is based on the descriptive approach. This paper is structured as follows: the first part of the paper is devoted to consideration the concept of adult education and its context in Serbia and countries of the region (Montenegro, Croatia, North Macedonia and Slovenia). Bosnia and Herzegovina was excluded because the authors could not find statistical data within its national and European sources. The

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second part of the paper presents statistical data on the state of adult education for different demographic groups within the period of last five years. Data were collected from national and European sources and processed by Excel tools. Some data for Montenegro and North Macedonia were not available and it is the main limitation of this study.

2. THEORETICAL BACKGROUND

2.1 Concept and importance of adult education

Adult education (AE) is not a new practice of upgrading competences, but over the last decade it has gained importance. Initial form was related to learning after completing formal education. During the time, different terms were used to describe learning during the person`s life [8]. Nowadays, lifelong learning (LLL) and adult learning (AL) are the terms that are more commonly used. Explanations of LLL and AL have been revised over time [9]. European Commission (2001) defined ''lifelong learning as all learning activities undertaken throughout life, with the aim of improving knowledge, skills and competences within a personal, civic, social and/or employment-related perspective'' [10, pp.3]. ''Adult learning means the participation of adults in lifelong learning. It usually refers to learning activities after the end of initial education and it covers participation in formal and non-formal education and training'' [11]. According to UNESCO ''adult learning and education encompasses formal, non-formal and informal learning and education for a broad spectrum of the adult population. It covers learning and education across the life course and has a special focus on adults and young people who are marginalized or disadvantaged'' [9, pp.28]. By exploring literature there are other institutions and authors who defined AL in very similar way. For the purpose of this paper the authors use the term ''adult education'' that covers all learning activities after the end or after leaving formal education (primary, secondary and tertiary). In this sense, population aged 25-64 was observed. Adult education encompasses various target groups and can differ in terms of objectives, contents, quality and learning outcomes. Furthermore, it can be performed in institutions of formal education, as well as in other institutions and organizations. [12]. Generally, there are three modalities of adult education – formal, non-formal and informal learning [13]. Formal learning occurs in all types of educational institutions and it results in diploma or certificate [12]. Non-formal learning refers to different workshops and trainings that can take place in different organizations and institutions that not belong to formal educational system [12, 14]. Informal learning results from everyday activities, it is not structured [12] and it includes ''learning from others, learning by doing and learning new things at work'' [14]. Globally, adult education has important role because it prepares individuals for present and future transformations in society, economy and the labour market [15]. European Education Area has recognised adult education as strategic priority for the period 2021-2030 [15]. Its significant role is noticeable in the 2030 Agenda for Sustainable Development adopted by the United Nations [16]. Furthermore, the importance of adult education has been recognized by many organisations and institutions worldwide (for example: ILO, OECD, BCG, WEF), as well as numerous institutes and associations of adult education and lifelong learning have been founded. The European Association for the Education of Adults (EAEA) identified adult education as a key instrument in overcoming the challenges facing the EU [17]. In this sense, adult education ''influenced the development of democratic societies in Europe'' (pp. 5), as well as it enhances participation of adults in social activities. Improvement of knowledge, skills, attitudes and behaviours has positive effect on health and well-being. Adult education ensures ''life skills'' (pp. 9) necessary in the 21st century, that provide new opportunities for individuals` careers and lives. Adult education brings people together and intensifies ''social cohesion, equity and equality'' (pp. 11). At organizational level, continual learning improves productivity, innovation and creativity. Acquiring the digital competences is important activity of adult education for today`s society. Migration and demographic change have caused challenges in communication and need for better understanding of different cultures. Adult education helps to close this gap. Finally, ''adult education is necessary to implement most European and international policies'' (pp. 21) [17].

2.2 Context of adult education in Serbia and countries of the region

In the Republic of Serbia adult education has been recognised as a part of unified educational system. There are two forms of adult learning – adult education and short cycle of study. Adult education occurs as formal, non-formal and informal learning, and it can be directed to general, vocational and/professional education. Adults imply to individuals over the 15 years old who have not completed primary education i.e., over the age of 17 who have not completed secondary education and persons over the age of 18 who want to improve their competences [18]. Promoters of adult education can be institutions of primary and secondary education, as well as other organizations within their registered activity. The area of adult education is regulated by the Law on adult education (adopted in 2013) and the Law on National Qualifications Framework in Serbia (adopted in 2018). According to Ministry of Education 453 institutions offer 635 different programmes of adult education [19].
Short cycle of study is organized at tertiary level of education. The main objective is related to acquiring competences for specific job in accordance with the labour market requirements. Short cycle of study is intended for persons who obtained secondary education, students, graduates and employees [20]. Furthermore, Serbia has been a part of the EPALE (Electronic Platform for Adult Learning in Europe) network since 2017 [21], and few organizations for adult learning are the members of EAEA [22]. Recognition of qualifications, acquired through adult education and short cycle of study, is regulated by the Law on National Qualifications Framework in Serbia [23].
The contexts of adult education in countries of the region (Montenegro, Croatia, North Macedonia and Slovenia) are very similar to the one in Serbia. All mentioned countries have recognized the importance of adult education for achieving lifelong learning objectives, and consequently Sustainable Development Goals. Adult education is intended for all persons over the age of 15 who do not participate in regular education. Unlike the other countries, Croatia established separated system of adult education at primary and secondary level, and higher education is not part of this system. Besides formal, non-formal and informal learning, Montenegro and Croatia identified self-directed learning. All countries adopted strategies for adult education, as well as a comprehensive body of legislation. The distribution of responsibilities is clearly defined, and recognition of qualifications is regulated by national qualifications framework [24]. All countries are the members of EPALE and EAEA.

3. THE STATE OF ADULT EDUCATION IN SERBIA AND COUNTRIES OF THE REGION

For the purpose of better understanding the state of adult education in mentioned countries, in Table 1 some demographic data are presented.

Table 1. Population size aged 25-64 by gender and educational attainment level
Source: [25, 26, 27, 28, 29, 30]

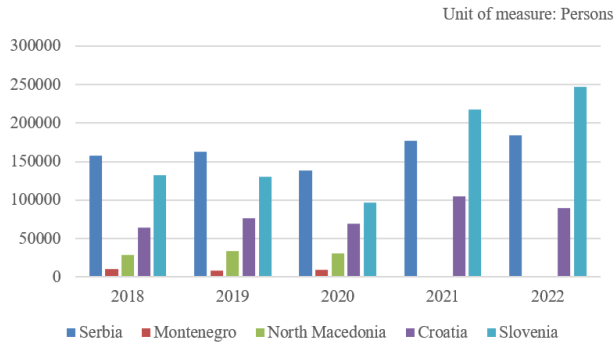
		Serbia	Montenegro	North Macedonia	Croatia	Slovenia
2022	Males	1757846	165107	499451	1013400	596038
	Females	1781416	166502	500655	1025700	547661
	Total (males and females)	3539262	331609	1000106	2039100	1143699
	Levels 0-2	601100	NA	NA	259600	100100
	Levels 3 and 4	2121700	NA	NA	1344600	569300
	Levels 5-8	923100	NA	NA	544900	448400
2021	Males	1838103	165933	499191	1017600	599794
	Females	1856877	167153	500256	1040400	551676
	Total (males and females)	3694980	333086	999447	2058000	1151470
	Levels 0-2	630500	NA	NA	277600	98300
	Levels 3 and 4	2142200	NA	NA	1350400	577400
	Levels 5-8	919100	NA	NA	540700	456200
2020	Males	1859563	166398	600915	1092400	602378
	Females	1880675	167556	585978	1081600	554120
	Total (males and females)	3740238	333954	1186893	2174000	1156498

	Levels 0-2	660700	41900	326100	293900	113500
	Levels 3 and 4	2176300	209900	586500	1343100	633000
	Levels 5-8	902400	86800	276000	552100	417700
2019	Males	1881607	167225	602197	1098700	602096
	Females	1905485	168308	586921	1096600	558226
	Total (males and females)	3787092	335533	1189118	2195300	1160322
	Levels 0-2	701800	41100	337100	314200	129300
	Levels 3 and 4	2181200	209900	598200	1337900	640700
	Levels 5-8	904400	87100	253200	558200	384200
2018	Males	1903735	167675	601755	1103600	596800
	Females	1931106	169016	586609	1111600	560635
	Total (males and females)	3834841	336691	1188364	2215200	1157435
	Levels 0-2	732500	44500	353700	331600	137300
	Levels 3 and 4	2201200	211200	592100	1333800	644500
	Levels 5-8	903800	81000	241500	567000	375700

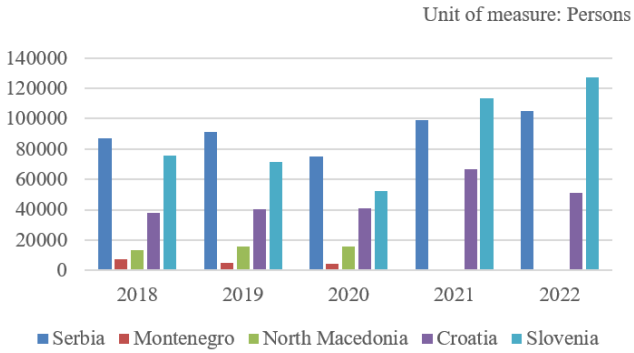
NA - not available
ISCED 2011: 0-2 levels- Less than primary, primary and lower secondary education; 3 and 4 levels-Upper secondary and post-secondary non-tertiary education; 5-8 levels- Tertiary education

Data in Table 1 indicate that the most people have obtained secondary education in all mentioned countries. Over the last five years, in Serbia, the number of people who acquired tertiary level of education has been increased, and consequently the number of those with primary and secondary education has been decreased. The situation is similar in other countries, except in Croatia where values have been varied or decreased during the observed years. In Slovenia, the differences in values between people who obtained secondary and tertiary education are smaller than in other countries, as well as Slovenia notes a greater increase in the number of people who obtained tertiary level of education.

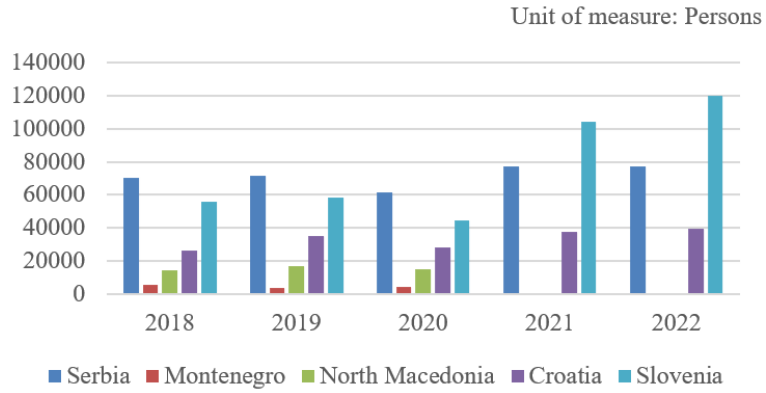
According to main idea of this paper, the following graphics present the participation of adults in education and training by age, gender and educational attainment level.



Graphic 1. Participation of adults aged 25-64 in education and training
Source: [31]

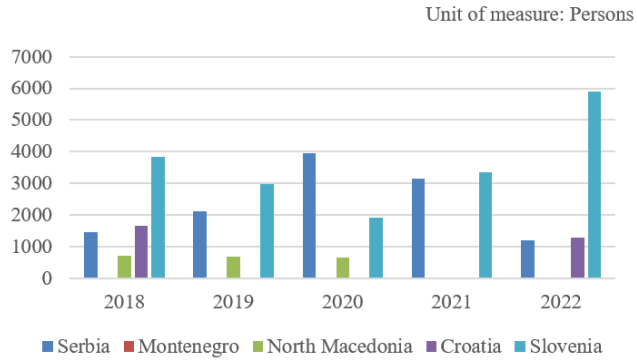


Graphic 2. Participation of females aged 25-64 in education and training
Source: [31]

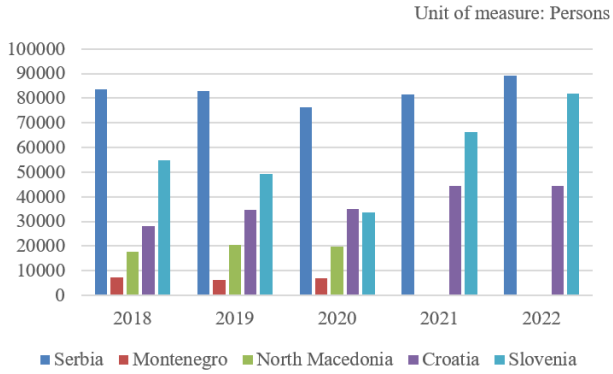


Graphic 3. Participation of males aged 25-64 in education and training
Source: [31]

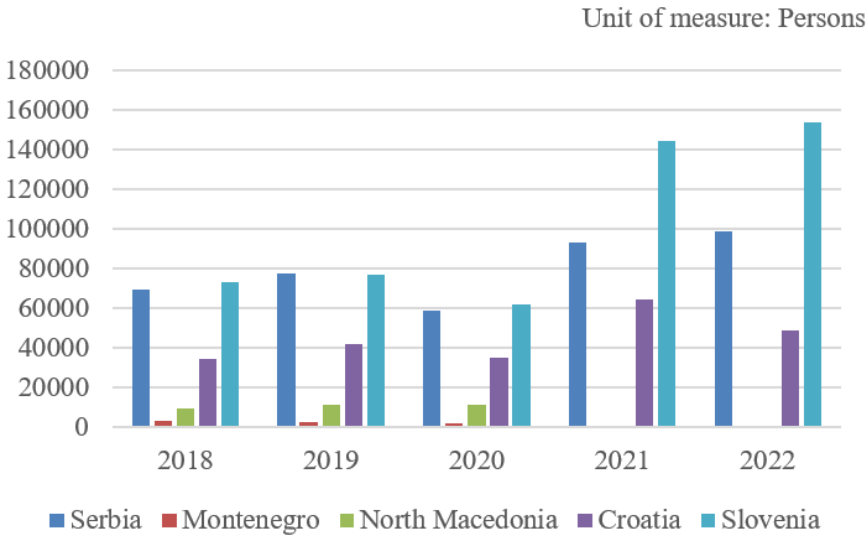
From the Graphic 1 to Graphic 3 it can be concluded that Slovenia has the largest participation of adults in education and training. If the numbers were to be converted into percentages (Graphic 1), participation rates in Slovenia were 11,4%, 11,2%, 8.4%, 18.9% and 21.6%, respectively. Since 2018 to 2022, in Serbia, participation rates were 4.1%, 4.3%, 3.7%, 4.8% and 5.2%. In other countries, the participation rates were at similar levels, but less than in Serbia. Generally, participation of women in adult education is greater than participation of men in all mentioned countries (Graphic 2 and Graphic 3).



Graphic 4. Participation of adults in education and training – aged 25-64 and who attained 0-2 educational levels
Source: [32]



Graphic 5. Participation of adults in education and training – aged 25-64 and who attained 3 and 4 educational levels
Source: [32]



Graphic 6. Participation of adults in education and training – aged 25-64 and who attained 5-8 educational levels
Source: [32]

In relation to educational attainment level (Graphic 4 to Graphic 6) the participation rate of adults in education is the lowest for the persons who have less than primary, primary and lower secondary education in all mentioned countries. Except Slovenia, in other countries these rates are less than 1%. In Serbia, the largest number of adults who participate in education and training are those who obtained secondary educational level, except in 2022 (Graphic 5). The same situations are in Montenegro and North Macedonia in the years of 2018, 2019 and 2020. Unlike these countries, in Croatia and Slovenia people who obtained higher education participate the most in adult education.
Besides previous presented data, the authors explored participation rate of adults in education for other age groups (25-34, 35-44, 45-54 and 55-64) [see: 31] and it appears that Slovenia is the most successful in adult education comparing to other countries of the region. Furthermore, in all mentioned cases Slovenia achieved better results than EU average levels and even more it was more successful than most European countries [31, 32].

4. CONCLUSION

In the age of technological revolution, rapid population ageing, efforts to environmental protection and the recovery from the Covid-19 pandemic, adult education has become increasingly important. Simply put, adult education includes all learning activities after the end or after leaving formal education. It appears in different forms, like formal, non-formal and informal learning, and it can be performed in educational, as well as in other institutions and organizations. The main objective of this paper was to explore the state of adult education in Serbia and countries of the region. The findings show that all mentioned countries have recognized the importance of adult education, and they have adopted strategies and necessary legislative framework. Despite the contexts of mentioned countries have been very similar, Slovenia was more successful than other countries over the last five years. Thus, the new question arises – why Slovenia achieved better results i.e., what made it different from the other countries, that could be the subject of future research.

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ENVIRONMENT AND SUSTAINABLE DEVELOPMENT. MECHATRONICS. OCCUPATIONAL SAFETY AND HEALTH AND FIRE SAFETY. SMART MANAGEMENT SYSTEMS. GRAPHIC ENGINEERING. DESIGN. TRAFFIC ENGINEERING. BIOTECHNOLOGY AND HEALTHCARE. MECHANICAL ENGINEERING. ECOTOURISM AND RURAL DEVELOPMENT.

APPLICATION OF THE PARETO ANALYSIS IN QUALITY CONTROL

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Abstract: *In the production process, operational waste is generated due to various causes. The quality control department, among other activities, deals with monitoring and analyzing the frequency of nonconforming products and the causes of nonconformities in order to reduce them. In this context, several statistical methods and techniques are used. The focus of this paper is on the application of Pareto, a simple, but very effective method for determining the most significant causes of nonconformities. Using this technique, it is possible to perform further analyses and to determine the trend of the occurrence of nonconformities. As a result, corrective measures can be planned and implemented.* T*he aim of this paper is to present the application of Pareto analysis in the production of micro-switches. The data are collected from one Division of the company that wanted to stay anonymous.*
Keywords: Pareto chart, Statistical Quality Control, Quality.

1. INTRODUCTION

In today's market environment, quality, among others, is ''the crucial factor of competitiveness, which determines the direct relationship between quality and production efficiency'' (Dunchenko, cited in [1], p1). Quality control, failure analysis, and improvement are central elements in manufacturing [2]. Improving quality contributes to improving production efficiency. Continuous improvement, as one of the eight quality management principles, is a set of repetitive actions, which are designed to increase the capacity to meet the requirements [3]. As one of the main objectives of each organization, quality is focused on continual improvements of the total performance [4]. In that context, the quality of a product is the highest interest of an organization. Therefore, one of the tasks for quality management is to apply appropriate tools and techniques [5].
Planning and operating the production are complex. Controlling and maintaining quality of production are important topics for manufacturing companies. In order to improve the production results, a number of techniques, methods or tools can be applied to increase production capacity, the volume of manufactured products, and the quality of semi-finished and finished products respectively. Most of them are focused on the technological processes, production machinery, and equipment, and less on human resources [6]. In each process, excessive variations and errors can cause nonconformities, that consequently may cause undesirable consequences - scrapped or wasted resources and "contamination" from undetected nonconformities. These consequences reduce the value of the product to the customer. The goals of quality control in every production system are to (*a*) eliminate nonconformities and their consequences, (*b*) eliminate rework and wasted resources, and (*c*) achieve these goals at the lowest possible cost [7].

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For achieving the previous goals, a number of methods and techniques could be used. Quality tools and techniques offer a variety of methods to visualize and control process data [2]. The most used methods in the practice are: the Pareto chart, Cause-and-Defect diagram, Control carts, Failure Mode, Check Sheet, Histogram and Scatter plot [1, 2, 5, 8]. With the help of Pareto diagram, which is mostly used to identify critical areas, the manufacturing defects in each stage of the production chain have been prioritized by arranging them in decreasing order of importance. Then cause and effect diagram is being applied to explore possible causes/factors of defects and to determine the causes/factors that have the greatest effect [9]. Pareto analysis is used to separate the "vital few" from the "trivial many" [10]. It serves as the tool for sorting different defects with their relative significance to the total rejection [9].

The goal of this paper is to present the application of Pareto analysis in the production of micro-switch parts in the company that wanted to stay anonymous. In the text below the authors will use *XZY* as the name of the organization. XYZ is a technological organization that produces systems for passenger and commercial vehicles, as well as industrial technology [11]. This organization has several divisions in Serbia, but the *D* division (not its original name) deals with the production of micro-switches. Its products are installed in basic household appliances (electric motors and generators for hybrids and electric drives, gear levers, and microswitches) [11]. Within this organization, the quality department deals with the analysis, monitoring, and control of the production process and product quality.

2. THEORETICAL BACKGROUND

The interest in research on quality management exists because decision-makers are aware of the importance of high-quality production in achieving a competitive advantage in the global market [12]. Quality performance is defined through eight dimensions:

1) performance (that refers to primary operating characteristics of a product);
2) features (refers to characteristics that support the basic functioning of the product);
3) reliability (refers to the probability of the product malfunctioning or failing within a specified period);
4) conformance (refers to the degree to which the product's design and operating characteristics meet standards);
5) durability (the amount of use the customer gets from the product before replacement is preferable to continued repair);
6) serviceability (refers to speed, courtesy, competence, and ease of repair);
7) aesthetics (based on individual preference for how the product looks, feels, sounds, tastes or smells);
8) perceived quality (based on image, brand name, and advertising that makes inferences about quality) (Cole, cited in [14]).

To achieve High quality production performance, the process of control has to be well planned and carried out after the completion of each stage of the production process. Statistical process control (SPC) methods may be used to make sure that the rate of produced defective products occurs in a stable and predictable manner (the process is in control) [15]. Among various methods applied in monitoring the production, descriptive statistics is used for the simple data presentation (scatter plots, histograms, etc), while Pareto is used to help the identification of different defects and their classification in relation to their significance [9].

Monitoring of nonconformities provides useful information about the processes and the operations of production lines. Montgomery, in [17, p 190], claims that clear data presentation is ''essential to good statistical thinking because of the important features they provide and the insight about the type of model that should be used in solving the problem''.

Among known methods, the Pareto chart is used for the causal analysis of phenomena (factors, nonconformities, causes, causative agents, quantitative, value, and other characteristic measures of the work process). This diagram shows, in descending order, the relative influence of an observed quantity or group of quantities in the set of quantities being analyzed. This is an effective tool for ranking quantities by degree of importance and identifying basic problems that require a solution. The application of the Pareto chart is found in a variety of industries. For example, it was applied in the pharmaceutical industry for identifying and analysing defects in products (Paul and Azeem, 2009) and in the lamp production process for minimization of defects (Ahmed and Ahmad, 2011). From the literature, it is clear that Pareto analysis is one of the essential tools to analyze and identify the causes of defects in industry [16]. To conduct Pareto analysis, needed data must be sorted in descending order, i.e. it is necessary for a checklist to be created. In this check-list, the frequency of defects is noted and then the accumulated frequency and corresponding accumulated percentage of defects are calculated. The reason for the wide application of Pareto is that it serves as a simple way to get the answer about the causes of defects that must be paid attention to and that must be eliminated [18].

3. THE APPLICATION OF PARETO ANALYSIS IN QUALITY CONTROL

The quality department of the *D* division of *XYZ* organization deals with product control and monitoring the production process on manual lines and automatic machines. The quality of micro-switch parts is monitored and controlled in each phase of the production, as well as their merging into one product. Data (number of nonconforming manufactured parts, error codes, shift number, and other relevant data) are entered into checklist called *Mistake collection,* according to the Inspection Plan and manipulated in the internal program, where the permissible limits of the qualitative and quantitative characteristics of the product are adjusted.

The Pareto method is used in the *D* division for a simplified presentation of the number of nonconformant products and the causes of nonconformities. Products produced on manual lines and automatic machines (per shift on a daily basis) are taken in consideration. The production and product control on manual lines is carried out in accordance with *the Control plan, Escalation plan and Instruction in case of non-conformance.* The Control of products produced on automatic machines is performed after setting up the machine and approving the production order. Then, the detection of nonconformities is performed by verifying the quality of the product. On the other hand, the control on manual lines is performed after each phase of the production.

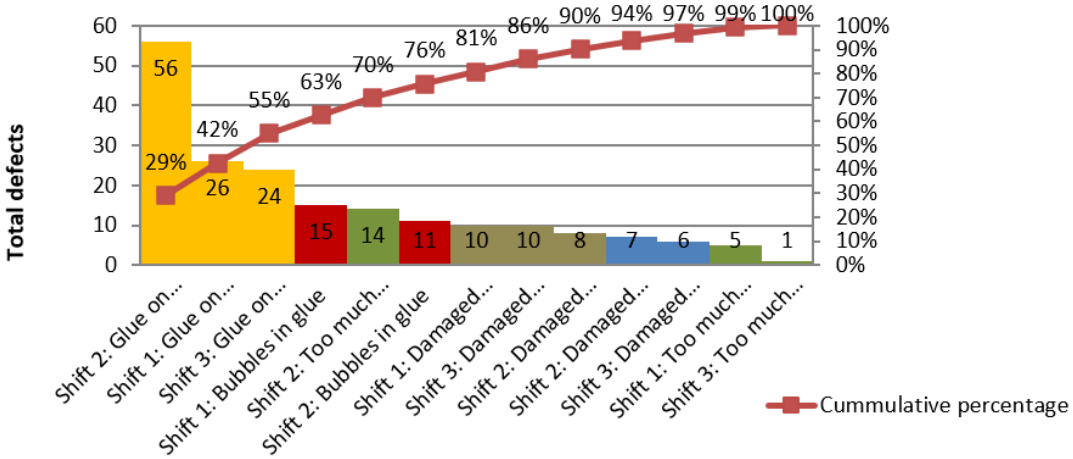

Figure 1. Pareto chart for the manual line
Source: XYZ organization

Figure 1 presents the Pareto chart of defects on manual lines in all three shifts per day. In total, operators produced about 1500 pieces of switches per day, and the total scrap was 56 pieces in the first, 96 pieces in the second, and 41 pieces in the third shift of the observed day.

Figure 1 indicates that the most frequent causes of nonconformities in total (on the manual line) are "Glue on isolation" in all shifts (29%, 13%, and 13% of the total number of nonconformities, respectively), "Bubbles in glue" in shift 1 (8%) and "Too much solder on the terminals" in shift 2 (7%). These are the first five nonconformity causes that make up 70% of all nonconformities in the observed period. Further analysis showed that the operator who was gluing the switches was a new worker on training, therefore the scrap in the third shift was twice as large as in the first and the second shifts.

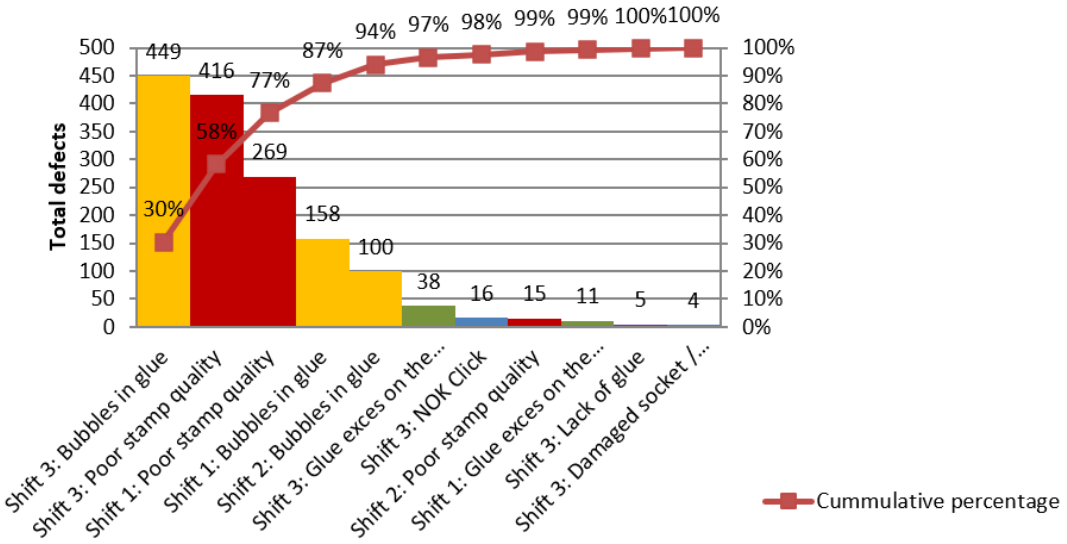

Figure 2. Pareto chart for the mashine line
Source: XYZ organization

Figure 2 shows the Pareto chart for the five most frequent nonconformities induced during the production process on the machine. These non-conformities are detected on a machine that produces 3000-4000 pieces per shift. The total number of nonconformant pieces per shift was 1476, where 438 were in the first, 115 in the second, and 923 in the third shift (see Figure 2). The most significant nonconformities in the observed period were: ‘’Bubbles in the glue’’ in shift 3 (30%), ‘’Poor stamp quality’’ in shift 3 and 1 (28% and 19%, respectively). These causes made up approximately 80% of the nonconformities in the observed period.
Subsequent analysis showed that the problems on the machine were in the vent pipe that was leaking glue, and the poor print (bad ink mixture) on the matrix. After that, the problems were solved.
In addition to the Pareto diagram, descriptive statistics and polygons are used to monitor the frequency and types of nonconformities trends.

4. CONCLUSION

It is well-known that quality management ensures continual quality improvements of processes, products, and overall business. Like the other systems, production processes have to be well planned, monitored, controlled, and continuously improved in order to ensure product quality. For this purpose, many statistical and engineering methods and techniques can be used. In the processes of monitoring and controlling, methods and techniques enable detecting defects and their causes in effective and efficient manner. With no neglecting the importance of other methods, this paper presents an example of the application of Pareto analysis in production quality control.
The Pareto method is a simple, but very effective quality tool that helps in underlining few crucial causes of the observed problem. By the Pareto diagram, which is mostly used to identify critical areas, the manufacturing defects in each stage of the production can be prioritized according to the decreasing order of importance.
D division of *XYZ* organization uses various statistical and engineering methods as a base for monitoring and controlling its processes. These methods are useful to minimize the risk of errors or

weaknesses in procedures or systems or in raw materials. Process flow management and statistical control feedback contribute to the physical quality of the product. Among various methods that are used in *D* division, the Pareto method is used as a simplified presentation of the number of nonconforming products and types of nonconformities produced on manual lines and machines, per shift on a daily basis.

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Data presented in the text, Figure 1 and Figure 2 are collected from XYZ company.

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ENVIRONMENT AND SUSTAINABLE DEVELOPMENT. MECHATRONICS. OCCUPATIONAL SAFETY AND HEALTH AND FIRE SAFETY. SMART MANAGEMENT SYSTEMS. GRAPHIC ENGINEERING. DESIGN. TRAFFIC ENGINEERING. BIOTECHNOLOGY AND HEALTHCARE. MECHANICAL ENGINEERING. ECOTOURISM AND RURAL DEVELOPMENT.

THE INFLUENCE OF DIGITAL TRANSFORMATION ON CUSTOMER PERCEPTION

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Abstract: *Digital transformation is fundamentally changing how organizations manage their relationships with stakeholders, operate, and deliver added value to customers. Customers become more connected, informed, empowered, and active, expecting customized products or services. To meet customers' high standards and expectations, organizations have to be agile, constantly innovate, and change themselves by embracing new technologies, but first of all, organizations must have understanding and empathy for customers. This paper provides an overview of the influence of digital transformation on customer perception using standards as tools for achieving better performances.*
Keywords: digital transformation, customers, standards

1. INTRODUCTION

The world is facing numerous risks and challenges: inflation, cost-of-living crises, trade wars, capital outflows from emerging markets, widespread social unrest, geopolitical confrontation, and the spectre of nuclear warfare [1, p. 6]. These affect organizations and their stakeholders. In addition to all of the above, organizations cannot continue to do things in the same old ways, due to disruptive digital technologies that are becoming the new standard and challenging traditional business rules [2, p. 891]. Digital transformation occurs in response to changes in digital technologies, increasing digital competition and resulting in fundamentally altered customer preferences [2, p. 895]. Customers, as one of the stakeholders, have changed and become more sophisticated. They value the whole experience, not just product or service quality and price. In such circumstances, agility becomes a hallmark across the organization, as it permits speed and flexibility without loss of product or service quality [3; 4, p. 28]. The aim of this paper is to discuss the influence of digital transformation on customer perceptions, as well as the benefits of ISO standards implementation in the digital economy.

2. DIGITAL TRANSFORMATION OF ORGANIZATION

Digital transformation, the integration of digital technology into business, is fundamentally changing how organizations manage their relationships with the stakeholders, operate, and deliver added value to customers [5]. Digital transformation accelerated across all industries at an unprecedented pace throughout the coronavirus pandemic, which was critical for business success. Digital transformation is multidisciplinary, involving changes in strategy, organization, information technology, supply chains, and marketing [2, p. 890]. It is a way to efficiently meet changing customer demands, enable remote work, enhance product or service development, production, and delivery, reduce costs, assess

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realistic benefits, etc. The impact of digital transformation on business performance depends on internal (organizational size, age, board composition, organizational structure, and organizational culture, digital growth strategies, digital assets, products vs. services, development of digital networking or big data analytics capabilities) and external factors (legal, technological, market, cultural, social, and economic environments, whether international, national, regional, or local), as the competitive landscape is changing drastically and moving the interests of customers to relatively new digital businesses. [2, p. 896]

Modern technology, digitalization, flexible data management, and highly agile processes help organizations achieve an intelligent and highly agile digital environment that predicts and responds to changes in the ecosystem to capitalize on new opportunities [5]. Since the launch of the World Wide Web and its global dissemination, more and more supporting technologies (e.g., broadband Internet, smartphones, Web 2.0, Web 3.0, SEO, cloud computing, voice recognition, online payment systems, and cryptocurrencies) have strengthened the development of e-commerce. Also, the prevalence of big data and disruptive digital technologies (artificial intelligence (AI), blockchain, Internet of Things (IoT), robotics, autonomous vehicles (AV), augmented or virtual reality (AR/VR), digital traceability, and 3D printing) have a significant effect on the economy [2, p. 890; 3, p. 4]. Also, new digital technologies impact the cost structure by replacing human labour in the provision of services with robots or virtual agents, optimizing logistic flows, and reducing supply chain costs through the use of AI and blockchains [2, p. 890].

The biggest challenges for organizations are ensuring accelerated transformation progress and creating digital innovations that lead to sustainable business values [6, p. 1]. The digital organization has digital products and services and powers core business processes and operations with technology [5]. Such an organization needs digital assets and acquires or develops capabilities related to digital agility, digital networking, and big data analytics. The organization should develop agile structures with low levels of hierarchy, internalize IT and analytical functional skills, and lead platform-based market development, customer co-creation, and platform diversification [2, p. 896]. New agile business models enable business continuity [5] and digital resilience as organizations compete with (new) digital players and absorb exogenous shocks from disruptive digital technologies [2, p. 896].

Businesses cannot digitally transform unless or until people transform. Therefore, digital transformation needs a change from organizational culture to digital culture and a radical rethinking of people, processes, and technologies [7]. Organizations should focus on reimagining work to fight change fatigue, building digital acumen across the enterprise, and deepening human connections between colleagues and teams [6, p. 1]. Digital transformation includes tectonic changes in human interactions within the ecosystem, as well as changes in tasks, rights, responsibilities, and obligations [5]. Accelerating digital transformation requires new digital skills, not just in IT but across all organizational functions. Training, reskilling, and upskilling keep the workforce prepared and optimized in an environment of digital transformation [4, p. 32].

Organizations with a digital culture use digital tools and data-powered insights to drive decisions and customer-centricity while innovating and collaborating across the organization. Digital culture drives sustainable action and creates value for all stakeholders. It is about being flexible and having a workforce that can respond to new challenges, effectively using technology, and having the right tools, structures, incentives, and mindsets to integrate new technologies into work. The organization develops innovative products and services to meet changing customer needs with tech and data-enabled delivery channels. Also, the organization fulfills ESG goals (circular economy) and develops integrated initiatives that transform business and have an impact on stakeholders, rather than implementing performative campaigns (“greenwashing”). [7, p. 8]

Digital transformation is essential for all businesses, from small to large. Therefore, the Center for Digital Transformation (CDT), in cooperation with the Ministry of Economy of the Republic of Serbia, sent out a public invitation in October 2023 for the new “Digital Transformation Support Program for Micro, Small, and Medium Enterprises 2023” to improve business, successfully adapt,

actively participate, and make progress in the digital age through the introduction of modern digital tools into the organization [8].
Digital transformation is blurring market boundaries and changing the roles of players (e.g., customers becoming co-producers, competitors becoming collaborators, and organizations integrating or bypassing stakeholders) [2, p. 890]. Consequently, organizations must know as much as possible about their customers and stakeholders.

3. CUSTOMER PERCEPTION IN THE DIGITAL ERA

A customer is an individual or business that purchases goods or services from another organization. Customers are the most important because they generate revenue. Without them, organizations can neither survive nor thrive. The organization should meet customer requirements and strive to exceed their expectations by understanding their current and future needs. Sustainable success is achieved when an organization attracts and retains the confidence of customers and other relevant interested parties so that every aspect of customer interaction provides an opportunity to create more value for the customer. [9, p. 13] Organizations compete to attract or retain customers by aggressively promoting their products or services, lowering prices to expand their customer base, or developing unique products, services, processes, and experiences that customers like.
Customer behaviour is changing in response to digital transformation. Customers have access to more information than ever before. The Forbes study showed that 90% of customers read online reviews before visiting a store and that these reviews influence 67% of purchase decisions [10]; 50% intend to increase their online spending in the next six months; 63% of customers have purchased products directly from a brand's website; 80% of customers said they would pay up to 5% more for sustainably produced goods; 40% would pay up to 10% more than average; 10% would go up to 30%; and nearly 7% say they would pay even higher prices [11]. Spending more on sustainability is most likely coming from Millennials and Generation Z, who are generally more conscious of social justice and environmental issues [11].
With the help of new search and social media tools, customers become more connected, informed, empowered, and active. Their criteria change. They look closely at what a brand says, does, and stands for. Customers often co-create value by designing and customizing products or services, taking over last-mile distribution, and helping other customers by sharing product or service reviews. Many customers don't make decisions based only on product or service price. [2, p. 890; 5] Lately, for the customers the most important is the experience (45,9%), then the quality of the product or service (33,6%), and price (20,5%) [12].
The COVID pandemic has permanently changed customer preferences. Hence, organizations must ensure their survival by implementing the four most important customer trends [13]:

1. Socio-political values are diversifying and increasingly influencing customer choices.
2. Customers are willing to use technology to optimize themselves and have virtual experiences that can overtake real-life experiences.
3. Brands are expected to offer more comprehensive services, use customer data, and promote well-being.
4. Customers are recognizing and appreciating distinctly human traits as the world becomes increasingly influenced by other forms of intelligence.

Organizations should better understand and strongly interact with hyper-connected customers. Cost, choice, and convenience are still relevant, but experience is more important. Globally, customers have access to more than 1 billion different products offered by traditional competitors and dynamic new entrants experimenting with new business models and methods of customer engagement. With increasing choice, loyalty is weakening, and customers are becoming more empowered. To meet customers' high standards and expectations, organizations have to remain agile, constantly innovate, and change themselves by embracing new technologies. [3, p. 2]

4. INFLUENCE OF DIGITAL TRANSFORMATION ON CUSTOMER PERCEPTION

Digital transformation occurs in response to changes in digital technologies, increasing digital competition and resulting in fundamentally altered customer preferences. Such disruptions force all businesses to engage their target customers in new ways using digital technology [2, p. 895]. Organizations understand the imperative to respond to customers evolving needs for customized products or services. To achieve this, organizations prioritize the innovation of all business processes, promote transparency in buying behaviors and customer choices, deliver tailored products or services to market at unprecedented speeds, and respond to unexpected disruptions related to supply issues, distribution channels, or facility closures. [3, p. 28] The proactive organizations use technologies such as generative AI and chatbots; invest in customer relationship management (CRM), mobile apps, and social media; build direct-to-consumer (D2C) and subscription capabilities; meet customer demands in terms of environmental, social, and governance (ESG) and sustainability; and only then expect to capitalize on growth in customer spending in the coming period [11]. Therefore, organizations strive for competitive advantages and empower customers by providing the necessary tools, information, technology, and support to make decisions [11].

Customers look like they believe in apps and new AI-based technologies. Creating the most appealing advanced experiences, physical or digital or both, starts with an outstanding understanding and empathy for the customer requirements, needs, and expectations, and brings to increased customer value, increased customer satisfaction, improved customer loyalty, enhanced repeat business, enhanced organizational reputation, expanded customer base, and increased revenue and market share [9, p. 15]. Regretfully, most organizations start with technology before understanding the customers they serve. The problem for organizations is that, in their never-ending attempt to increase operational effectiveness, digital transformation has become more crucial than customer empathy. Without a compelling comprehension of customer requirements, engaging digital experiences are impossible to create. If efforts focus on what motivates customers to click and switch, organizations don't achieve the desired results and long-term satisfaction, loyalty, and retention. To satisfy customer expectations, organizations should improve their customer initiatives, and measure customer satisfaction, customer loyalty, customer relationship, and employee engagement in customer experience [14]. Here are some good examples [12]: customer experience is the number one brand differentiator in recent years; 1 in 3 customers will leave a brand they love after just one bad experience; 49% of customers have made impulse purchases after receiving a more personalized customer experience; customers that rate the organization with a high customer experience score (i.e. 10/10) spend 140% more and remain loyal for up to 6 years; 64% of customers are more likely to recommend a brand to others if it offers simpler experiences and communications; 71% of customers recommend a product or service because they received a "great experience"; 65% of all customers find a positive experience with a brand to be more influential than great advertising.

Organizations that cannot adapt to these changes become less attractive to customers and are likely to be replaced by ones that use such technologies [2, p. 891]. ISO standards provide organizations with tools to improve their performance.

5. BENEFITS OF ISO STANDARDS IMPLEMENTATION IN THE DIGITAL ECONOMY

ISO has published more than 22.000 international standards and related documents that represent globally recognized guidelines and frameworks based on international collaboration to help governments, industry, and customers [15]. ISO standards define what great looks like, setting consistent benchmarks for businesses and customers, ensuring reliability, building trust, and simplifying choices. They guide businesses in adopting sustainable and ethical practices, creating excellent customer purchases, and safeguarding our planet. In essence, standards seamlessly blend quality with conscience, enhancing customer everyday experiences and choices [16]. ISO standards apply to all organizations, regardless of size, industry, or nature of business. Each of these standards can be efficiently implemented independently, but their integrated application is more effective.

The UN Guidelines for Consumer Protection outline that the right to informed choice and to redress where expectations are not met is fundamental to effective relations with customers and is a basic right [17]. Therefore, ISO has a range of standards that help organizations address every aspect of customer satisfaction, from codes of conduct to handling complaints and disputes. These standards bring together the best international practices for customer satisfaction [18]:

1. ISO 10001, Quality management – Customer satisfaction – Guidelines for codes of conduct for organizations;
2. ISO 10002, Quality management – Customer satisfaction – Guidelines for complaints handling in organizations;
3. ISO 10003, Quality management – Customer satisfaction – Guidelines for dispute resolution external to organizations;
4. ISO 10004, Quality management – Customer satisfaction – Guidelines for monitoring and measuring.

In addition, standard *ISO/PC 317:2018 Consumer protection: privacy by design for consumer goods and services* assists organizations in dealing with customer protection in the digital economy in areas such as data protection, artificial intelligence, the sharing economy, and legislation on the online consumer experience. This standard enables organizations to comply with regulations and generates greater customer trust at a time when it is needed most [19]. Implementation of ISO standards helps organizations to ensure that their products and services perform as expected and continuously improve: quality and reliability, consistency in the delivery of services, choice, and fair competition; transparency in production information, suitability of products for vulnerable populations; and standards have the credibility to support consumer protection laws [18].

6. CONCLUSION

Modern technology, digitalization, flexible data management, and highly agile processes help organizations achieve an intelligent and highly agile digital environment that predicts and responds to changes in the ecosystem to capitalize on new opportunities [5]. Customers look like they believe in apps and new AI-based technologies, so organizations strive for competitive advantages and empower customers by providing the necessary tools, information, technology, and support to make decisions [5]. But it seems that for many organizations, digital transformation has become more crucial than customer understanding and empathy [14]. The survival, growth, development, and sustainable success of an organization mean achieving the desired results, as well as customer satisfaction means long-term loyalty, retention, increasing the number of customers, and repeat purchases offline or online. This implies increasing the availability of products and services, improving the total customer experience, providing customized value and impact for customers, focusing on their incentives and recognition, and educating customers through a stronger focus on product credibility and environmental, social, and governance (ESG) awareness and sustainability [20]. The Government of Serbia is giving support programs for micro, small, and medium enterprises to improve business, successfully adapt, actively participate, and make progress in the digital age through the introduction of modern digital tools into the organization [8]. Also, implementing ISO standards benefits organizations in fulfilling customer satisfaction and protection.

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ENVIRONMENT AND SUSTAINABLE DEVELOPMENT. MECHATRONICS. OCCUPATIONAL SAFETY AND HEALTH AND FIRE SAFETY. SMART MANAGEMENT SYSTEMS. GRAPHIC ENGINEERING. DESIGN. TRAFFIC ENGINEERING. BIOTECHNOLOGY AND HEALTHCARE. MECHANICAL ENGINEERING. ECOTOURISM AND RURAL DEVELOPMENT.

THE EFFECTIVENESS OF ENVIRONMENTAL SOCIAL AND GOVERNANCE DUE DILIGENCE IN DRIVING SUSTAINABLE OUTCOMES IN THE OUTDOOR APPAREL INDUSTRY

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Abstract: *Due diligence in the areas of environmental, social, and governance (ESG) has grown to be a crucial tool for assessing and enhancing business practises. The study investigates the qualitative assessment of how ESG due diligence encourages sustainable performance inside organisations. Using a combination of case studies, data analysis, and theoretical frameworks, the study explores best practises for attaining tangible progress across several industries. The report also shows links between improved resource efficiency, worker wellbeing, risk reduction, stakeholder involvement, and successful ESG due diligence. It highlights the opportunity for data analytics and technology to improve impact assessment precision. The report explains how ESG due diligence leads to sustainable outcomes by giving organisations a path for assessing and publicising their sustainability successes. It helps businesses to better comprehend the importance of their ESG due diligence efforts and to take defensible actions to improve their sustainability performance.*
Keywords: ESG due diligence, corporate sustainability, impact measurement, investor perspective

1. INTRODUCTION

The complex aspect of sustainability in the outdoor apparel industry is the main topic of this article. It's becoming more and more clear in today's corporate environment that businesses need to give social and environmental responsibilities equal weight with financial goals. More than 90% of S&P 500 businesses and over 70% of Russell 1000 businesses publish ESG reports [26]. This indicates that stakeholders, consumers, investors, and regulators - are calling for increased openness and a dedication to sustainable business practices. Through an examination of supply chain procedures, labour conditions, and environmental effects, this article seeks to disentangle the complex web of possibilities and problems that the garment industry faces as it makes its way toward sustainability. In doing so, it hopes to clarify how companies may satisfy the demands of a worldwide consumer base that is becoming more and more aware of social and environmental issues while balancing profit with social and environmental well-being.

In order to fully investigate these concerns, this article takes a multimodal approach. It draws from a variety of sources, including academic literature, industry publications, case studies, and sustainability efforts within the garment sector, and blends qualitative and quantitative research approaches. As a result, it presents an analysis that combines academic research, field data, and empirical evidence to give a comprehensive view of the possibilities and problems that enterprises in the garment industry confront. It also makes use of the OECD's Due Diligence Guidance for Responsible Supply Chains in the Garment and Footwear Sector and the United Nations Guiding Principles on Business and Human Rights (UNGP) to offer a workable framework for resolving environmental and human rights issues. The content of the paper is organised so that it gradually examines important topics. It starts with a focus on labour conditions and modern slavery in the apparel supply chain, moves on to the role of HRDD in reducing human rights violations, and ends

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with a thorough analysis of the environmental effects of clothing over its whole life cycle. In doing so, it hopes to offer insightful analysis and practical suggestions for businesses attempting to balance profit with social and environmental responsibility in the competitive corporate world of today.

2. THE RISING NEED FOR ESG DUE DILLIGENCE

Due to market pressures, it is now crucial to focus on sustainability and integrate ESGs into business operations [25, 27]. According to Banerjee et al. [2], using corporate resources in socially responsible ways may improve a company's reputation and foster stakeholder involvement. Freeman and Dmytriyev [12] assert that a commitment to ethical operations not only helps businesses develop a sustainable strategy by generating economic value through social benefits, but also boosts their competitiveness and profitability by attending to social needs.

Despite the fact that modern slavery and forced labour are pervasive in many facets of the economy, apparel imports into G20 countries at risk for modern slavery ranked second [21]. The supply chain workforce is severely impacted by short lead times and low price requirements, which frequently results in forced labour or underpayment of wages [1]. While businesses are aware of the need to educate their suppliers and staff about the risk of modern slavery, a study revealed that they typically ignore the influence that their purchasing policies have on the supply chain employees [22].

The UN developed the Guiding Principles on Business and Human Rights as a framework to aid companies in conducting human rights due diligence (HRDD) in order to avoid, contribute to, or at the very least mitigate negative effects on human rights, such as those seen in the supply chains for clothing. Concerns over human rights in enterprises throughout the world led to the publication of the United Nations Guiding Principles on Business and Human Rights (UNGP) in 2011. In order to detect, avoid, reduce, and repair any negative human rights repercussions associated with their operations and supply chains, businesses should follow the human rights due diligence (HRDD) framework [23]. Fashion companies of all sizes may execute due diligence procedures at each level of the UNGP HRDD framework according to their capabilities and resources. The OECD's Due Diligence Guidance for Responsible Supply Chains in the Garment and Footwear Sector provides this advice [20].

The whole supply chain has an influence on the environmental sustainability of a specific manufacturer, hence it is essential to incorporate the emphasis on economic sustainability into business models. The findings of Cai and Choi [5] may suggest that less effort is put into mitigating human rights risk in supply chains than is put into mitigating environmental risk. The analysis of the environmental effects of garments over the full product life cycle shows that the stages of manufacturing, processing, and consumer use outweigh those of transport and product end-of-life [17].

3. MEASURING ESG IMPACTS IN THE OUTDOOR APPAREIL INDUSTRY

In recent years, there has been an increase in the implementation of sustainability measures due to increased awareness of the environmental and social problems surrounding the apparel sectors and customers [16]. Environmental and social risks are becoming a major focus of due diligence, an approach to lowering commercial and financial risks. The process involves a thorough investigation, often carried out by one firm against another, to look into any potential wrongdoing or area of non-conformity that does not meet the expected level of conduct. Performing due diligence is a way to foresee potential future social, environmental, and ethical issues that might have an impact on the business [6].

Consumers are particularly interested in and concerned about sustainable practices in the outdoor apparel industry, which is supported by initiatives of brands such as REI, Patagonia, Nike, and Black Diamond [8]. Two significant players in the outdoor apparel market, Patagonia and REI, have adopted practices that include recycling clothes, accepting old clothing back for resale, and giving customers instructions on how to maintain their own equipment [17]. Although many businesses in the outdoor

sector are thought of by the public as being transparent in practicing environmental care, this is not always the case. Only five (5) of the fourteen (14) firms studied publicly demonstrated a full sustainability plan, according to the study, and the majority of outdoor brands did not even publicly announce their attempts to produce sustainable clothes [4].

3.1 Social performance: Working conditions and supply chain health

The Fair Wear Brand Performance Check is a tool used to evaluate how much business practices enhance working conditions throughout the company's supply chain and promote more open and trustworthy relationships with its manufacturing partners. Every year, Fair Wear evaluates its operations by examining how successfully the firm has located, assessed, and resolved problems with its suppliers. To guarantee accountability and openness, the audit results are made available to the general public. For the objectives of the study, three brands at random from the FairWear website were selected: Equip, Dynafit, and Jack Wolfskin[2]. Best practices and suggestions to enhance working conditions and supply chain sustainability were looked for in their reports.

The major goal of the sourcing strategy should be maintaining long-term partnerships. Implement stringent supplier onboarding procedures and extensive supplier due diligence procedures. Create a policy for onboarding new suppliers. Create a risk analysis in accordance with the OECD's guidelines. Conduct a supplier-level risk assessment and risk scoping. During the process, include all eight labour standards and use the gender analysis lens. Apply a gender perspective to all improvement activities as they are implemented. Use Fair Wear nation studies and other outside sources to pinpoint country risks and evaluate their likelihood and gravity. Consolidate the supply chain to be able to demand better working conditions at major production sites. Analyse the expenses of funding pay raises across the supply chain. To assist the supplier's transition to living wages, pay additional costs to the manufacturer for a set length of time. Increase your understanding of the cost breakdowns for all product categories, but refrain from making one-time charity donations. Calculate the labour minute costs of the goods to be able to determine the precise expenses of labour and connect this to the price of your purchases. Provide purchasers with cost breakdown training, utilising tools such as the Fair Price app[3]. Create a fair contract using the Common Framework of Responsible Purchasing Practises (CFRPP). Prefer to source from nations where employees are allowed to establish or join a union and/or engage in collective bargaining. Include feedback from employees, vendors, and other stakeholders in the risk-scoping process. Promote the complaints mechanism helpline. In addition to feedback from stakeholders and workers, audits should also monitor other third-party audits. Make sure supplier-level monitoring is in place to evaluate and comprehend supplier risk. Analyze the compliance with human rights of suppliers' subcontractors.

After each season, evaluate the manufacturing process with the supplier and make any necessary adjustments for future planning. Establish order timescales as early as feasible to provide the supplier with some sense of certainty. Take proactive action against excessive overtime by planning ahead for capacity and raw materials, and exploring the underlying reasons for excessive overtime with suppliers. Follow the development of yearly audits. Participate actively in discussions with suppliers for living wages. During pricing discussions, take into account changes in the legal minimum wage as well as salary levels, desired wage increases, and other relevant information. Implement a wage structure that pays the higher of the worker's hourly and piece rate rates. Every year, compare the salaries paid to suppliers to the estimated living wages in the country. Check to see if the required minimum wage was paid. Include the Global Living Wage Coalition's standard[4]. Strive for greater pay and create a systematic, time-bound strategy.

Examine whether the factories have anti-harassment committees or policies. Encourage businesses to elect workers' representatives. Encourage vendors to use posters and team meetings to spread the word about worker representatives. Establish independent worker representation in factories, and

[2] Equip Source, Dynafit Source, Jack Wolfskin Source
[3] Source: https://app.fair-price.org
[4] Source: https://globallivingwage.org

include these representatives in monitoring and correcting issues. Ensure the workers can complain. Provide assistance to vendors who scored poorly on the human rights due diligence requirements so they may correct any violations. Assist in organizing or financing training for suppliers on social dialogue and Freedom of Association. Find the source of complaints to stop them from reoccurring. All factories where this is a risk should implement training.
Include employee and supplier feedback in the assessment process. Suppliers and worker representatives should always be included in the evaluation of the internal grievance process. The results of the evaluation should be shared with the aforementioned parties and discussed about ways to improve. Suppliers and employee representatives should be informed of the corrective action plans. Support the development of capability, and put internal grievance procedures into practise at suppliers. Establish improvement schedules as soon as possible.

3. 2 Environmental performance: Environmental impact and product life-cycle assessment

Throughout the whole lifespan of the product, textile, and garment items have a substantial environmental impact [11], and understandably so since the industry employs 9.3% of the global workforce and accounts for 4% of global exports [24]. Various producers, such as fabric mills, dyeing facilities, and finished products facilities, are a part of the intricate worldwide networks that make up apparel supply chains. Before reaching a retailer and a customer's hands, a pair of shoes may pass through multiple distinct facilities in five different nations. If a business cannot find a method to overcome these obstacles and build strong relationships with its partners along the global value chain, it will be impossible to track and manage the various impacts all the facilities have.
The five tools that make up the Higg Index evaluate the social and environmental performance[5] of the value chain as well as the effects of products on the environment. They are the Higg Facility Environmental Module (FEM), Higg Facility Social & Labour Module (FSLM), Higg Brand & Retail Module (BRM), Higg Materials Sustainability Index (MSI), and Higg Product Module (PM). It gives businesses verifiable data to analyse, improve, and share performance. The Higg Index for Materials, the most popular sustainability grading system for the apparel industry, evaluates materials from "cradle to gate" while taking into account the effects of chemicals, fossil fuel use, water scarcity, excessive eutrophication, and the effects of global warming. However, after greenwashing claims in 2022, it moved away from producing consumer-facing reports [10].
The need for positive environmental practises in the clothes sector is expanding, but little study has been done on how to help apparel designers, producers, merchandisers, and customers incorporate environmental concerns into their products [16]. These decisions include how the materials are used, how much waste is produced by the forms they choose, how products are made and packaged, where they will be made and sold, how much energy is used in transportation, and how customers will use and dispose of the product [13]. Retailers may wrongly promote specific materials as being more ecologically friendly than others because the Higg MSI assessment methodology favours synthetic materials generated from fossilised carbon over bio-based textiles like wool, silk, and leather. Because it uses a "cradle-to-gate" strategy rather than a "cradle-to-grave" or "soil-to-soil" strategy, the Higg MSI is flawed in a number of ways. In order to determine sustainable impact, it only looks at the environmental impact of an item rather than its environmental, economic, and social costs of production. Animal fiber products like wool, silk, and alpaca rate lower than the preferred materials used by the majority of apparel manufacturers, such as cotton and synthetics, as a result of differences in how different fiber types are scored. There is yet no one system that incorporates all sustainability measures and ranks the best materials and manufacturing techniques, therefore the only thing to do is to wait for the Higgs index to develop. Before evaluating and making a decision, the companies are forced to take the more time-consuming route: understand each stage of their product lifecycle, each production phase’s emissions data, energy inputs, and associated emissions, pollution, and environmental impacts directly attributable to each stage of processing and use for a specific weight of the fabric, and the impacts on water pollution [9]. The paper analyzed the best practices in the

[5] Source: https://apparelcoalition.org/higg-facility-tools/

outdoor industry looking at websites, sustainability reports, and commentary on top-ranked sustainable outdoor brands. The following is the best practice approach towards improvement of environmental impact in phases of design, production, consumption, consumer care, and garment afterlife. Find out what garment characteristics and what issues are most essential to you. Learn the performance standards for your fabric. In contrast to typical fibers, consider alternate fibers with comparable performance. On technical equipment, apply a coating that is PFC-free and water-repellent. Despite making technical textiles water-resistant, PFC coating may be dangerous for both human and animal health. As a result of a longer life cycle, Bédat [18] claims that increasing a product's lifespan by twofold leads to a 44% decrease in greenhouse gas emissions. While developing a product, the entire lifespan of the product should be considered. Make products that will last for as long as possible. Give a lifelong repair warranty to encourage consumers to modify their consumption patterns [7].

Change to completely biodegradable, reusable, or recyclable packaging, and make an effort to get rid of virgin petroleum fibers. Remove single-use plastics from the supply chain. Keep as much operating waste out of landfills as you can. By using only one material in the item's creation, the lifespan of the original material may be enhanced by up to ten times, making it easier to recycle and transform into another useful product. In November 2019, Salomon[6] presented a novel shoe design that could be completely converted into ski boots. To prevent the Forte sleeping bag from ending up in landfills, NEMO made it totally recyclable[7]. For years, as a part of the ScrapMeUp programme, Houdini has been upcycling and has used manufacturing excess fabric to make limited-edition clothes. Foster a culture of sharing above owning. Clients were able to rent shell apparel from Houdini's retail outlets by using an access economy strategy[8]. Avoid deforestation by adopting bio-based materials, such as polyester made from sugarcane waste, and ensure that no slash-and-burn farmlands are a part of the project. Create a supply chain map. Picture[9] is a good example of supply chain transparency. Work on locating and reducing the carbon footprint of value chain operations. Avoid using carbon offsets. Instead, encourage suppliers to switch to sustainable energy sources.

4. CONCLUSION

In order to maintain sustainable development and competitive advantage, it is becoming more and more important for businesses to prioritise non-financial performance, such as ESG due diligence, as we navigate this changing terrain. It is clear that businesses with an emphasis on sustainability are drawing long-term investor interest, which benefits their standing, employee happiness, and innovation. The study presented in this paper is consistent with the conclusions drawn by a number of authors [14, 19, 15], however, it is important to recognise that different rating and scoring services use different methodologies, which leads to different ESG ratings. This disparity underscores how industry-wide ESG measures must be standardised. The ESG ratings indicate a significantly larger range of correlations, from 38 to 71 percent, whereas credit scores from agencies such as S&P and Moody's show a substantial correlation. While credit scores from agencies like S&P and Moody's exhibit a strong correlation, the ESG ratings show a much wider range of correlations, from 38 to 71 percent [3]. Moreover, organizations such as the Sustainability Accounting Standards Board (SASB) and the Global Reporting Initiative (GRI) employ different metrics, further complicating the landscape. It is obvious that further study is required in the future to improve ESG measuring techniques and determine their wider effects on sustainability, business performance, and innovation. The intricacy of ESG due diligence demands continuous research endeavours to cultivate a more profound comprehension of its function in promoting sustainability. Future developments for sustainable business practises will be largely shaped by the industry's dedication to ESG efforts and a more standardised approach to measurement in the years to come.

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[6] Source: Salomon Case Study
[7] Source: https://www.rei.com/blog/camp/good-gear-nemo-top-selling-sleeping-bag-fully-recyclable
[8] Source: https://thefaircottage.com/en/blog/post/tfcs-top-3-european-sustainable-outdoor-brands
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OCCUPATIONAL SAFETY AND HEALTH AND FIRE SAFETY.
SMART MANAGEMENT SYSTEMS. GRAPHIC ENGINEERING. DESIGN.
TRAFFIC ENGINEERING. BIOTECHNOLOGY AND HEALTHCARE.
MECHANICAL ENGINEERING. ECOTOURISM AND RURAL DEVELOPMENT.

QMS & EMS IMPLEMENTATION IN SERBIAN ORGANIZATIONS – A DRIVING FACTOR FOR SUSTAINABLE DEVELOPMENT

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Abstract: *In the last few years, the development of management system standardization has been accelerating. A special focus is placed on QMS and EMS implementation in organizations, given that it is very important for the sustainable development of the country. As Serbia is still a developing country that strives for sustainable development and economic prosperity, it is very important to raise awareness of the importance of implementing the mentioned management systems in organizations. This paper provides an overview of the state related to standardization in Serbia, especially the ISO 9001 and ISO 14001 standards, as well as an overview of the value of certificated Management Systems in accordance with the requirements of the ISO standards in Serbia in the last decade. Organizations that own the aforementioned certificates are safe and attractive for both domestic and foreign products and services customers, but they are also socially responsible because, in addition to profit maximization, they also take into account the ecological side of the business. Unfortunately, there is a scarce number of studies on this topic in Serbia and the region, so the recommendation for future researchers in this field is to pay more attention to this important issue.*
Keywords: QMS, EMS, Standardization, Sustainable Development

1. INTRODUCTION

The business of every organization, regardless of the economic sector in which it operates, consists of a series of tasks that need to be performed on a daily, weekly, monthly, or annual basis, in order to ensure a normal and smooth business process. All these tasks require rules that define the scope, quality, methods, and techniques that should be followed during their performance, in order to ensure quality and reduce the possibility of business errors. If there were no clearly defined rules in business, operational chaos would occur. Thus, that is why clearly defined rules are implemented into the organization's business process, and the most prominent type of such rules are ISO standards. ISO standards are internationally agreed by experts and it can be said that they are a formula that describes the best way of doing something [1]. The internationally recognized organization that develops and publishes ISO standards is the International Organization for Standardization (ISO).
The Institute for Standardization of Serbia (ISS) is the only national standardization body of the Republic of Serbia that has the status of a legal entity and operates in accordance with the regulations governing the legal position of public services. ISS is founded by the Government of the Republic of Serbia [2]. Serbian standards can be created as original standards, or as standards based on national, international, European, or regional standards or related documents of other countries, in accordance with the agreements concluded with the standardization bodies of those countries [2]. Nowadays, ISO is an independent and non-governmental international organization whose portfolio includes 24997 international standards (covering almost all aspects of technology, management, and production), 169

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national standardization bodies with membership in it (one member per country), and 824 technical committees and subcommittees (take care of the standards development) [3].
The preparation of the Serbian standard takes place in four steps, respecting the principles and rules established by international and European organizations for standardization [2]:

1. Involvement of all interested parties in the Serbian standard's adoption process;
2. Preparation of the preliminary Serbian standard draft;
3. Draft of the Serbian Standard's Commission;
4. Public discussion on the Serbian standard's draft.

It has been revealed that both management systems, Quality Management System (QMS) and Environmental Management System (EMS), significantly contribute to the improvement of the organization's performance. The implementation of requirements of the ISO 14000 standard in the organization is the second step after the implementation of requirements of the ISO 9000 standard, i.e. most of the organizations that implemented EMS implemented the QMS earlier [4]. Today, the most important and applied standards are ISO 9001 - QMS, ISO 14001 - EMS, and ISO 22000 - FSMS, which represent a framework for business standardization around the world [5].
"Sustainable development (SD) is development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (p. 16), thus, "future generations do not vote; they have no political or financial power; they cannot challenge our decisions" (pp. 16) [6]. The concept of SD can be complete only if all three of its components are respected: economic, ecological, and social. However, usually the ecological component remains unrealized, thus, future generations cannot experience well-being in the true sense of the word if they live and work in degraded environmental conditions. The connection between QMS, EMS, and SD is very strong, which is indicated by a large number of scientific papers [7, 8, 9, 10, 11]. ISO contributes to all of the SD goals [1]: 1) no poverty; 2) zero hunger; 3) good health and well-being; 4) quality education; 5) gender equality; 6) clean water and sanitation; 7) affordable and clean energy; 8) decent work and economic growth; 9) industry, innovation, and infrastructure; 10) reduced inequalities; 11) sustainable cities and communities; 12) responsible consumption and production; 13) climate action; 14) life below water; 15) life on land; 16) peace, justice and strong institutions; 17) partnerships for the goals.
This manuscript is structured as follows: section 2 – previous research; section 3 – general participation of standards in sustainable development - a brief review; section 4 – participation of standards in Serbian sustainable development; section 5 – a conclusion and recommendation for future research are given.

The aim of this paper is to discuss the state related to standardization in Serbia, especially the ISO 9001 and ISO 14001 standards, as well as to give an overview of the value of certificated Management Systems in accordance with the requirements of the ISO standards in Serbia in the last decade.

2. PREVIOUS RESEARCH

A large number of scientific works testify to the important connection between QMS, EMS and SD. Unfortunately, in our region, the number of such works is scarce.
Thus, one of such works in our region is the work of Professor Majstorović and others [5], which deals with the issue of business standardization in Serbia and the world. The authors concluded that business standardization entered a new era with the adoption of Annex SL[4] and the release of new models of QMS and EMS: 2015, as well as that these documents laid new basics for the development and application of other standardized management systems (SMS), and in such a way this will be significant for users, as they will be able to easily integrate two or more SMS.

[4] According to ISO, Anex SL is normative or harmonized structure (identical clause numbers, clause titles, text and common terms and core definitions) for Management System Standard (MSS).

Afterwards, a group of authors from the University of Novi Sad [14] in one of their papers dealt with the issue of key competence factors of organizations in Serbia with certified management systems. The authors based the study on The European Manufacturing Survey questionnaire and analyzed the competence of Serbian companies through the implementation of the ISO 9001 standard. The study revealed a significant difference between certified and non-certified companies, in terms of the quality of products and services, as well as that the implementation of QMS in business is of great importance for SD.

A group of authors [7] investigated the connection between SD, QMS, and EMS on the example of Slovakia. The authors concluded that environmental labeling is of great importance for SD within EMS and that ISO 9001 is particularly relevant to organizations that tend to label their products as CE[5]. Another paper [8] testifies to the importance of QMS for SD. In other words, there is a need to define activities in the field of QMS that have to be implemented in the organization, and which will serve as a source of inspiration in creating value for interested parties. As well, QMS has to be integrative, inclusive, and adaptable in order to respond to SD challenges and support companies in their business challenges.

Another group of authors [9] dealt with the issue of EMS in the field of architecture, engineering, and construction, as well as with the issue of SD in that context. Their study generated a wide range of benefits to support the implementation of ISO 14001 in AEC sectors[6], while using ISO 14001 as a framework would certainly help companies to focus on achieving SD goals.

3. GENERAL PARTICIPATION OF STANDARDS IN SUSTAINABLE DEVELOPMENT – A BRIEF REVIEW

The following table (table 1) shows the number of ISO standards participating in each of the SD goals.

Table 1. The number of ISO standards that apply to each SD goal
Source: International Organization for Standardization, [1]

SD goal		Number of ISO standards
1.	No powerty	393
2.	Zero hunger	604
3.	Good health and well-being	3559
4.	Quality education	639
5.	Gender equality	238
6.	Clean water and sanitation	712
7.	Affordable and clean energy	1109
8.	Decent work and economic growth	2838
9.	Industry, innovation and infrastructure	14407
10.	Reduced inequalities	656
11.	Sustainable cities and communities	2810
12.	Responsible consumption and production	3179
13.	Climate action	1423
14.	Life below water	393
15.	Life on land	1206
16.	Peace, justice and strong institutions	243
17.	Partnerships for the goals	16

It can be concluded that the largest number of ISO standards participate in the 9th SD goal – Industry, innovation, and Infrastructure (14407), while the lowest number of ISO standards participate in the last SD goal – Partnerships for the goals (16). Some of the most significant examples of ISO standards that participate in the 9th goal of SD are: ISO 44001 – Collaborative business relationship management systems, and ISO 56002 – Innovation management systems.

As QMS and EMS are of key interest for this work, the following figures (figure 1 and figure 2) show which SD goals the ISO 9001 and ISO 14001 standards participate in.

[5] CE marking i.e. the presence of the CE logo means that the manufacturer/importer confirms the conformity of the goods with EU standards of health, safety and environmental protection, and it is not a quality indicator or a certification mark.

[6] Architecture, Engineering and Construction sector.

Figure 1. Participation of ISO 9001 in the goals of SD
Source: International Organization for Standardization [1], Author's creation

The life cycle of the ISO 9001 standard began in 1987 (ISO 9001:1987), and the last version was published in 2015 (ISO 9001:2015). The standard is revised every five years. The ISO 14001 standard participates in the 1st, 9th, 12th, and 14th goals of SD. The ISO 9001 standard is based on seven quality management principles (QMP) [12]:

1. QMP 1 – Customer focus;
2. QMP 2 – Leadership;
3. QMP 3 – Engagement of people;
4. QMP 4 – Process approach;
5. QMP 5 – Improvement;
6. QMP 6 – Evidence-based decision making;
7. QMP 7 – Relationship management.

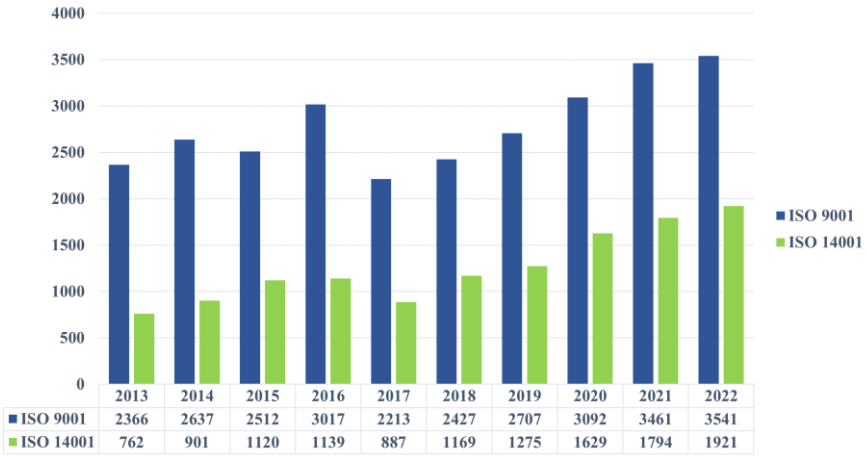
Together, these principles can form the basis for performance improvement and organizational excellence, likewise, the implementation of QMS brings numerous benefits to the organization, such as: clear goal setting and identifying new business opportunities, working in a more efficient way, meeting the necessary statutory and regulatory requirements, expand into new markets, identifying and addressing business risks, etc. [12, 13].

Figure 2. Participation of ISO 14001 in the goals of SD
Source: International Organization for Standardization [1], Author's creation

The life cycle of the ISO 14001 standard began in 1997 (ISO 14001:1997), and the last version was published in 2015 (ISO 14001:2015). The standard is also revised every five years. As well as the ISO 9001 standard, the ISO 14001 standard participates in the 1st, 9th, 12th, and 14th goals of SD. However, this standard also participates in the 2nd, 3rd, 4th, 6th, 7th, 8th, 13th, and 15th SD goals. It can be concluded that EMS is in almost every goal of SD and that is why its implementation in the organization's management system is of great importance for the successful business process.

4. PARTICIPATION OF STANDARDS IN SERBIAN SUSTAINABLE DEVELOPMENT

Serbia is still in the transition process, aspiring to join the European Union and accelerate its economic growth, therefore, Serbian companies are forced to implement QMS in their business because the quality of products and services is the most important factor of competitiveness nowadays [14]. There is also a need to implement EMS in the business process, because today foreign capital prefers to go to socially responsible locations, and the time when only cheap workforce was the main attraction factor for foreign investors is passing. Thus, figure 3 shows the number of certificates (ISO 9001 and ISO 14001) in Serbia in the last decade.



	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
ISO 9001	2366	2637	2512	3017	2213	2427	2707	3092	3461	3541
ISO 14001	762	901	1120	1139	887	1169	1275	1629	1794	1921

Figure 3. The number of certificates in Serbia in the period from 2013 - 2022
Source: International Organization for Standardization [15], Author's creation

It can be concluded that the number of ISO 9001 certificates is significantly higher compared to the number of ISO 14001 certificates, which points to the fact that it is necessary to raise awareness in Serbian companies about the implementation of EMS, regardless of the fact tha implementation of this standard is voluntary, i.e. it is not required by law, but organizations have to become aware of the importance of environmental protection and socially responsible business. Also, it can be seen that the number of both certificates dropped significantly in 2017. The reason for that could be the introduction of a new global financial crisis, similar to the crisis of 2007/2008. Back in 2017, economic experts warned of an inevitable new global economic crisis, which could also begin with the bursting of the so-called financial bubble, as well as the previous crisis (unrealistically high values of certain parts of assets in the area of securities, real estate, etc.). Hereafter, the growth of public and private debt with insufficient economic growth almost always represents a serious problem for the economy of a country. Deteriorated business conditions, tensions, and the trade war between the United States and China have disrupted global trade flows by raising tariffs and other barriers to trade [16]. On the other hand, it is encouraging that, in recent years, there has been a constant increase in the number of both certificates, thus, even the COVID-19 pandemic did not disrupt that flow.
Table 2 shows the value of certificated EMS and QMS in accordance with the requirements of the ISO standards.

Table 2. The value of certificated EMS and QMS in accordance with the requirements of the ISO standards in the period from 2013 - 2022
Source: Cornell University, INSEAD[7], and WIPO[8], [17 - 26]

Year	Value of certificated EMS and QMS (bn PPP$ GDP)	
	ISO 9001	ISO 14001
2013	36.40	6.60
2014	39.40	10.50
2015	24.70	7.90
2016	27.50	9.40
2017	25.70	11.50
2018	29.70	11.20
2019	27.00	11.10
2020	19.80	10.10
2021	21.40	10.10
2022	24.40	12.80

[7] The Business School for the World
[8] World Intellectual Property Organization

It is noticeable that the value of the ISO 9001 is higher than the value of the ISO 14001. Also, the lowest value of the ISO 9001 was recorded in 2020, and the highest in 2014, while the lowest value of the ISO 14001 was recorded in 2013, and the highest in 2017. The low value of the QMS in 2020 may be the outbreak of the COVID-19 pandemic.
The next figures (figure 4 and figure 5) show annual variation of the total of the data reported by the providers that took part in both the ISO surveys 2020 and 2021, and ISO surveys 2021 and 2022.

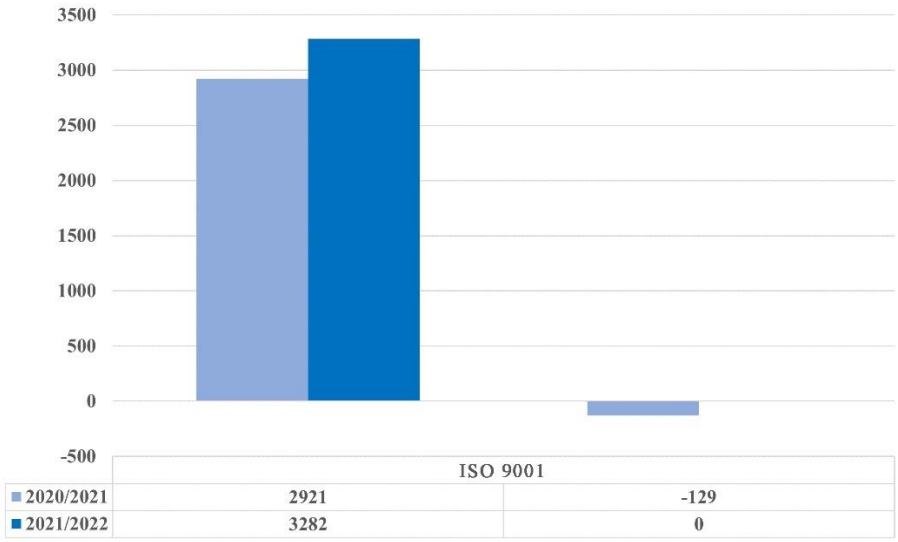


Figure 4. Annual variation of the total of the data reported by the providers that took part in ISO 9001 surveys 2020. and 2021, and 2021 and 2022.
Source: International Organization for Standardization, [15]

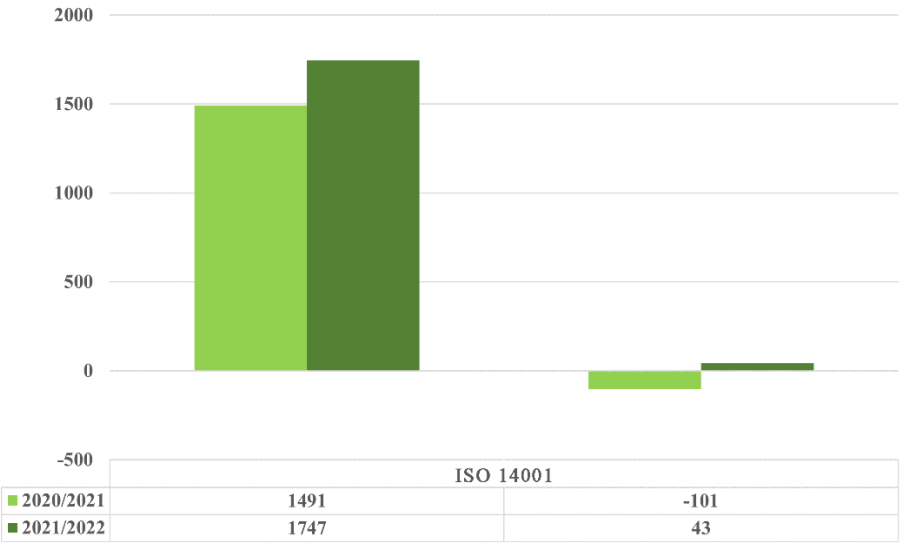


Figure 5. Annual variation of the total of the data reported by the providers that took part in ISO 14001 surveys 2020. and 2021, and 2021 and 2022.
Source: International Organization for Standardization, [15]

The difference between the number of ISO 9001 certificates in 2021 compared to 2020 is a negative number (-129), which means that the number of certificates in 2021 decreased, while the difference is zero when it comes to 2022 compared to 2021, i.e. the certificate number remained unchanged. On the other hand, when it comes to ISO 14001 certificates, in 2021 compared to 2020, a negative number of certificates was detected i.e. also decreased (-101), while in 2022 compared to 2021 that number is positive (43), which means that the number of certificates in 2022 has increased.

5. CONCLUSION

The concept of SD is based on its three pillars – economic, environmental, and social. However, the fact is that the greatest importance is tacitly given to the environmental pillar. The reason for that lies in the long-term neglect of the ecological component of SD. By implementing QMS and EMS in businesses, current generations will protect the rights of future generations to an environment that is safe for their life and health. In the world, there are a large number of those who exploit natural resources excessively, leaving little for future generations, but there is a much larger number of those who consume insufficiently natural resources and live on the edge of existence (poverty, hunger, disease, etc.) [6]. Therefore, it is important to preserve a healthy environment and not to consume natural resources excessively. Standardization in the field of product and service quality and the environment significantly helps countries on their way to achieving healthy SD.

When it comes to Serbia, it is still necessary to raise awareness about the importance of environmental protection and encourage companies to implement EMS in their operations. The complete system of ISO standards is based on principles that allow the company to establish a vigorous relationship with customers, suppliers and employees, as well as to stand out on the market for the quality of products and services, as well as environmental responsibility.

Compared to the rest of the world, Serbia and the region do not stand out in the terms of the number of scientific works in the field of standardization and SD, therefore, the recommendation for future researchers from these areas would be to deal more with this issue.

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SOCIALLY RESPONSIBLE CHAINS: INVESTIGATING THE SOCIAL IMPLICATIONS OF SUPPLY CHAIN DUE DILIGENCE IN CORPORATE SUSTAINABILITY

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Abstract: *As businesses increasingly recognize the interconnectedness of social responsibility and corporate sustainability, the role of supply chain due diligence in shaping socially responsible chains gains prominence. The aim of this paper is to investigate the social implications of supply chain due diligence and its contribution to fostering corporate sustainability with a strong emphasis on social welfare. The study investigates how supply chain due diligence affects social dimensions within organizations and across their supply chains. Through case studies and qualitative analysis, the paper examines how due diligence practices contribute to fair labour practices, human rights protection, and community engagement. The study emphasises the transition from transactional supplier relationships to collaborative partnerships that prioritise ethical and social factors. Finally, this research contributes to the discussion of corporate sustainability by shedding light on the social consequences of supply chain due diligence. It emphasises the critical importance of due diligence in developing socially responsible chains, where ethical issues are as important as environmental ones. By providing insights into best practices and potential challenges, the paper contributes to developing strategies that align supply chain due diligence with broader corporate sustainability goals.*
Keywords: *supply chain due diligence, corporate sustainability, fair labour practices, socially responsible supply chains*

1. INTRODUCTION TO SUPPLY CHAIN DUE DILIGENCE

Bad labour practices in the textile industry sparked intense discussions on the responsibility of multinational corporations for the working conditions and environmental effects of their supply chains. They were fueled by tragedies such as the Rana Plaza collapse (2013) and the Tazreen Fashion factory fire (2013) [27], as well as unveiling the state-sponsored forced labour system [9] in 2020 in Xinjiang, China [11]. They clarified the necessity for regulation to hold companies accountable for supply chain practices. According to Gustafsson et al. [21], the focal subject of these discussions is foreign corporate responsibility (FCA), which is the obligation of corporations to have adverse effects brought about overseas by their suppliers or subsidiaries. Multinational corporations have responded to the need to "clean up" their supply chains with a variety of voluntary corporate governance initiatives [3]. These private governance systems are critiqued for a variety of well-documented shortcomings, such as insufficient coverage, a lack of publicly disclosed accountability mechanisms, a lack of sufficient independent oversight, and ineffective implementation [8].
Multinational corporations traditionally relied on voluntary actions for due diligence. However, key issues like the gender pay gap, biodiversity, environmental conservation, and more remain underreported globally. Some countries now mandate due diligence to address these concerns. The European Commission has led sustainability and transparency efforts, from the European Green Deal [16, 17] to the Corporate Social Responsibility Directive (CSRD) [19]. France, the Netherlands, the UK, Australia, and Germany (2021) have adopted national due diligence regulations. African nations, including the Democratic Republic of the Congo and Rwanda, mandate supply chain management

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for conflict minerals [15]. Initially voluntary, the German Supply Chain Act (2023) resulted from inadequate voluntary measures. The European Commission's draft directive (2022) extends binding duties to major European corporations [20]. However, no regulation offers a comprehensive human rights due diligence framework. Effective regulation should clarify due diligence components and empower affected individuals and communities.

2 THREATS IN EUROPEAN SUPPLY CHAINS

More consumer goods are imported from developing countries by the European Union (EU), than by the combined imports of the United States, Canada, Japan, and China [18]. Due to its low or absent domestic production of soybeans, palm oil, coffee, and cocoa and their consequently high consumption, the EU has emerged as a significant worldwide consumer of deforestation manifested in trade [22]. When it comes to the apparel sector, numerous accounts of abusive working conditions, including unpaid overtime wages, long hours, hazardous working conditions, harassment, and discrimination in the factories and fields characterise the EU’s Asian-based suppliers [23]. The likelihood of employee exploitation increases with increasing demand for quicker production periods and more products [2].

Ethical Trading Initiative [12] has defined the major areas of human rights risk for workers in global supply chains: forced labour, child labour, discrimination, freedom of association and the right to collective bargaining, living wages, irregular employment, occupational health and safety, working hours, and harsh or inhumane treatment. As a company's supply chain is typically international, it is necessary to be aware of the most important risk factors. Poor laws, rules, and oversight systems in authoritarian nations are to blame for the lack of government protection of employment rights. Lack of transparency and indirect employment are caused by the existence of subcontractors and intermediary employment agencies in the supply chains. The ability, resources, and political will of the supplier's state to determine if there is a lack of labour inspection and monitoring.

Supply chains that are overly lengthy or intransparent might result from complex production processes that include a single product that is obtained from several locations. High unemployment and poverty rates, unstable states, and armed conflict can describe the dynamics of some labour markets. Due to exorbitant fees charged by recruiters, hiring practices can be dishonest and entail holding employees in debt as bondsmen.

According to the Ethical Trading Initiative [13], social auditing, a growing $50 billion business, may account for up to 80% of expenses for ethical sourcing. It often entails a physical examination of a facility (such as a factory, farm, mine, or vessel), as well as a documented review and interviews with management and sometimes personnel. It is often not detailed enough to pick up on hidden crimes such as child work or modern slavery nor assess the risk of future violations. Furthermore, different brands inspect certain factories more than once in a single month. This leads to audit fatigue and an overall lack of interest. Despite the fact that a number of brand firms and retailers label their audits as "comprehensive," in practice, they usually only look at a tiny subset of top-tier suppliers.

Prior to the catastrophic events, the Tazreen Fashion factory and the Rana Plaza building's clothing factories underwent social assessments. According to the audits' findings, the workplaces were legally compliant [23, 24]. Audit programmes are still used as a primary compliance tool [23, 25] despite the fact that there is little evidence that audit programmes have improved social performance issues. More than 20 years of research demonstrate that audits frequently fail to identify serious labour violations in supply chains such as working hours, overtime, salary levels, freedom of association, and modern slavery.

3 POTENTIAL CHALLENGES

In supply chain production, codes of conduct, typically supported by social audits, are frequently employed as a framework for monitoring business compliance with human rights regulations. Such codes rely on corporate engagement, but their credibility and potential longevity are dependent on

how businesses engage with other stakeholders (trade unions, civil society, and workers) in their development and enforcement [31]. However, many research studies demonstrate that social audits should not be employed as a substitute for human rights due diligence [4, 26, 10].
Social audits frequently focus on the effects of labour breaches rather than their causes, therefore often overlooking the impact that a company's business strategy and procurement policies play in exploitative labour practices farther down the supply chain [1]. A checklist approach to social compliance characterised by the superficial Yes/No audit procedure is inadequate for identifying the root causes of issues. Labour infractions in the garment industry, for instance, are not just a factory-level issue that can be resolved by better compliance monitoring, but rather a widespread and predictable result of the broader business model [29].
Despite their inadequacies, most companies continue to rely on audits and compliance-based strategies to manage and mitigate human rights risks given their limited resources, abilities, and increasingly competitive marketplaces [12]. Businesses rather outsource and delegate risk management to their suppliers, auditors, and other professionals in order to inform them of what they need to know and do. As a result, the companies' relationships with their suppliers suffer, as does their sense of ownership and responsibility for potential human rights issues. Compliance audits assert that they provide exhaustive *data* and unbiased verification of the social and environmental conditions at supplier factories using defined metrics. In reality, audit data is politicised, incomplete, and typically kept secret. When retailers add supplier improvement requirements, certain information categories get points while others with egregious violations go unpunished. Audits provide a perception of transparency and accountability, yet they frequently conceal the worst business practices from view [24].

3.1 Positive effects of supply chain due diligence

For companies to raise the level of their due diligence and successfully manage both internal and external risks, they must approach environmental and social problems in a more honest and effective manner [7]. Because it involves a wide variety of stakeholders for data collection, supply chain due diligence produces superior analyses of risks and repercussions. Better decision-making is made possible because individuals who are most directly impacted can identify the issues and the best ways to solve them. It leads to increased productivity, decreased staff turnover, improved hiring and training, improved reputation and credibility, and improved visibility of and intelligence on supply chains. It also helps supply security by lowering the risk of disruption due to labour unrest [14].

3.2 Best practices

According to the Ethical Trading Initiative [12], for businesses to manage and mitigate risks more efficiently, they should perform better risk assessment and detailed analysis of human rights risks, impacts, and causes. Companies should also implement internal reviews of approaches, policies, and practices to determine which of these directly or indirectly contribute to human rights risks instead of performing audits and outsourcing due diligence assessments. In the long-term, effective internal stakeholder relationships internally, with other companies, suppliers, trade unions, government agencies, civil society groups, experts, and multi-stakeholder initiatives are shown to be a far more successful and less expensive approach.
To ensure thorough due diligence, companies employ a mix of different methods, including human rights impact assessment, social impact assessment with an integrated human rights approach, and/or human rights risk assessment [5]. Various human rights assessments indicated that the commitment of senior management was a key element in the process. Cultural awareness aided interactions with workers and other stakeholder groups that were involved [28].
Companies should pursue fewer, more committed supplier relationships. Knowing where the items are created and confirming that they are made decently becomes easier to accomplish when the number of suppliers the company deals with decreases. In addition, when the supply chain of a

business is independently verified by a third party, it gives the business a better understanding of what actually occurs at the manufacturing sites [5].

3.2.1. DeFacto, Turkey: apparel industry

About 60% of the workforce in the Turkish textile industry is unregistered, and many of these individuals are employed by small subcontractors. With so many unregistered workers, it is challenging to guarantee their human rights as they are not officially recognised as employees. In the past several years it is estimated that three million individuals applied for refuge in Turkey. Some of them work at apparel factories. DeFacto first tracked the clothing they produced before collaborating with suppliers to enhance the conditions in their facilities. Follow-up and effective communication are crucial in building confidence with suppliers after the baseline audit evaluation. Suppliers become cooperative when they feel comfortable doing business with the company and believe that the partnership enables them to improve. Instead of feeling obliged to just address audit findings and then be done with the process, they start addressing the company proactively. DeFacto requires that its vendors disclose the names of the companies whom they subcontract so that the company can trace their supply chain. This step also encourages a sense of shared accountability among supply chain actors [6].

3.2.2. AkzoNobel, the Netherlands: chemicals industry

Akzo Nobel employs the supplier support visits (SSV) programme to mentor suppliers and assist them as they gradually adapt to the needs of the company. Through this supplier management tool, the company can build long-term relationships focused on tackling systemic issues. Rather than an audit programme, the SSV programme aims to improve the capabilities and performance of local suppliers in emerging markets so they become long-term partners. Supportive visits are planned in advance and executed by teams from the health, safety, procurement, and environmental departments. AkzoNobel’s suppliers believe that being members of the project helps them gain market awareness and commercial prospects [6].

3.2.3. UPM Raflatac, Finland: paper industry

Self-adhesive label manufacturer UPM Raflatac has a database of more than 5,000 foreign vendors. To increase awareness in 2015, the heads of the sourcing and sustainability divisions of UPM Raflatac launched a rather inventive campaign. They created a film with the sourcing team and other departments in order to include the purchasing staff in educating suppliers about the criteria for ethical sourcing. By using straightforward language and including their own, culturally diverse staff across all levels of hierarchy in their regular work environments, the video was successful in communicating to its suppliers the company's commitment to responsible sourcing, banning child labour, and forced labour [30].

3.2.4. Nestlé, Switzerland: consumer goods industry

In Ghana and Côte d'Ivoire, the cocoa industry employs an estimated two million children in child labour. Being the key ingredient in Nestlé products, the company's decision on cocoa suppliers has a direct impact on both its capacity to perform commercially and how it affects society. In 2012, Nestlé and the International Cocoa Initiative (ICI) worked on establishing the Child Labour Monitoring and Remediation System in Côte d'Ivoire. The system's objective is to identify young people who could be engaged in child work and to take corrective measures. The system has also significantly helped to reduce child labour occurrences. The reduction reached 55% according to 2019 statistics [30].

3.2.5. Total, France: energy and gas industry

Total is one of the biggest energy firms in the world, with operations in more than 130 nations and more than 100,000 suppliers around the globe. Effectively identifying and human rights risks of such a vast supply chain offers a significant challenge. Since 2012, Total has mapped its supply chain's human rights concerns and identified high-risk nations as well as product and service categories. However, further action was hindered by a lack of internal support from the larger procurement department, especially in relation to supplier social audits. In 2019, the previous conclusions from the mapping process were used to develop a sustainable procurement mapping tool that would provide procurement teams with access to a list of the core risks related to each category. The instrument provided a set of recommendations that might be implemented in addition to the risk-mitigation measures to further minimise the risks [30].

4 CONCLUSION

The paper underscores the shift from transactional supplier relationships to collaborative partnerships that prioritise ethical and social considerations. It explores good practices that companies use to leverage supply chain due diligence, ensure the fair treatment of workers, prevent human rights violations, and support local communities. It also highlights the challenges and opportunities associated with incorporating social criteria into supplier evaluation. It emphasises the crucial role that due diligence plays in creating socially responsible chains, where ethical issues are just as important as environmental problems. Future research may focus on impact assessments, comparative analyses, stakeholder engagement, transparency effects, regulatory frameworks, technological advancements, cross-sector collaboration, standardised metrics, human-centered approaches, and the outcomes of initiatives to improve education and capacity. Further research will expand our knowledge of morally upstanding supply networks that value social and environmental responsibility.

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PPP PROJECTS AND ECONOMIC GROWTH IN SERBIA

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Abstract: *Project management, as a specific management field, faces numerous challenges nowadays. Those challenges are related to meeting project deadlines, simultaneous work on several projects, unplanned risks, economic instability, lack of resources or knowledge, legal barriers, etc. When it comes to the economic development of the country, special attention is given to public-private partnership (PPP) projects, because they are the driving force of economic growth. At the same time, these projects represent the most complex form of financing economic growth. A large number of factors affect the implementation of PPP projects in the country, thus, in this paper, the focus is on the legal aspect, as well as the analysis of the state of these projects in Serbia, in the terms of projects approved by the authorities, foreign investors – donors, i.e. origin of that capital, etc. Attention is also set on the impact of investments in PPP projects on economic growth in Serbia, in a theoretical sense, while the proposal for future researchers of this issue is the beginning of a model in the region that would both quantitatively express and measure this important impact.*
Keywords: PPP, PPP projects, Economic growth

1. INTRODUCTION

Public–private partnership (PPP) can be defined as an approach that aims to increase the economic value of infrastructure outputs, and it includes a wide spectrum of public sector infrastructure [1]. There is a positive trend in the development of PPP in Serbia, both in the terms of the number of projects and the quality of projects [2]. The Commission for PPP (CPPP) of Serbia invested a lot of effort in promoting this financing model to invite all local governments to propose projects within which they will supervise the provision of services and have a control mechanism, and not, as in the previous traditional model, be a service provider [2]. So far, a total of 272 projects have been approved in the field of PPP, both PPP project proposals and concession act proposals, which is a great success compared to, for example 2019, when the total number of such projects was 134 [3]. The essence of PPP is cooperation between the public and private sector, where the private sector is the investor, which ensures the allocation of risk to the partner that has better performance in the terms of control and management of unpredictable events [4].
A PPP project *("Sl. glasnik RS", br. 88/2011, 15/2016 i 104/2016)* is a project that is developed, proposed, approved and implemented according to one of the PPP models and consists of a series of interconnected activities, which take place in a certain order, in order to achieve defined goals within a certain period of time and certain financial resources, which in accordance with this law was

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approved as a PPP project, with or without concession elements. In PPP projects, the degree of involvement of the private sector is proportional to the degree of allocated risk, thus, the lower the participation of the private sector in PPP, the lower the risk, and vice versa [4]. In other words, privatization allocates the entire risk to the private sector, and in the conditions of traditional financing, all risks are the expense of the public sector, i.e. citizens as taxpayers [4].
On the other hand, when it comes to economic growth, PPP are of great importance. Economic growth is closely related to the wealth of the nation because it is of the greatest importance for the living standard and, in general, the quality of life of a country. Economic growth is the main indicator of the quality of the functioning of the national economy, and it refers to the continuous increase in the value of the production of a country over time, and is basically a long-term and slow process [5]. PPP and economic growth nexus is strong, i.e. the development of PPPs has a general tendency to reflect the changes of economic growth of a country expressed by the growth of the Gross Domestic Product (GDP) [6].

This paper is structured as follows: section 2 – previous research; section 3 – a brief overview of the project evaluation tools; 4 – an overview of PPP projects in Serbia; section 5 – conclusion and recommendation for future research.

The aim of this paper is to observe the nexus between PPP projects and Economic Growth in Serbia, as well as to discuss the state related to PPP projects in Serbia.

2. PREVIOUS RESEARCH

There is a large number of works by foreign authors dealing with the issue of PPP projects and economic growth. As well, the number of domestic works shows a growing trend in recent years. Depending on the observed sample, different authors revealed different connections between PPP projects and economic growth, and some of these connections are positive, some are negative, and there are also those with mixed research results.

Thus, according to Zangoueinezhad and Azar [7] there are three key factors by which PPP projects stimulate the economic growth of the country: the number of PPP projects under way; the value of PPP projects; and the ideal type of PPP contracts in use.
A group of authors [8] investigated the macroeconomic benefits of PPP projects on the example of developing Asia. The results revealed that increasing the ratio of PPP project investments to GDP improves quality of infrastructure services and increase economic growth.
Another group of authors [9] dealt with the analysis of PPP and economic growth on the example of sectoral analysis of developing countries. The authors used GMM estimation technique and concluded that aggregate PPP investments and energy investments have a positive impact on economic growth.
A group of domestic authors from the University of Belgrade [10] investigated the question of feasibility of PPP in Local Government in Serbia. The authors concluded that there are quite low human capital and technical capacities in Local Government about realizing and understanding the concept of PPP.
Another group of authors [11] analyzed PPP projects for infrastructural development as the key to promoting intergovernmental corporation during the Covid-19 pandemic. The research revealed that the implementation of PPPs is the basis for boosting intergovernmental companies globally during the Covid-19 pandemic, thus, countries around the world should use PPPs to strengthen intergovernmental companies to successfully address a number of issues related to the pandemic, as well as similar issues that could arise in crisis situations in the future.

3. A BRIEF OVERVIEW OF THE PROJECT EVALUATION TOOLS

There are two groups of methods for project evaluation [12]:

1. *Static (non-discounting) tools* are based on the account of nominal values from the representative i.e. base year, thus, these tools neglect the time value of money. These include the following:
   - Return on Investment (ROI), and
   - Static payback period;
2. *Dynamic (discounting) tools* are based on the calculation of discount values, therefore, these tools respect the time value of money and start from the assumption that the net cash flow is reinvested every year, during the lifetime of the project's exploitation. These include the following:
   - Net Present Value (NPV),
   - Internal Rate of Return (IRR), and
   - Dynamic payback period.

It would be useful if the growing number of scientific research dealing with PPP issues could include the evaluation of PPP projects, especially dynamic methods because they give a more realistic picture of which project should be prioritized, given that they are based on the concept of the time value of money, i.e. they take into account discounting (reducing the future value to the present value of the project). However, it is very often the case that the priority of the PPP project is not determined using the above-mentioned methods, where the emphasis is on the financial effect of the project itself. In such situations a combined evaluation is used, where a broader aspect of the project's impact is considered – the secondary impact of the project on economic activities that generate GDP.

4. AN OVERVIEW OF PPP PROJECTS IN SERBIA

In recent years, an upward trend in the number of approved PPPs has been noticeable in Serbia, and therefore the need to involve citizens and civil society organizations in these projects is growing, because PPP projects that include them are more effective. In order to strengthen cooperation between the public and private sector, it is necessary to adopt appropriate regulations that will encourage civil organizations and citizens to get involved in these projects in the future.

The following, table 1 shows the list of approved projects in Serbia by The Commission for Public-Private Partnership of Serbia (CPPP). So far, a total of 272 projects have been approved by this Commission, and the table below shows only some of them, in the form of project proposal or concession.

Table 1. List of approved projects in Serbia by CPPP, either in the form of a project proposal or a concession act, until 2023

Source: The Commission for Public-Private Partnership of Serbia [3]

1. Road infrastructure	
PPP project proposal	**Proposal of the concession act**
"Direkcija za izgradnju Apatin" - Municipality of Apatin; Municipality of Stara Pazova; The city of Smederevo; The city of Vršac; The city of Pančevo; The city of Sremska Mitrovica; The city of Kruševac; Municipality of Krupanj; Municipality of Srbobran; Municipality of Mali Zvornik; The city of Sombor; Municipality of Veliko Gradište; Municipality of Babušnica; Municipality of Ada; Municipality of Brus; Municipality of Trstenik; The city of Zrenjanin.	"JP Putevi Beograd" – The city of Belgrade.
Description: - Construction of a port and a road terminal; - Financing, construction and maintenance of local road infrastructure;	Description: - Financing the purchase, installation and maintenance of escalators and elevators for the disabled people, reconstruction and maintenance of parts of underground passages and the purchase, installation and connection of

- Financing, design, reconstruction, i.e. rehabilitation and maintenance of local road infrastructure.	digital cameras that provide "motorized remote position and zoom control", and equipment for recording and collecting traffic information and software for traffic management; - Financing of regular maintenance of horizontal traffic signalling in school zones in seven city municipalities of the city of Belgrade (Barajevo, Grocka, Lazarevac, Mladenovac, Obrenovac, Sopot, and Surčin).
2. Telecommunications	
PPP project proposal	**Proposal of the concession act**
"JKP Informatika Novi Sad" – The city of Novi Sad.	
Description: - Realization of the project of construction and extension of the existing open type optical telecommunication network according to the principle of FTTH (fibre to the home - optical fibre to the end user).	
3. Passenger transport	
PPP project proposal	**Proposal of the concession act**
The city of Belgrade; The city of Jagodina; "Javno komunalno preduzeće Direkcija za javni prevoz grada Niša" – The city of Niš; The city of Požarevac; The city of Užice; The city of Bor; The city of Kragujevac.	The city of Loznica; Municipality of Topola; Municipality of Srbobran; The city of Niš; The city of Jagodina; The city of Šabac; Municipality of Negotin; Municipality of Paraćin; The city of Belgrade; Municipality of Kanjiža; Municipality of Ruma; The city of Valjevo; Municipality of Lajkovac; Municipality of Koceljeva; The city of Pirot; Municipality of Bačka Palanka; Municipality of Ćuprija; Municipality of Knjaževac; Municipality of Kovin; The city of Smederevo; The city of Zaječar; The city of Kraljevo; Municipality of Sokobanja; The city of Novi Pazar; The city of Sremska Mitrovica; The city of Pančevo; Municipality of Šid; Municipality of Vladimirci; Municipality of Mali Zvornik; Municipality of Ljig; The city of Prokuplje; Municipality of Prijepolje; Municipality of Bačka Topola; Municipality of Bogatić; Municipality of Veliko Gradište; The city of Užice; Municipality of Kula; Municipality of Aleksinac; Municipality of Kuršumlija; Municipality of Medveđa; Municipality of Žagubica; The city of Kruševac; Municipality of Inđija; The city of Leskovac; Municipality of Kladovo; Municipality of Blace; Municipality of Kučevo; Highway E-763 Beograd-Požega.
Description: - Performance of communal activities of public urban and suburban passenger transportation.	Description: - Entrusting the performance of city-suburban passenger transportation activities; - Proposal for a concession act with an analysis of the financial and economic effects of granting a concession on the E-763 highway Belgrade-Požega.
4. Public lighting	
PPP project proposal	**Proposal of the concession act**
The city of Sremska Mitrovica; Municipality of Majdanpek; Municipality of Sremski Karlovci; Municipality of Sečanj; Municipality of Plandište; Municipality of Bor.	
Description: - Reconstruction of part of the public lighting system; - Reconstruction, replacement and installation of LED lamps, maintenance and management of the public lighting system; - Replacement of existing public lighting lamps with economical "LED" lamps in the zone of streets, parks, promenades, on public areas, external decorative lighting of public buildings and monuments in settlements.	
5. Energy consumption	

PPP project proposal	Proposal of the concession act
"Zdravstveni centar Negotin" - Municipality of Negotin; The city of Leskovac; The city of Vršac; The city of Subotica; "Javno komunalno preduzeće Standard Vrbas" – The city of Vrbas; The city of Zaječar; The city of Sombor; Municipality of Opovo; "JKP Gornji Milanovac" – Municipality of Gornji Milanovac; Municipality of Kula; The city of Vranje; The city of Bor; Municipality of Bačka Palanka; The city of Niš;	
Description: - Proposal for a PPP project for contractual delivery of thermal energy to the Negotin Health Center with the construction of a new biomass-fired boiler room and renovation of exterior carpentry; - Contractual supply of heat energy with the reconstruction of the heat production system; - PPP project proposal submitted by "JKP Gornji Milanovac", which proposes long-term delivery of thermal energy to the district heating system of "JKP Gornji Milanovac" from newly installed wood biomass boilers and hot water gas boilers; - PPP project proposal, proposing long-term delivery of thermal energy from newly installed gas-fired condensing boilers for ten public buildings in the municipality of Kula; - Contract delivery of heat energy with the construction of new boiler houses from renewable energy sources - wood biomass and natural gas; - Entrusting the performance of communal activities of production and distribution of thermal energy, with mandatory reconstruction of the district heating system; - Substitution of part of the production of thermal energy from fossil fuels (natural gas, heating oil and fuel oil), with contractual delivery of thermal energy from wood biomass.	

It can be concluded that, in the field of road infrastructure, the largest number of approved projects are in the form of PPP project proposals, while "JP Putevi Beograd" of the city of Belgrade are in the form of concession act proposal. Likewise, the largest number of approved projects in the form of concession act proposal is in the field of passenger transport (a total of 48 projects).

The fact that a large part of Serbian capital is foreign should not be overlooked, because Serbia like many other countries in development and transition, finds the key to economic development in foreign capital, or Foreign Direct Investments (FDI). Serbia has benefited significantly from trade and economic integration with the EU. The EU has traditionally been Serbia's key trade partner, accounting for more than 54% of Serbia's total trade in goods, in 2022 [13]. Thus, table 2 shows the largest foreign investors – donors in Serbia in 2022.

Table 2. The largest foreign investors – donors in Serbia in 2022

Source: EU u Srbiji [13]

EU	CEFTA[7]	China	Russia	SAD	Other countries
Total trade (billion EUR)	Total trade (billion EUR)	Total trade (billion EUR)	Total trade (billion EUR)	Total trade (billion EUR)	Total trade (billion EUR)
39.08	6.40	5.80	4.03	1.19	10.00

It can be concluded that, by far, the largest capital inflow comes from the EU (39.08 billion EUR).

[7] Central European Free Trade Agreement.

The following table (table 3) shows some of the PPPs and their estimated values in Serbia.

Table 3. Some of the PPPs in Serbia
Source: Public procurement portal of Serbia [14]

Purchaser	Procurement name	Type	Procedure	Estimated value	Publication date	Submission deadline
"Elektroprivreda Srbije" The city of Belgrade	Ventilation and air conditioning maintenance services	Services	Open	500.000,00	09.11.2023	01.12.2023
"Opštinska uprava opštine Apatin" The city of Apatin	Selection of private partner for implementation of PPP project for long-term delivery of heat energy for heating of 11 public facilities with reconstruction of production systems in the municipality of Apatin	Services	Open	590.709.451,00	25.10.2023	18.12.2023
Municipality of Šid	The selection of a private partner and the award of a PPP contract for the long-term supply of thermal energy for heating 24 public buildings with the reconstruction of the thermal energy production system in the municipality of Šid	Services	Open	660.147.206,00	21.10.2023	12.12.2023
"Aerodromi Srbije d.o.o. Niš" The city of Niš	Maintenance of company vehicles, batch 1 – Maintenance of Skoda brand vehicles	Services	Open	700.000,00	26.09.2023	09.10.2023
"Opšta bolnica Novi Pazar" The city of Novi Pazar	Nutrition of the patient	Goods	Open	3.011.137,00	09.06.2023	21.06.2023
"Opštinska uprava opštine Trstenik" Municipality of Trstenik	Selection of a private partner and awarding of a PPP contract for the reconstruction, rationalization and maintenance of public lighting in the territory of the municipality of Trstenik	Services	Open	440.173.267,00	05.05.2022	28.09.2022
"Opštinska uprava opštine Batočina" Municipality of Batočina	Award of a public contract for the implementation of a PPP project without concession elements for the construction	Services	Open	40.081.207,39	18.12.2021	02.03.2022

	of a sports and recreational complex					
"Gradska uprava Pirot" The city of Pirot	Entrusting the performance of urban and suburban scheduled passenger transportation in the territory of the city of Pirot, PPP with concession elements	Services	Open	755.136.000,00	13.11.2020	12.01.2021

5. CONCLUSION

PPP implies long-term cooperation between the public and private sector to ensure financing, construction, reconstruction, management, or maintenance of infrastructural and other facilities of public importance and provision of services of public importance, which can be contractual or institutional [15]. The public and private partners invest in cooperation to ensure the reconstruction, financing, construction, maintenance of infrastructure or other facilities of public importance, etc. Nowadays, in Serbia, good practice in the terms of PPP projects is becoming increasingly stronger, which is a great success after twelve years since the adoption of the Law on Public-Private Partnership, in December 2011. As many as 272 PPP projects have been approved until 2023 by the CPPP, as in in the form of a PPP project proposal, as well as in the form of a concession act proposal. The largest number of projects are from the service sector, and they are open type projects. However, it is necessary to increase the number of these projects in the field of public lighting and road infrastructure in Serbia. A recommendation for future researchers would be a greater emphasis exclusively on the connection between PPP projects and economic growth on the example of Serbia and countries in the region.

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THE THREATS AND OPPORTUNITIES IN MODERN FORWARDING BUSINESS

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Abstract: *It's important for forwarding businesses to stay informed about industry trends and adapt to changing conditions. A robust business strategy that addresses both threats and opportunities is essential for long-term success in this competitive field. In this paper, the items that threaten the business of the forwarding company and those items that open up new opportunities are systematically defined. The paper enables forwarding companies to more easily orient themselves towards successful business in this complex environment.*
Key words: forwarding business, logistics, international economy

1. INTRODUCTION

Modern forwarding businesses, also known as modern freight forwarding or logistics companies, are entities that specialize in facilitating the efficient movement of goods from one location to another, often across international borders [1]. These businesses have evolved to meet the demands of an increasingly globalized and technologically advanced world.
Modern forwarding businesses heavily rely on advanced digital technologies and software solutions. They use sophisticated logistics management systems, transportation tracking software, and communication tools to streamline operations, provide real-time visibility, and enhance efficiency.
Modern forwarding business leverage data analytics to optimize routing, improve supply chain visibility, and make informed decisions. Predictive analytics may be used to anticipate demand fluctuations and optimize resource allocation. Modern forwarders have a global presence and often operate in multiple countries. They have an extensive network of partners, agents, and carriers worldwide, allowing them to provide comprehensive shipping solutions. Offering a variety of transportation modes, including air freight, sea freight, road freight, and rail freight, they can seamlessly combine these modes to create efficient multimodal shipping solutions. [2].
Modern forwarders have a deep understanding of customs regulations and international trade compliance. They help clients navigate complex customs procedures, documentation, and tariff classification. Many modern forwarding businesses prioritize sustainability and implement eco-friendly practices in their operations. This includes optimizing routes to reduce emissions, using energy-efficient vehicles, and exploring alternative fuels [3]. They focus on providing exceptional customer service. Modern forwarders offer online booking and tracking systems, 24/7 customer support, and personalized solutions to meet the unique needs of each client. They offer end-to-end visibility into the supply chain, allowing clients to monitor the status and location of their shipments in real-time. This transparency helps clients make informed decisions and plan efficiently. Also modern forwarding businesses understand the importance of risk management, offering insurance solutions to protect shipments against loss or damage and have contingency plans in place for supply

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chain disruptions. These companies are committed to ongoing improvement and innovation. They invest in technology upgrades, process optimization, and employee training to stay competitive and provide top-notch service Very often they form strategic partnerships with carriers, customs brokers, and other logistics service providers to enhance their capabilities and offer a broader range of services. Modern forwarders offer flexible pricing models, including transparent pricing structures and customizable solutions, allowing clients to choose the services that best meet their needs and budget. In summary, modern forwarding businesses are at the forefront of the logistics industry, leveraging technology, global networks, and customer-centric approaches to provide efficient and reliable shipping and supply chain solutions in a rapidly changing world.

2. THE MAIN THREATS FOR FORWARDING BUSINESS

Running a forwarding business, also known as a freight forwarding or logistics business, can be lucrative, but it also comes with its fair share of challenges and problems. Here are some common problems in the forwarding business:

1. Regulatory Compliance: The logistics industry is heavily regulated, and forwarding businesses must navigate a complex web of rules and regulations, both domestically and internationally. Ensuring compliance with customs, import/export laws, and safety regulations can be challenging [4].
2. Fluctuating Freight Rates: Freight rates can be highly volatile, influenced by factors like fuel prices, demand-supply imbalances, and geopolitical events. These fluctuations can impact profitability and make it difficult to plan for the future [5].
3. Competition: The forwarding industry is highly competitive, with many players offering similar services. To stand out, businesses need to differentiate themselves through pricing, service quality, technology, and other means.
4. Infrastructure and Technology: Keeping up with the latest technology and infrastructure improvements is crucial. This includes modernizing warehousing, transportation, and communication systems to stay competitive and efficient.
5. Global Supply Chain Disruptions: Events such as natural disasters, pandemics, and geopolitical tensions can disrupt global supply chains. Forwarding companies must have contingency plans in place to deal with these disruptions and ensure the timely delivery of goods .
6. Cybersecurity Threats: As businesses rely more on digital systems for tracking and managing shipments, they become susceptible to cyberattacks. Protecting sensitive customer and shipment data is vital [6].
7. Environmental Concerns: With growing awareness of environmental issues, there is increasing pressure on the logistics industry to reduce its carbon footprint. Forwarding companies may face challenges in adopting more eco-friendly practices.
8. Customer Expectations: Customers expect real-time visibility into their shipments and efficient tracking systems. Meeting these expectations requires investment in advanced tracking technology and 24/7 customer support.
9. Talent Shortage: Finding and retaining skilled employees, such as logistics experts and drivers, can be a challenge. The labor shortage can affect the quality of service and overall operations.
10. Currency Fluctuations: International forwarding businesses are often affected by currency fluctuations, which can impact pricing and profit margins. Hedging strategies may be necessary to mitigate this risk.
11. Insurance Costs: The cost of insuring shipments can be significant, and it's essential to find the right balance between adequate coverage and cost control.
12. Customs and Documentation: Navigating customs requirements and handling documentation accurately and efficiently is crucial for international shipments. Errors or delays in this area can result in fines and shipment disruptions [7].

13. Supply Chain Complexity: As supply chains become more complex, with multiple suppliers and distribution points, managing the flow of goods can be challenging. Visibility and coordination are key issues. [8].
14. To succeed in the forwarding business, companies must be adaptable, technologically savvy, and capable of providing excellent customer service while navigating these challenges effectively. Staying informed about industry trends and continuously improving operations is vital for long-term success.

3. OPPORTUNITIES FOR MODERN FORWARDING BUSINESS

The forwarding business, like many industries, is continually evolving to adapt to changing global dynamics, technological advancements, and customer expectations. Several key trends are shaping the development of forwarding businesses:

1. Digital Transformation: Embracing digital technology is a fundamental trend. Forwarders are increasingly investing in advanced logistics management systems, data analytics, and automation to enhance efficiency, provide real-time tracking, and improve customer experiences. Digital technologies have automated various aspects of the forwarding process, from order processing to document management. This has reduced manual workloads, minimized errors, and improved overall efficiency. The digitization of documents such as bills of lading, invoices, and customs declarations has streamlined administrative tasks. It has also made it easier to share and access important documents in real time [9].
2. Advanced tracking and monitoring systems powered by GPS, RFID, and IoT (Internet of Things) devices allow forwarders and their clients to track the location and status of shipments in real time. This visibility enhances customer satisfaction and helps prevent delays.
3. Data Analytics: Data analytics tools enable forwarders to gain insights from vast amounts of data. They can use this information to optimize routes, improve inventory management, and make data-driven decisions for cost reduction and process optimization [10].
4. Supply Chain Visibility: Digital technology provides end-to-end visibility into the supply chain. Forwarders can track goods from the point of origin to the final destination, ensuring better control and the ability to address any issues promptly [11].
5. Warehouse Management Systems (WMS): WMS software helps forwarders efficiently manage inventory in warehouses. It provides features such as real-time stock tracking, order fulfillment automation, and demand forecasting [12].
6. Transportation Management Systems (TMS): TMS software helps optimize transportation logistics by assisting with route planning, carrier selection, load optimization, and real-time tracking. It can reduce transportation costs and improve delivery times. [13]
7. Customer Portals: Many forwarders offer customer portals or apps that provide clients with real-time access to shipment information, documentation, and analytics. This enhances transparency and customer satisfaction.
8. Artificial Intelligence (AI): AI and machine learning are being used to optimize routing, predict demand, and improve supply chain decision-making. Chat bots and virtual assistants also help provide quicker responses to customer inquiries. Digital technology allows forwarders to remotely monitor and control various aspects of the supply chain, including temperature-sensitive cargo, security systems, and equipment maintenance. It can help forwarders reduce their carbon footprint by optimizing routes for fuel efficiency, using electric vehicles, and implementing sustainable practices throughout the supply chain [14].
1. Blockchain for Transparency: Blockchain technology is gaining traction for enhancing transparency and security in supply chain transactions. It can be used to create unchangeable records of shipments, reducing fraud and errors. While blockchain offers many advantages, its widespread adoption in the forwarding business is still in progress. Challenges related to standardization, integration with existing systems, and regulatory acceptance need to be addressed (Ahmad2021). Nonetheless, forward-thinking companies are exploring blockchain

solutions to improve their operations, increase efficiency, and enhance the overall customer experience in the logistics and supply chain industry [15].

2. Sustainability and Eco-Friendly Practices: With growing environmental concerns, forwarders are adopting sustainable practices such as optimizing routes to reduce emissions, using alternative fuels, and implementing green packaging solutions.
3. Customized Solutions: Forwarders are offering more personalized and flexible solutions to meet the unique needs of their clients. This includes tailored shipping options, pricing models, and value-added services.
4. End-to-End Visibility: Providing complete supply chain visibility is crucial. Forwarders are using IoT (Internet of Things) devices and sensors to track shipments in real-time and offer clients greater control and transparency [16].
5. Predictive Analytics: Predictive analytics helps forwarders anticipate demand fluctuations, capacity constraints, and potential disruptions in the supply chain. This proactive approach can lead to better decision-making and cost savings [17].
6. Last-Mile Delivery Solutions: Innovations in last-mile delivery, including autonomous vehicles and drones, are being explored to improve the efficiency of delivering goods to the final destination.
7. E-commerce Integration: The growth of e-commerce has led to an increased demand for efficient logistics and forwarding services tailored to online retailers. Forwarders are integrating their systems with e-commerce platforms to provide seamless order fulfillment [18].
8. Regulatory Compliance: Forwarders are keeping a close eye on changing trade regulations and tariffs. Ensuring compliance with customs and trade regulations is essential to avoid delays and fines.
9. Collaborative Platforms: Collaborative platforms and marketplaces are emerging, allowing forwarders, carriers, and shippers to connect and transact more efficiently.
10. Alternative Energy Solutions: The exploration of alternative energy sources for transportation, such as electric and hydrogen-powered vehicles, is becoming more prominent as forwarders seek to reduce their carbon footprint.
11. Customer-Centric Approach: Customer expectations for convenience and transparency are driving forwarders to adopt a customer-centric approach. Online booking, real-time communication, and 24/7 support are becoming standard. [19].
12. Geopolitical Considerations: Forwarders are closely monitoring geopolitical developments that can impact trade routes, tariffs, and logistics operations.

To thrive in the forwarding business, companies need to stay agile, adapt to these trends, and continue to innovate in response to the evolving needs of their clients and the broader global logistics landscape. In summary, digital technology has revolutionized the forwarding business by improving efficiency, visibility, and customer service. As technology continues to advance, forwarders that embrace and adapt to these innovations will be better positioned to meet the evolving demands of the global logistics and supply chain industry.

4. CONCLUSION

The forwarding business, also known as freight forwarding or logistics, involves coordinating the shipment of goods from one location to another on behalf of clients. It plays a crucial role in global trade and commerce. In summary, the forwarding business offers a range of opportunities, from embracing technology and sustainability to specializing in specific industries or regions. Success in this industry often comes down to staying adaptable, customer-focused, and informed about industry trends and regulations. There is a huge range of threats in forwarding business, from regulatory compliance to global chain disruption. The sources of a forwarding company depends on navigating these challenges effectively.

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ENVIRONMENT AND SUSTAINABLE DEVELOPMENT. MECHATRONICS. OCCUPATIONAL SAFETY AND HEALTH AND FIRE SAFETY. SMART MANAGEMENT SYSTEMS. GRAPHIC ENGINEERING. DESIGN. TRAFFIC ENGINEERING. BIOTECHNOLOGY AND HEALTHCARE. MECHANICAL ENGINEERING. ECOTOURISM AND RURAL DEVELOPMENT.

CONTEMPORARY APPROACHES TO LEADERSHIP, MANAGEMENT, KNOWLEDGE AND INNOVATION

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Abstract: *In the highly dynamic contemporary business environment, it is crucial to keep up with and implement new technological processes. The traditional concept of business has become inadequate in the pursuit of gaining a competitive advantage in the market. Understanding digitalization has become vital for productivity and efficiency in achieving company goals. It significantly simplifies and improves performance in various fields, including business, education, project management, communication, and many other areas. This paper emphasizes the importance of a good leader-manager relationship as key to business success and corporate management. Leaders and managers perform different roles and have different qualities, as well as approaches in leading employees and achieving goals. A modern approach to business encompasses various aspects related to changes in how business is conducted, resulting from technological advancements, social changes, and market evolution. A contemporary approach to business implies dynamism, rapid changes, and openness to new ideas and strategies. Companies that successfully implement these principles are usually competitive and prepared to face potential future challenges.*
Keywords: leader, management, governance, organization, artificial intelligence

1. INTRODUCTION

Contemporary approaches to leadership and management require an open and flexible mind, a willingness to change, and the ability to efficiently manage resources and people in a dynamic business environment. Modern leadership is regarded as a process different from management. It is perceived as a process in which individuals other than managers can be leaders, with a focus on leader-follower interaction. This is a relationship that aims at the mutual achievement of a common purpose, not just the leader's purpose. Leadership is a process that seeks to bring about significant change, instead of solely achieving a current primary goal [1]. In the ever-changing modern business environment, a contemporary approach to leadership encompasses a range of new strategies to effectively lead organizations. Therefore, the leader's role and abilities are of great significance for the development of an organization and the attainment of a competitive advantage. Monitoring trends, continuous leader development and improvement, and acquiring new skills and knowledge, are integral parts of modern and effective organizational leadership. Technology and management are closely linked and both are essential aspects of any type of organization. Management deals with people, resources, and processes, while the implementation of emerging technologies results in improved productivity, efficiency, and faster goal achievement. Therefore, these are two inseparable aspects of modern business that bring about an organization's competitive advantage.
This paper will highlight some of the general characteristics of a good leader, as well as the importance of management, tracking, and implementing emerging technologies to ensure the success of company operations. In order to elevate the position of an organization, it is necessary to invest in research and development, the management of which is based on fundamental knowledge and

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management principles [2]. The leader defines and guides the organization's strategy. They are responsible for shaping the vision, long-term goals, and action plans that will ensure the organization achieves its strategic purpose and objectives [3].

2. LEADERSHIP AND POWER

Leadership and the use of power are closely linked. Employees expect leaders to use power in order to achieve above-average performance. Leaders at all levels in the organizational structure must utilize power as employee loyalty is not assured [1]. There is no leadership without authority and influence.

As influence is a key element in the leadership process, power is an important capacity of leadership. Power is the ability to influence or shape the behavior of another social actor. Power is the "force" that drives the social system, or an organization [4]. By influencing someone's behavior, and often their attitudes, they are encouraged to perform the necessary activities accurately and in accordance with the company's needs and objectives. Leadership is also defined as the relationship between an individual and a group based on the influence gained through authority and power. Leaders who use their power responsibly and ethically can contribute to the development of an organization and its members. We will list a few key aspects of leaders' power and influence.

1) Legitimate Power: This type of power is derived from the leader's formal position or title within the organization. For example, a director, president, or manager holds a certain authority based on their position. Legitimate power is often the basis for decision-making and resource management.
2) Power of Reward: Leaders have the power to reward their followers, whether through financial incentives, promotions, recognition, or other forms of encouragement. This type of power can motivate and inspire employees to achieve their goals.
3) Coercive Power: Similar to Power of Reward, leaders have the power to punish employees for failure or disobedience. This type of power can be used to maintain order and discipline in the organization.
4) Charismatic Power: Charismatic leaders have a pronounced ability to inspire and attract their followers. Their influence stems from their personal qualities, charisma, and the ability to articulate their vision [4].
5) Expert Power: Leaders who possess exceptional knowledge, skills, or expertise in a particular field have Expert Power. Their influence stems from their ability to solve problems and make expert decisions.
6) Referent Power: This type of power is derived from the respect and esteem that leaders command among their followers. Leaders who are principled, ethical, and represent desired behavior acquire Referent Power [5].
7) Power of Influence and Persuasion: Leaders use their communication skills and argumentation to influence the thoughts and behaviors of others. The power of persuasion is often crucial for decision-making and achieving consensus within an organization [5].
8) Power of Networking and Social Connections: Leaders with strong connections and contacts in society or industry can leverage this networking power to attain support, resources, or information.

Leaders who use their power responsibly and ethically can contribute to the development of an organization and its members. However, the abuse of power may have negative consequences for organizational culture and employee motivation. It is important for leaders to be aware of their power and how they use it, in order to achieve positive results in the organization.

3. LEADERSHIP AND MANAGEMENT

Companies need both leaders and managers to achieve predetermined and planned goals. Leaders and managers perform different roles within organizations and have different qualities and approaches to

leading people and achieving goals. According to Kotter [5], leadership is comprised of three processes: conducting activities by developing the organization's vision, adjusting to the organization's vision through effective communication, and motivating and inspiring employees by empowering their activities despite potential barriers. In contrast to leadership, management consists of qualitatively different processes such as: planning and budgeting focused on establishing short-term goals, organizing and staffing by creating an organizational structure and allocating resources, controlling and problem-solving by monitoring the alignment of achieved results with previous plans [4,5].

Figure 1. The difference between a manager and a leader [6]
Source: https://liderioo.blogspot.com

It's important to emphasize that leadership and management are not the same concept, despite the fact that leadership is often associated with management and is crucial for management. A person can be a successful manager - a good planner and a fair, organized administrator - but lacks the motivational abilities of a leader. On the other hand, some may be successful leaders - capable of inspiring enthusiasm and loyalty - but lack the managerial skills to channel the energy they generate into others. In the modern world, many organizations consider it vital for managers to possess leadership skills [6].

4. INNOVATION AND ENTREPRENEURSHIP IN THE DIGITAL ERA

In the 21st century, the only certainty is that everything is uncertain. Furthermore, conducting business in such conditions, while dealing with increased risk and uncertainty, is a primary characteristic of entrepreneurial individuals [7]. Innovation requires introducing something new. This can entail products, technological processes, new organizational models, market offers, and so on. We often hear that we are living in the digital era. Digital innovations represent the application of emerging technologies and digital resources to enhance existing products, services, and business processes, or to create entirely new products and business models. These innovations play a crucial

role in modern business and society and can be applied across various sectors. We will provide a few examples of digital innovations and how their implementation affects a variety of areas.

a) E-commerce and M-commerce: Digital innovations are crucial in the development of e-commerce and mobile commerce. Online stores, digital shopping platforms, and mobile applications enable users to purchase products and services via the Internet and mobile devices. This has transformed the way retailers operate and consumers shop.
b) Financial Technology (Fintech): Digital innovations in finance encompass new payment methods, financial management, loans, and insurance. Fintech companies utilize technologies like blockchain, artificial intelligence, and mobile applications to enhance financial services and make them more accessible [8].
c) Healthcare: Digital innovations have led to the development of telemedicine services, mobile health tracking applications, electronic health records, and artificial intelligence for medical diagnosis. This has improved access to healthcare and facilitated health monitoring.
d) Education: Digital innovations have led to the development of online education, e-learning, and mobile learning applications. Learning Management Systems (LMS) make it easier for teachers and students to track and assess progress.
e) Transportation and Logistics: Smart cities, autonomous transportation, cargo tracking technologies, and route optimization are all outcomes of digital innovations. This can improve transportation efficiency and reduce environmental impact.
f) Artificial Intelligence and Machine Learning: These technologies enable computers to learn and improve their performance in various tasks. They are used in data analysis, pattern recognition, service personalization, and many other applications.
g) Blockchain Technology: This technology enables a secure and transparent way to store and exchange data. Its most well-known application is in cryptocurrencies, but it is also used for creating secure supply chains and data management.
h) Internet of Things (IoT): IoT refers to physical device networking with the aim of exchanging data and information. This technology is used in smart homes, smart cities, manufacturing, and other sectors.
i) 3D Printing: A digital innovation that enables the creation of physical objects layer by layer. It is used in manufacturing, medicine, and many other fields.

Companies and entrepreneurs who can leverage the advantages of these innovations are often more successful in the modern digital age. The digital era requires entrepreneurs to be flexible and quickly adapt to changes in technology and the market. Digitalization enables the creation of new business models, such as subscription services, freemium models, and other revenue-generation methods. Entrepreneurs face competition from around the world and must also be cautious about data security and the privacy of their clients.

5. APPLICATION OF ARTIFICIAL INTELLIGENCE (AI)

When it comes to the application of artificial intelligence in business, opinions are divided. Artificial intelligence facilitates work and life in many areas, but its rapid development, advancement, and implementation raise numerous security and ethical issues. The fact remains that its application can be a great help to leaders and managers in various ways. AI can analyze large amounts of data faster and more accurately than humans. Leaders can use AI to make better data-driven decisions, which contributes to efficiency and success. Routine and time-consuming tasks can be automated in favor of AI, freeing up time for leaders to think creatively and strategically. AI is used for resume analysis and identifying candidates that best fit specific positions, thereby streamlining the recruitment and selection process. It can also be used for developing personalized training and education for employees. Leaders can ensure that team members acquire relevant skills and knowledge. Through the use of virtual assistants, performance monitoring, and evaluation, AI can identify possible risks

and alert leaders to potential threats, allowing them to prepare for crisis situations in advance. Chatbots and conversational AI systems can enhance leaders' internal and external communication.
AI can assist leaders, but it cannot completely replace the human element in leadership, such as empathy, moral leadership, and creativity. AI should be used as a tool to support leaders in their activities and decision-making.
The primary modern trends for the development of AI systems include expert systems development and neural network development. Expert systems attempt to replicate human thinking patterns through symbols, while neural networks do so from a biological perspective, mimicking the structure of the human brain with the help of genetic algorithms. Many scientists are skeptical about the possibility of developing true AI. The functioning of human thought patterns is still not entirely understood, which is why the computer design of intelligent systems will remain fundamentally incapable of representing these unknown and complex processes for a long time to come [9].

6. CONCLUSION

With this paper, we have observed that the modern approach to leadership, management, knowledge, and innovation is deeply rooted in rapid technological changes. While technology plays the main role in this changing landscape, the human factor is irreplaceable in leadership and management. Empathy, communication, and moral leadership remain essential aspects of successful leadership. Rapid changes require leaders and managers to be continuously educated and ready to adapt to new situations and challenges. This includes developing skills in problem-solving, creativity, and decision-making. Keeping up with technological trends and innovations is crucial for the survival and growth of organizations in the modern business world. Leaders should encourage a culture of innovation and knowledge management to create a competitive advantage. Organizational structures are shifting towards greater horizontal communication and collaboration. Although leaders and managers have different roles and responsibilities, their collaboration and cooperation play a crucial role in achieving organizational goals. The link between leadership and management is essential for the organization's success.
Essentially, leaders and managers together form the "dream team" for managing an organization. Their close collaboration enables a balance between inspiration and execution, long-term goals, and day-to-day operations, which is the key to the success of an organization in today's complex business environment.

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ENVIRONMENT AND SUSTAINABLE DEVELOPMENT. MECHATRONICS. OCCUPATIONAL SAFETY AND HEALTH AND FIRE SAFETY. SMART MANAGEMENT SYSTEMS. GRAPHIC ENGINEERING. DESIGN. TRAFFIC ENGINEERING. BIOTECHNOLOGY AND HEALTHCARE. MECHANICAL ENGINEERING. ECOTOURISM AND RURAL DEVELOPMENT.

STYDY ON THE ATTITUDES OF ELECTRONIC BANKING USERS IN SERBIA

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Abstract: *Global changes in the sphere of business as well as the development of technology create great opportunities in the banking sector and in this way banks improve their services, reduce business costs and improve their operating efficiency. The first development of new electronic banking services in Serbia took place in 2003, and until today they have experienced major transformations in terms of improving electronic banking platforms. However, since its inception, the development trend was very slow when compared to developed countries. These limitations are reflected in information illiteracy and the population`s lack of interest in the changes offered by the bank in the market for services. In recent years, and especially during the corona virus pandemic, the use of electronic and mobile banking has increased greatly. Banks have made some progress in terms of customer trust and promotion of new electronic services, all in order to have a positive impact on their users. In this paper, the authors described the history, development and use of electronic banking, and they conducted a research on the territory of Serbia with the aim of finding out what are the further directions of the development of electronic banking services.*
Keywords: electronic banking, development, research, bank and Serbia.

1. INTRODUCTION

The development of IT technology has had a positive effect on the expansion of business in all spheres of business. With the application of computer processing as well as the use of modern means of communication, changes have taken place in the world of business in all major companies. Electronic business developed slowly. The traditional form of business as well as paper documentation has been replaced by a new type of business. Today`s business is based on a contemporary modern digital platform that allows business transactions to be carried out electronically, which is called e-business [1]. Electronic business has proven to be applicable in practice and it is certainly preceded by the emergence of the Internet. The Internet represents the most developed global medium that has enabled faster, more accessible, affordable and mass communication. Internet technology has led to the fact that certain products and services on the basis of which the business operates are on the market, and thus they have acquired the element of information. Thus, electronic business represents the use of technological solutions both for the exchange of business information, as well as maintaining business contracts and conducting transactions with the use of modern devices. As evidence that electronic business affects business, we can see that hundreds of billions of sales and financial transactions are made in the world annually. That is why electronic business is a term that is recognizable in many different economic and state entities. Today there is e-commerce, e-government, e-banking, e-learning, e-health, etc. Electronic business is a process that is carried out with the help of a computer network and refers to a broader concept than electronic commerce, while electronic banking is only one area of electronic business [2]. New digital technologies allow banks to enter the market with the

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help of an electronic platform and thus move their business from their branches to the clients` premises that suit them best. Banking services are provided with the help of new distribution channels, i.e. the Internet [3]. Electronic banking is a system that provides clients with access from their computers and therefore general information about the services offered by the bank via the Internet [4]. Electronic banking represents the use of technology by the bank to connect with its clients and enables the provision of financial services [5]. Hence, electronic banking represents a set of several ways of performing financial transactions using information and telecommunication technologies. The most frequently used synonyms for electronic banking are internet banking, PC banking, online banking and home banking [6]. The most commonly used means for performing financial transactions in electronic banking are smart cards, payment cards, QR code, electronic wallet and digital money. U istraživanju autora In the research of the authors Vehapi et al., based on the values shown, it can be established that the respondents have the most favorable attitudes regarding the statement Using internet banking saves my time (AS = 4.53), while the most unfavorable views are expressed regarding the statement Internet banking enables quick response to customer complaints (AS = 3.72) [12]. While, Đekić and his colleagues point out that the use of the Internet in the Republic Serbia is showing increasingly intense growth, the domestic market has good initial characteristics for a more successful implementation of electronic banking [13]. The structure of this paper is as follows: in the second section, a literature review is presented. The third section provides information on the methodology used in this paper as well as the results obtained in this research. At the end of the paper, the authors proposed further research directions and guidelines that the management of the banking sector could use.

2. DEVELOPMENT OF ELECTRONIC BANKING IN SERBIA

Beginning in 2000, countries in transition are slowly starting to achieve growth in the use of electronic banking services [7]. The change in the banking sector began in 1992, but major changes began after 2000, when Serbia became ready for the arrival of foreign banks [8]. With the adoption of the Law on Payment Services on January 1st, 2003, and with the Decision on the electronic method of making payment transactions, which is contained in the Law, and the institutional conditions for the beginning of the development of electronic banking are enabled. All payment transactions were then transferred from the state to the banking [9]. In the last twenty years, a large number of reforms have been implemented in the financial sector in Serbia, and a significant reform was the development of electronic banking and the reform of the payment systems. The new Law on Payment Services was passed by the National Assembly of the Republic of Serbia, and its implementation began on October 8th, 2015 and this Law defines payment via the Internet and mobile applications. It has been completely modified according to the standards that are regulated in the countries of the European Union, so that Serbia has an efficient and modern payment system. The Law was adopted with the aim of improving and modernizing payment transactions in Serbia and establishing cooperation with foreign countries with the aim of introducing electronic money institutions. This Law introduced greater competition in the field of payment services, it introduced payment institutions and electronic money institution, regulated three areas: the payment system of Serbia, electronic money and payment transactions, and it also adopted the protection of financial services consumers and competitive market.

The development of electronic banking in Serbia is reflected in the installation of a greater number of ATMs, POS terminals, as well as the introduction of new payment instruments. The following cards are in use: VISA, Master, as well as the national DinaCard. Payment cards are starting to be used mostly when paying for goods and services and at ATMs. Every client has access to the bank and its services throughout the day, which is made possible by the electronic banking service. Banks have joined the new interbank settlement systems based on world principles, where they use RTGS systems, better known in our country as the SVP system for priority and large payments. For small payments in Serbia, the Clearing or SMP Small Payment System is applied.

3. RESEARCH METHODOLOGY AND RESULTS

The aim of the research is to examine the existing secondary sources on electronic banking and to indicate which elements are used the most. The primary aim of the research is to examine the presence of electronic banking in Serbia based on the users` opinions, as well as what are the advantages and disadvantages of electronic banking. Based on the report of the National Bank of Serbia, the indicator is that the number of card transactions and electronic money transactions which were used for purchasing goods and services online, has increased. Thus, in the first trimester of 2023, a total of 12,489,426 transactions of goods and services were made online with cards and electronic money in all currencies, which is 25.42% more than in the first trimester of 2022 [10]. In the research of Todić et al. (2018), it was concluded that 62% of respondents use mobile banking services, while 74% are satisfied with mobile banking services [11]. The initial hypothesis is: H_0 A large number of respondents use e-banking. H1 The e-banking users have full confidence in this system. H2 Users believe that the technical part of the application should be improved in the future.

The total sample consists of 150 respondents. The survey was conducted online in the period from the beginning of January to the end of February 2023. Below is a tabular representation of the structure of the sample in relation to the gender of the respondents.

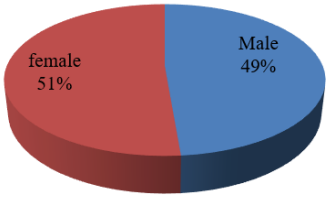

Figure 1 Sample structure with regard to the gender of the respondents
Source: Authors

With regard to the gender of the respondents, the highest response was among female respondents, but this difference was not significant. The following figure shows the structure of the respondents in relation to the age structure.

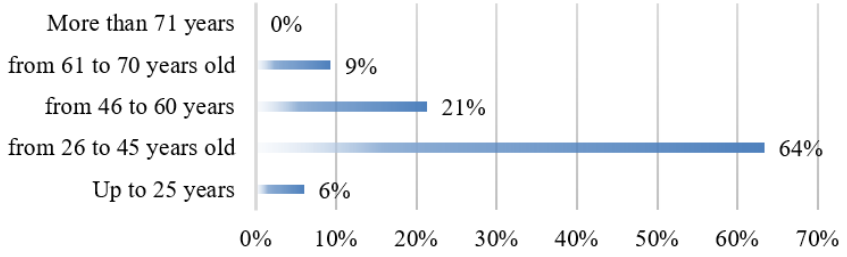

Figure 2 Sample structure with regard to the age of the respondents
Source: Authors

As far as the age population is concerned, the highest response was among respondents in the 26 to 45 age range. Figure 3 shows the structure of the respondents in relation to the educational level of the respondents.

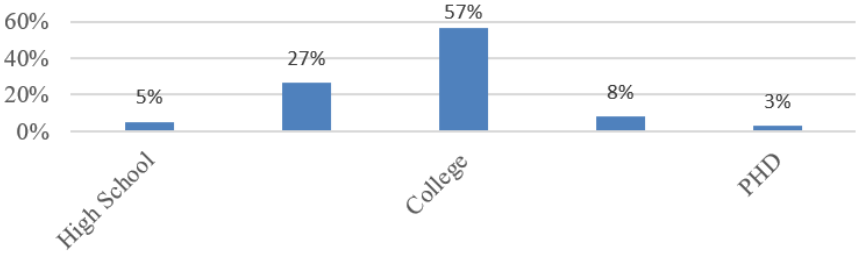

Figure 3 Sample structure with regard to the educational level
Source: Authors

From the aforementioned reseach, we can conclude that college graduates use electronic banking services most often. Educated respondents mostly use electronic banking. Figure number 4 shows the structure of the respondents in relation to the place of residence of the respondents.

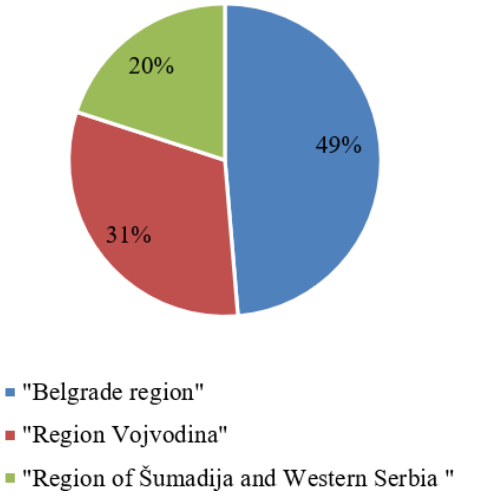

Figure 4 Sample structure with regard to the respondents` places of residence
Source: Authors

In relation to the place of residence, the largest number of respondents were from the capital which is also the main financial centre. The following figure 5 shows the structure of the sample in relation to the height of the monthly peaks.

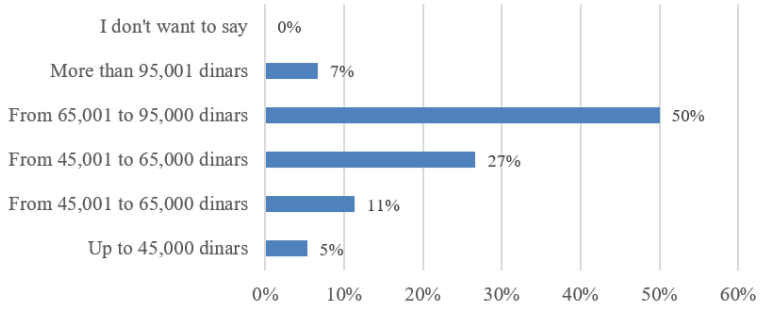

Figure 5 Sample structure with regard to the amount of monthly income
Source: Authors

The obtained results show that most respondents have incomes from 65,001 to 95,000.00 dinars. The following figure number 6 shows the structure of the respondents in relation to the working status of the respondents.

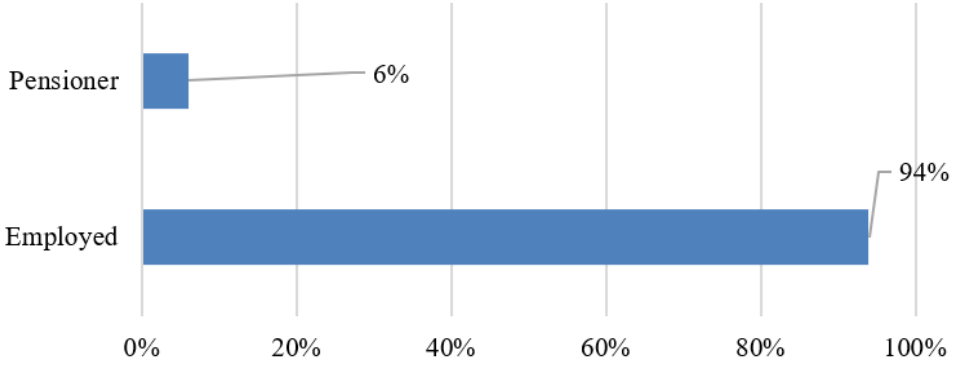

Figure 6 Sample structure with regard to the employment status of the respondents
Source: Authors

When we analyse the employment status, the majority of the respondents are employed. Figure 7 shows the percentage of respondents who have a bank account.

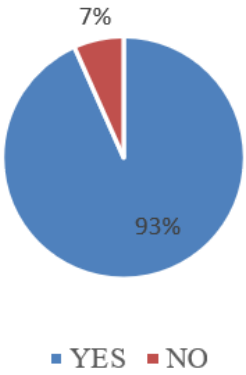

Figure 7 Do you have a bank account?
Source: Authors

We came to the result, after the analysis, that almost all respondents have bank accounts. The following 8 shows the structure of respondents who use electronic banking services.

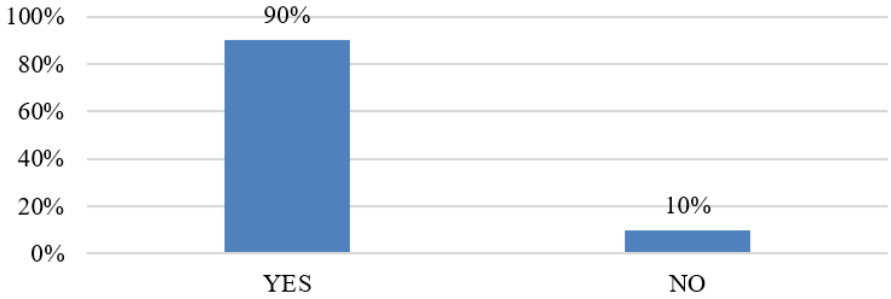

Figure 8 Do you use electronic banking?
Source: Authors

Based on the answers to this question, over 90% use e-banking. Figure 9 shows the structure of respondents in relation to the lack of electronic banking.

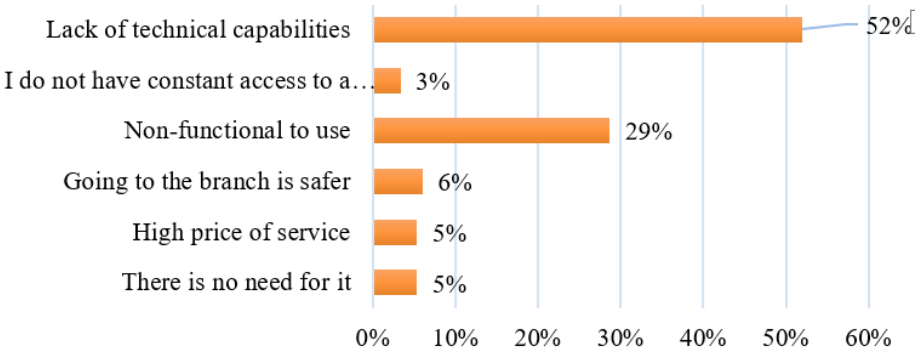

Figure 9 What do you consider to be the biggest disadvantage of e-banking?
Source: Authors

The majority of respondents believe that in the coming period banks could improve the technical characteristics of electronic banking, as they are considered as shortcomings. They include ease of use, privacy, execution of payment orders. The biggest problem is that temporary employees cannot use all electronic banking services. Many banks have merged in Serbia. For this reason, most transactions made through electronic banking are not stored.
The largest number of respondents, 32%, use electronic banking services two to three times a month, and 29% use it once a month. The following figure number 10 shows the structure of the sample in relation to the respondents' opinion as the most important element of electronic banking.

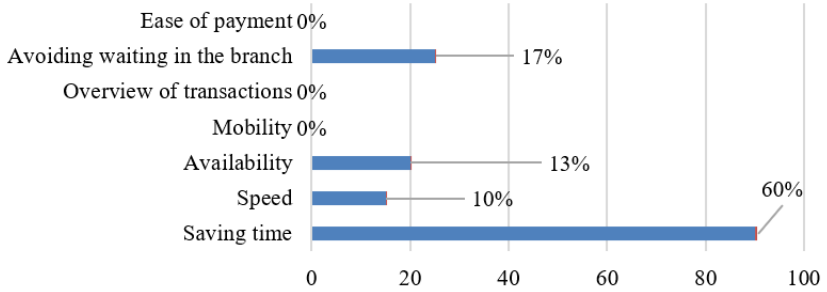

Figure 10 What is the most important element of electronic banking for you?
Source: Authors

The most important element of e-banking is saving time. Analysing the extent to which the respondents are satisfied with the e-banking service, 73% of respondents gave it the highest rating. When asked in which bank they have accounts, the largest number of respondents have accounts in the following banks: Intesa 39.2%, Postal Savings Bank 32.9%, Raiffeisen Bank 18.1%, while slightly less than 10% have accounts in other banks. When asked if they have paid for services by e-banking, almost 95% of respondents answered affirmatively. To the question related to security, trust and data protection, 59.3% of respondents expressed satisfaction, 22.5% respondents were satisfied with data protection, and 18.2% of respondents are in the middle and are not sure if their banks keep information about them. When asked whether they think that e-banking will replace traditional banking, 72.1% of respondents answered affirmatively. When asked if they would recommend e-banking, 52.6% of respondents answered affirmatively.
H_0 A large number of respondents use e-banking wass confirmed in the research. H1 The e-banking users have full confidence in this system was confirmed in the research. H2 Users believe that the technical part of the application should be improved in the future the same is confirmed in table number 9. In the coming period, banks will adapt and introduce new electronic services. Traditional banking will exist to a minimal extent.

4 CONCLUSION

The practice of using internet banking services has become an immanent part of the everyday life of the average banking client in developed countries. Although with some delay, similar trends are also noticeable in developing countries. The improvement of the range, quality, level and convenience of using banking services are the consequences of the introduction and development of internet banking and the key reasons for the growth of its market share. Clients of electronic banking are becoming more aware of the benefits it provides. This is indicated by the growth indicators of the number of users. We should not ignore the fact that electronic banking is still not sufficiently implemented in an adequate manner in Serbia. This refers to certain services that most banks do not currently provide. With the epidemiological situation that affected the world and Serbia, the population quickly adapted to the new ways of bank operations. Even before the corona virus, banks were ready for this type of business and relationship with their clients. Today, e-banking is becoming a synonym and is applied in all spheres of banking business. Based on primary and secondary sources, we can conclude that the young population uses e-banking, but not to the extent that banks expect. In Serbia, electronic banking is expanding and its maximum has not been reached yet. Only some banks in Serbia operate online (these are Yettel and Pro Credit Bank). Other banks tend towards online business. Certainly, in Serbia and the neighbouring countries, it is impossible to imagine bank operations without traditional banking for the time being. In the coming period, a large number of banks will merge, and banks should improve and simplify e-banking platforms. Further research, as well as marketing activities, should be focused on young people so that they animate older population to adapt as much as possible to today`s needs. Also, it is necessary to examine the legal regulation of electronic banking. When it comes to the limitations of the conducted research, it should be emphasized that the research sample was relatively small, and future research should include a larger sample of

respondents. It is a convenience sample in which respondents of all age groups participated and all regions of Serbia were included.

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NEW TECHNOLOGIES, LABOR MARKET AND HUMAN RESOURCES

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Abstract: *Continuous adaptation of company size and internal configuration to the demands of social, technical, technological, and market factors is conditioned by dynamic changes in their external environment, which leads to endless alteration of a company's existing position. A company can enhance its position by actively influencing external environmental factors through an appropriate response to challenges and opportunities from its environment. As a result of such behavior, the company enters a process of growth and development. Company growth is the process of increasing the size of an enterprise and can manifest as an increase in: the number of employees, strength and installed capacity, total revenue, market share, profit, and so on. The process of company growth, as an uncertain consequence of its efforts to improve its position, often leads to diversification of the company's activities, changes in its organizational structure, and other adaptive changes.*
Keywords: emerging technologies, labor market, human resources, manager

1. INTRODUCTION

Emerging technologies bring significant challenges and have a profound impact on the global labor market. One of the greatest contemporary challenges is the need for the development of new skills and knowledge of employees. Managers play a crucial role in management and organization, and should therefore be prepared for change and having to adapt to new challenges. Developing a strategy with an innovative approach to hiring and candidate selection facilitates the identification of talents that can contribute to the success of an organization in the modern business environment. Additionally, the challenges brought about by automation and artificial intelligence in terms of employment should be taken into consideration. These technologies may lead to increased productivity and efficiency, but may also lead to workplace redundancy. In the modern business environment, company growth and development are directly linked to technological advancements and changes in the labor market. Companies that adapt to emerging technologies and market demands can achieve long-term vitality and competitiveness in their respective industry. In this regard, managers play a crucial role in the development and implementation of emerging technologies in business. They must be ready to recognize and seize new opportunities while developing new skills and competencies for managing employees in the modern business environment [1]. As a result, the growth and development of a company must be observed together, while taking into consideration their mutual interaction and synergistic effects. In this context, the analysis of a company's growth and development processes, in addition to their relationship with technological advancements and the labor market, is crucial for devising effective company development strategies and success in modern business. Companies that aim for long-term digitalization should consider their organizational structure, accumulation capacity, and size as part of the growth and development process. There are two elementary forms of growth and development [1]: directed development, which is the result of a company adapting to market changes, and autonomous development, which entails a proactive response to market changes and adopting innovation. However, in the real world, the distinction

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between these two forms of development is often unclear, as there are numerous transitional forms. Companies should analyze the functionality of development factors when forming their development policies and strategies. In this regard, the role of the technology market is crucial in shaping the company's development strategy.

2. PREREQUISITES FOR THE PREPARATION AND LAUNCH OF MODERN APPROACHES TO EMERGING TECHNOLOGIES

In order to prepare and implement modern approaches to emerging technologies, certain prerequisites must be met. This includes, first and foremost, understanding and assessing market needs, as well as identifying industry trends that can be utilized to enhance existing products and services. It is also necessary to secure financial resources for the implementation of emerging technologies, as well as skilled personnel responsible for the aforementioned implementation and maintenance. Additionally, it is vital to have a clearly defined development strategy focused on the company's long-term goals and building relationships with key partners and suppliers in order to achieve synergistic effects. All of these prerequisites must be carefully planned and calibrated to ensure the successful adoption of emerging technologies and the creation of a competitive advantage in the market. A company conducts various activities during its business operations to maintain and improve its market position. These activities are a result of the company’s need to adjust to the demands of its environment, primarily the market, and they manifest as changes in the type and scope of operations, product range, organizational structure, and technological foundation. Company development is a process of adaptation to changes and environmental requirements. To make this process efficient, the company must identify the factors influencing its development, as well as the key characteristics of these factors [1]. Taking this into consideration, the company conducts suitable activities in accordance with its capabilities, needs, and business objectives. It is important to differentiate between factors depending on their impact on the company's business operations. One group of factors may pose a challenge and, if adopted, an opportunity for development and prosperity. Another group may include factors that, if not accordingly taken into account, could pose a threat to the company's business operations and lead to its cessation. However, the same factor can be both an opportunity and a threat to the company's business operations. Should a company fail to monitor contemporary technological trends in its field of business, it will jeopardize its competitive position and survival.

A series of activities should be conducted in order to maintain and enhance the market position of a company. These activities arise as a result of the company's response to the demands of its environment, primarily the market, and are manifested through changes in the type and scope of operations, product range, organizational structure, and technical and technological foundation. The aforementioned changes reflect the company's ability to adapt and change according to the demands of its environment and depending on its capabilities and conditions for survival, alongside market position improvement. Company development represents the process of approaching modifications and environmental requirements. For this process to be effective, the company must identify the factors influencing its development, as well as the fundamental characteristics of these factors.

3. THE IMPACT OF EMERGING TECHNOLOGIES ON THE LABOR MARKET

Emerging technologies such as artificial intelligence, automation, blockchain, etc. have had a significant impact on the labor market and the way employees prepare for new jobs and challenges. The impact of emerging technologies on both unemployment and employment rates can differ depending on the industry sector and areas of business. Automation and artificial intelligence can have a significant impact on unemployment rates in sectors where jobs are repetitive and require manual labor. Such jobs are prone to a reduction in the human workforce in favor of machines. On the other hand, the use of new technologies also creates new jobs that require different skills and qualifications, which in turn leads to changes in the qualifications sought after in the labor market. For example, increased use of artificial intelligence, data analysis, and machine learning is driving up

demand for experts in these fields. Additionally, blockchain technology has the potential to affect unemployment rates in the finance sector, as it can automate many processes and reduce the need for human labor. Emerging technologies also affect different sectors in different ways. For example, the manufacturing sector has already undergone significant changes with the use of automation in production lines, while the education and healthcare sectors are still undergoing changes due to the increased implementation of emerging technologies. In any case, the impact and introduction of emerging technologies to the labor market and employment will vary depending on the industrial sector. Therefore, managers must be prepared to adapt to new technological trends and develop new skills to successfully manage employees in a new business environment.

In the late 1970s, the emergence and introduction of information and communication technologies caused a change in the way many organizations conducted their business. The development of the first communication media, such as the telephone and the fax machine, was followed by the advancement of computers and sophisticated forms of high technology, such as computer network systems, optical technology, satellites, and wireless technologies. Electronic business and the Internet have become indispensable in today's globally interconnected business world, altering the very concept of business. Nearly every major organization today has developed its own intranet, an internal organizational communication network that uses Internet technology and is accessible only to employees. Not only does this significantly contribute to the collection and distribution of knowledge, but it also facilitates and accelerates the decision-making process in business. The use of information and communication technology and modern information systems in business can be observed at three levels: at the production level, at the organizational level including management, and at the general level, which refers to broader global application. Management Information Systems (MIS) provide the information that organizations require for efficient and effective management. These are computer systems used for the analysis and facilitation of strategic and operational activities, providing managers with the data required to make decisions and solve problems. The Enterprise Resource Planning (ERP) system is a business management software that a company can use to store and manage data from every phase of its operations.

Technology has a significant impact on organizational behavior, and management must keep pace with and adopt technological changes while simultaneously aligning technological and sociological aspects. People, both employees and customers, should be regarded as crucial organizational resources, and management should not prioritize technology over them. Technological development and new forms of business that may emerge in the future could significantly change the existing forms of many organizations. Small, technologically advanced organizations boast organic structures and work in teams of highly skilled professionals who create new products and improve existing ones through better communication and collaboration among employees. It is imperative to monitor technological changes and align them with the needs of both employees and customers, in order to enable the organization to successfully adapt to new challenges and remain competitive in the market.

4. NEW ORGANIZATIONAL STRUCTURES THAT HAVE APPEARED IN THE MARKET DUE TO EMERGING TECHNOLOGIES

Lately, technological progress has led to the creation of new organizational structures. Rapid technological changes, international trade, and competition have put pressure on organizations' ability to keep up with new and often unpredictable competitors. Therefore, senior managers in many organizations are engaged in the development of new structural possibilities. New organizational structures arise from technological innovations that lead to "creative destruction of the industry" or technological advancement that replaces existing competencies. There are two outcomes of the search for new competitive approaches [2]:

1. The creation of a new organizational structure that requires a unique combination of strategy, composition, and management processes, i.e., a dynamic network. This new structure is both the cause and the consequence of the competitive modern environment, as the "same competitive

beast" that some companies do not understand serves as a solution to the competitive challenges of other companies.

2. The new organizational structure necessitates the development of new concepts that explain the meaning and functions within this process while providing fresh insights into the functioning of existing strategies and structures. In the future, many organizations will be designed using concepts such as vertical disintegration, internal and external intermediation, complete information system transparency, and market failures against administrative mechanisms.

The new organizational structure is both the cause and effect of the changing competitive nature; therefore, many organizations believe that their structure and management require modification for the organization to formulate new strategies that would meet the latest competitive conditions [3]. In this chapter, various new structural designs are typically described, such as: team-based organizational structure, network organizational structure, digital organizational structure, and T-shaped organizational structure.

4.1 Team-based organizational structure

The team-based organization is one of the latest approaches to creating an organization. It places teams at the center of the organization, leading to increased organizational dynamism. Team-based organization breaks down the barriers between certain organizational units or parts of the organization and makes the organizational structure more flexible [4]. Team structures are often used to eliminate possible weaknesses in organizational functioning, and many globally recognized companies incorporate them into their preexisting structure. The need to strengthen horizontal connections within the organization and create greater flexibility leads to the formation of various types of teams focused on solving different problems. In a team-based organization, the teams are important for achieving a joint work result, while bringing together people with different ideas and knowledge to solve a specific problem. Teams provide the organization with the necessary flexibility to respond more quickly and efficiently to the demands of a constantly changing environment, while simultaneously serving as a mechanism that gathers the knowledge and skills needed to solve complex work tasks. A team's success requires a joint purpose, a shared approach, mutual accountability, as well as complementary knowledge and skills [5]. The team-based organization is one of the latest approaches to creating organizations. In such an arrangement, teams take center stage, contributing to the company's dynamism. Team organization allows for the removal of boundaries between individual organizational units and makes the organizational structure more flexible. Team structure is most commonly used to eliminate functional structure weaknesses by introducing organic structure elements into existing organizational models. For a team to operate successfully, team members must share a common purpose and approach. Additionally, a team should practice mutual accountability and possess complementary knowledge and skills. The size of the team is also important, with an optimal range of two to ten members. Teams can be formed at different levels and in various parts of the organization. The most common types include advisory, action, project, cross-functional, production, self-managing, and virtual teams [4]. Based on the provided information, it can be concluded that teamwork is being increasingly used in many modern organizations. The team-based organizational structure typically consists of various teams that coordinate their activities and collaborate directly with partners and customers with the aim of achieving objectives [5]. In this organizational model, the hierarchy is notably flat (Figure 1).

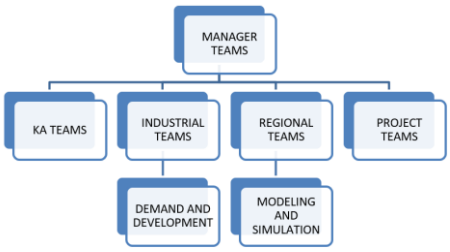

Figure 1. Global team organizational structure
Source: https://shorturl.at/nBLU9, (Accessed: 1 Apr. 2023)

In team-based organizations, as in all other modern forms of organization, information technologies play a significant role in team member relationships and performance [5].

4.2. Digital organizational structure

There are various definitions and descriptions of digital organizations that differ from one another, but they all use terms such as the absence of a physical structure, reliance on information and communication technology, transcending traditional boundaries, networks, mobility, and flexibility. A digital organization is considered to be a temporary network of participants (which can include entire organizations, parts of organizations, teams, or specific individuals) connected by information and communication technology, who flexibly coordinate their activities and combine their knowledge and resources to achieve common goals, without relying on traditional hierarchical structures of centralized direction and control. The coordinating entity in a digital organization is the organization itself, by using information and communication systems to synchronize all activities in the digital network. Both in practice and in the business world, we encounter several types of digitalization, ranging from long-distance outsourcing to employees using only the phone and email for global communication. Significant types of digital organization that are most commonly observed include digital products and services, remote work, mobility, and digital teams [6].

4.3 Network organizational structure

Outsourcing has led to organizations retaining solely their core activities while forming networks with their outsourcing partners to better respond to customer demands for a comprehensive product or service. Networking is the way a virtual organization is realized. It emerges as a response to the more complex business conditions and the increasing speed of change in business operations. Given the progressively complex and unpredictable environment in which modern enterprises operate, a growing number of companies are resorting to networks or a network organizational structure, whereby they find protection from market uncertainty. The network organizational structure is regarded as the most modern 21st-century organizational form; it is rapidly expanding, and due to the unlimited possibilities of entering and exiting the network, it is considered an organization without borders [7]. As a rule, a network organization lacks structure, while members of the network typically operate in a flat organizational structure. Enterprises connect in various ways, which is why there are networks with chain, networking, or multi-channel network forms. In a chain network form, only a certain number of network members have direct connections, while others have only indirect ones. In a networking network form, there is a key member who plays a crucial role in the network and is connected to the other members (Figure 2). A multi-channel network form is modular and flexible, making it a dynamic organization with open membership which, although imperceptible, connects all its members via computers. The biggest advantage of this network form is its adaptability, which allows gathering an amount of knowledge otherwise impossible in any individual enterprise.

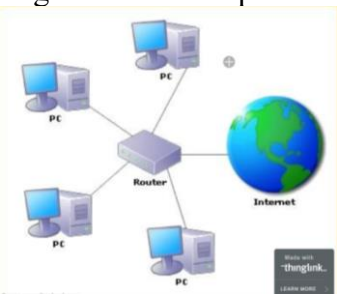

Figure 2. Network organizational form - networking
Source: https://shorturl.at/axzNT (Accessed: 2 Apr. 2023)

Organizational networking is considered one of the most important trends in the modern business environment, and its primary purpose is to reduce uncertainty and risks that are increasingly present in the organizational environment [7].

4.4 T-shaped organizational structure

The T-shaped organizational structure represents a fusion of traditional physical organization and digital components that include customers, suppliers, competitors, strategic agreements, and other partners. By establishing a digital organization structure, everything that was once handled with traditional paperwork is replaced with digital records and electronic connections. This enables a connection between customers and suppliers, ensuring the delivery of goods to the customer on a "Just in Time" basis [8]. The key characteristics and advantages of the T-shaped organizational form, or technological organization, include a high degree of managerial freedom in shaping the organizational structure, the ability for management to communicate with a much larger number of associates, significant organizational flexibility, electronic (digital) connections between customers and suppliers, trust-based rather than control-based supervision, replacement of functional units in favor of project teams, comprehensive education, and a focus on customer satisfaction [5]. The matrix organizational structure, which was temporarily neglected due to conflicts between line and project management, has been reintroduced as a result of information technologies providing it with positive change and flexibility [5]. Along with the advantages offered by the T-shaped organizational structure, such as project teamwork, merging organizations in strategic clusters, the establishment of digital departments, and remote work, internal organizational conditions are developed. Furthermore, digital communication and remote employee supervision are established. However, a key disadvantage of the T-shaped organizational form is its dependence on external partners.

5. CONCLUSION

The previous chapters of this paper discussed new technologies, and touched upon various descriptions of organizational structures and networked organizations, along with the impact of information and communication technologies on organizations and employees. It is evident that modern technologies have created not only new challenges, but also new opportunities for employees, and that managers are a key factor in motivating and retaining quality employees in the modern business environment. Additionally, through examples of different organizational structures, this paper has observed the different ways in which emerging technologies are used in business organizations and how they can affect organization efficiency and flexibility. In the modern business era, the implementation of new technologies can help automate routine tasks, freeing up space for innovation and creativity. Managers must keep up with innovation development and adopt the latest digital tools. In order to increase productivity and maintain adequate productivity levels, managers must be sufficiently tech-savvy to effectively apply emerging technologies, work with digital tools, and understand the development of a digital strategy. Additionally, emerging technologies enable enhanced collaboration and communication on a global scale, the development and presentation of the latest products, and networking with business partners on a global scale.

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THE IMPACT OF THE KELVIN REDEFINITION WITHIN THE SI SYSTEM ON THE IMPROVEMENT OF TEMPERATURE MEASUREMENT TECHNOLOGIES

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Abstract: *In May 2019, four of the seven base units of the International System of Units (the SI): the kilogram, the ampere, the kelvin and the mol, were redefined in terms of fundamental physical constants. The SI unit of thermodynamic temperature, the kelvin, symbol K, is no longer based on an exact value for the temperature of the triple point of water (T_{TPW} = 273.16 K), but instead on a fixed value of the Boltzmann constant ($k = 1.380\ 649 \times 10^{-23}$ J K^{-1}).*
The kelvin redefinition led to the development of primary-thermometry methods and the realization of first practical thermometers linked to the redefined kelvin. An early version of such thermometers are the so-called Johnson noise thermometers. It is predicted that with the development of Johnson noise thermometry (JNT), the need to calibrate conventional temperature sensors, such as thermocouples or platinum resistance thermometers, will eventually become unnecessary due to the fact that this primary temperature measurement technique is not subject to sensor drift. Therefore, in this paper, advances in Johnson noise thermometry and its perspective both for metrological measurements and for practical application in industry, were discussed.
Keywords: kelvin redefinition, triple point of water, energy of molecular motion, thermodynamic temperature scale, Johnson-noise thermometry

1. INTRODUCTION

Temperature, a fundamental physical quantity, plays a significant role in various aspects of our lives, from scientific researches and medical diagnosis to industrial processes and everyday comfort [1]. For example, in industrial production processes, accurate temperature measurements are necessary to control product quality, optimize production and ensure product consistency.
Measuring temperature has a long history. In the 3rd century BC, the ancient Greek engineer Philo of Byzantium (c. 280–c. 230 BC) came up with what may be the first thermometer-like device: a hollow sphere filled with air and water, connected by tube to an open-air pitcher. The idea was that the air inside the sphere would expand as it was heated (e.g. if the sphere is exposed to the sun) and bubbles will be released, pushing water into the tube. Conversely, when the sphere is moved into shade, the air inside the sphere would contract due to cooling and water rises in the tube. It was later noticed that the air contracted in volume by about one third as the sphere was cooled from the boiling temperature of water to the ice point. This caused scientists to speculate on what would happen if one could keep cooling the sphere [2,3]. In the middle of the 19th century, British physicist William Thomson, 1st Baron Kelvin (1824–1907), also became interested in the idea of „infinite cold“, a state we now call the absolute zero of temperature. He estimated that absolute zero was approximately –273 degrees on the Celsius scale (–273 °C). In honor of his research, the unit of absolute temperature scale, the kelvin, is named after him [2]. Likewise, the Kelvin scale or absolute temperature scale is recognized as the international standard for scientific temperature measurement. The null point of the Kelvin scale (0 K) is absolute zero temperature, known as the lowest possible temperature in universe. This is the point at which the particles in a substance stop moving

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entirely and all disorder disappears. Thus, nothing can be colder than absolute zero on the Kelvin temperature scale.
When Lord Kelvin carried out his research, the kinetic molecular theory, according to which all substances were made of extremely small particles called molecules in ceaseless motion, was not yet universally accepted. Nowadays, it is well known that temperature is a measure of the average kinetic energy of the molecules in a substance, and absolute zero corresponds to the lowest possible temperature, a state in which the thermal movement of molecules has stopped [2]. After the revision of the SI basic units, starting from May 20th, 2019, the temperature is defined in terms of the molecular motion energy, also called thermal energy (kT), where k is the Boltzmann constant. This way, the implemented redefinition of the SI base unit kelvin provided the possibility of using modern technologies for measuring temperature in a wide range. Furthermore, new approaches for realization of the measuring unit of the thermodynamic temperature scale, the kelvin, are now mainly based on quantum effects with the highest accuracy.

2. NEW DEFINITION OF THE KELVIN AND ITS PRACTICAL REALIZATION

2.1 Redefinition of the SI base unit kelvin and its impact on temperature scales in practical use

At the 10th General Conference on Weights and Measures (*Conférence Générale des Poids et Mesures*, or shortly, CGPM), in 1954, the thermodynamic temperature scale is defined by choosing the triple point of water (TPW) as the fundamental fixed point, and assigning to it the temperature T_{TPW} = 273.16 K, exactly [4]. Later, at the 13th CGPM in 1967, the kelvin, unit of thermodynamic temperature is defined as „*the fraction 1/273.16 of the thermodynamic temperature of the triple point of water*“ [4,5].
The TPW is the unique physical state of water in which all three phases (solid, liquid and vapour) coexist at thermodynamic equilibrium [6]. In practice, it is realized by using TPW cells [7] (see **Figure 1**), in sealed borosilicate glass or fused-silica-envelopes containing approximately half a liter of high-purity water having approximately the isotopic composition of the so-called Vienna Standard Mean Ocean Water (VSMOW): 0.00015576 mole of ^{2}H per mole of ^{1}H, 0.0003799 mole of ^{17}O per mole of ^{16}O and 0.0020052 mole of ^{18}O per mole of ^{16}O' [4]. When a fraction of the liquid is frozen by cooling the cell and the cell is accommodated in a thermostat bath controlled at a temperature close to 273.16 K, the equilibrium between the three phases is automatically established within the cell and can be maintained for many months. The kelvin definition thus is not linked to a specific artefact, in the sense that there is no international prototype of the kelvin since any laboratory can realize the kelvin by manufacturing its own TPW cell [6].

Figure 1. Triple point of water cell – National Institute of Standards and Technology (NIST)
Source: https://t.ly/wnMM_

The following definition of the kelvin was adopted at the 26th CGPM in 2018 [8]:
The kelvin, symbol K, is the SI unit of thermodynamic temperature. It is defined by taking the fixed numerical value of the Boltzmann constant k to be 1.380 649 × 10^{-23} when expressed in the unit J K^{-1}, which is equal to kg m^2 s^{-2} K^{-1}, where the kilogram, metre and second are defined

in terms of *h*, *c* and Δv_{Cs}, where *h* is the Planck constant, *c* is the speed of light in vacuum and Δv_{Cs} is the caesium frequency corresponding to the transition between the two hyperfine levels of the unperturbed ground state of the ^{133}Cs atom.
This definition implies the exact value of the Boltzmann constant $k = 1.380\ 649 \times 10^{-23}$ J K^{-1}. By fixing the value of *k*, the kelvin is now defined in terms of the SI derived unit of energy, the joule (symbol J), which is the proportionality constant between thermodynamic temperature and the associated thermal energy *kT*. The new definition has its origin in statistical mechanics, where thermodynamic temperature is a measure of the average thermal energy per degree of freedom in the system. Its effect is that one kelvin is equal to the change of thermodynamic temperature *T* that results in a change of thermal energy *kT* by $1.380\ 649 \times 10^{-23}$ J [4]. Therefore, the advantage of the new kelvin's definition is that thermodynamic temperature can be realized directly at any point in the scale without referring to the singular temperature of the TPW [9].
The value of *k* adopted for the new definition (the CODATA 2017 value by D. B. Newell *et al*. [10]) ensures that the best estimate of the value of T_{TPW} remains 273.16 K. One consequence of the new kelvin's definition is that the former relative uncertainty in the determination of *k*, 3.7×10^{-7}, is transferred to the temperature of the triple point of water, T_{TPW}. The standard uncertainty of T_{TPW} is hence now approximately 0.1 mK. The common practice to call the difference "$T - 273.15$ K" Celsius temperature, symbol *t*, remains the same. The unit of Celsius temperature is the degree Celsius, symbol °C, which is, by definition, equal in magnitude to the kelvin [4,9,11].
It is important to point out that the redefinition of the kelvin in terms of the Boltzmann constant has no effect on the temperature values or realization uncertainties of the present two defined scales: the International Temperature Scale of 1990 from 0.65 K and above (ITS-90, [12]), and the Provisional Low Temperature Scale of 2000 from 0.9 mK to 1 K (PLTS-2000, [13]), which are used in practical measurements of temperature. This is caused by the fact that the fixed-point temperatures assigned in all of the defined scales are exact (there is no assigned uncertainty) and fixed (the value remains unchanged throughout the life of the scale). In particular, the status of the TPW as a fixed point, with a defined temperature value on the ITS-90, will remain unchanged. Thus, the uncertainty of realization of the TPW on the ITS-90 will not acquire any additional uncertainty due to the change in definition of the kelvin [4].

2.2 Principles and advantages of Johnson noise thermometry in practical use

The redefinition of the SI base unit the kelvin has opened new possibilities for realizing and disseminating temperature through different approaches, with direct traceability to the redefined kelvin [9,14]. More precisely, the creation of an extended *mise en pratique* ("practical realization") of the definition of the kelvin (*MeP*-K[2]), incorporates both of the defined International Temperature Scales (ITS-90 and PLTS-2000) in current use and approved primary-thermometry methods for determining thermodynamic temperature values [4].
The following primary-thermometry methods are recommended for practical use: acoustic gas thermometry (AGT), spectral-band radiometric thermometry, polarizing gas thermometry (PGT), dielectric-constant gas thermometry (DCGT), refractive-index gas thermometry (RIGT) and Johnson noise thermometry (JNT) [11]. Primary thermometry implies direct measurement of thermodynamic temperature, without calibration against a more accurate thermometer. It is performed using a thermometer based on a well-understood physical system, for which the equation of state describing the relation between thermodynamic temperature (*T*) and other independent quantities can be expressed explicitly without unknown or significantly temperature-dependent constants. Thermodynamic temperature can be obtained by measuring or otherwise determining values of the independent quantities. Furthermore, no reference is made to any temperature fixed point [4,11]. In the long term, primary thermometers are predicted to become competitive with practical thermometers traceable to ITS-90 and PLTS-2000, as future advances in techniques will improve their repeatability, uncertainty and ease of use [9]. They will become more widely used and will completely

[2] The *MeP*-K is a guide that makes reference to the information needed to perform measurements of temperature in accord with the SI at the highest level.

replace conventional thermometers eventually [4,11]. Because of many advantages they provide when measuring temperature in various aspects of our lives, compared to conventional thermometers, the working principle of the currently most promising Johnson noise thermometers is explained below.

Conventional temperature sensors, such as thermocouples or resistance thermometers, are known to be used for temperature monitoring and control in a wide range of processes. However, they don't measure the temperature directly, instead they typically possess some property, such as voltage or resistance, which varies with temperature and can be measured. Therefore, they need to be calibrated regularly, so that users can have confidence in the measurements, which can be expensive and time-consuming. For various practical applications any improvement in confidence that can be achieved is crucial to support innovation. To overcome the need for calibration, the thermometer must measure temperature directly, as in the case of a Johnson noise thermometer [15].

Johnson noise thermometry is a primary temperature measurement technique based on the fundamental properties of thermal fluctuations in conductors. More precisely, Johnson noise (also: *thermal noise*, *Johnson-Nyquist noise*, *white noise*) is the electronic noise generated by the thermal agitation of the charge carriers (usually the electrons) inside an electrical conductor, which happens regardless of any applied voltage. The most important aspect of Johnson noise is that the power of the Johnson noise is directly proportional to the absolute temperature. There is no material property or calibration requirement to derive the absolute temperature, just electrical measurements. The accuracy of a Johnson noise thermometer can't drift over time. Therefore, a significant advantage of this technique is that it isn't subject to sensor drift [15]. By measuring the tiny electrical fluctuations associated with the random thermal motion of charge carriers (the Johnson noise), *the Johnson-Nyquist equation*[3] can be used to determine true thermodynamic temperature of the sensor, even if the sensor material degrades during exposure in harsh environments, such as high temperatures or ionizing radiation. Accordingly, by practical application of primary Johnson noise thermometry all properties that affect the temperature measurement can be measured continuously, so that the Johnson-noise thermometer always yields the correct temperature [15].

Johnson noise is usually characterized by its mean square of a noise voltage (v_n), conventionally called the noise power. For frequencies below 1 MHz and temperatures above 25 K, it is approximated to better than 1 part in 10^6 by Johnson-Nyquist equation [17]:

$$\left\langle v_n^{\,2} \right\rangle = 4kTR\Delta f \tag{1}$$

where Δf is the bandwidth in hertz over which the noise voltage is measured, T is the resistor's absolute temperature in kelvins, R is the sensor resistance in ohms (Ω) and k is the Boltzmann constant in joules per kelvin.

It is interesting to note that the noise power in a conductor (resistor) is independent of the resistance. Re-arranging the previous equation gives the thermodynamic temperature:

$$T = \frac{1}{4k} \cdot \left\{ \frac{v_n^{\,2}}{R\Delta f} \right\} \tag{2}$$

In conventional JNT systems, one measures the noise power from a sensor at a known temperature (usually at the triple-point temperature of water, which has a conveniently defined value in the International System of Units: T_{TPW} = 273.16 K), and the noise power of a second sensor at the unknown temperature. The unknown temperature is inferred using equation (1) from the ratio of the measured noise powers and the ratio of the sensing resistances [17].

The Johnson noise thermometry offers huge advantages over conventional practical sensors which exhibit progressive loss of accuracy in harsh environments. The practical Johnson noise thermometer is independent of any calibration and it can measure with confidence all parameters which are needed to

[3] In 1927, John Bertrand Johnson (1887–1970), conducted a series of experiments that showed that electrical noise exists in all conductors and that this noise is inherent and is not the result of poor component design. Johnson also provided a formula for the noise. Later, in 1928, Harry Nyquist (1889–1976), applied the principles of quantum and statistical mechanics and derived on a theoretical basis Johnson's formula [16].

yield the true temperature for prolonged periods. This results in improved process control and better efficiency, in terms of energy use, product yield and reduced process downtime [15].
The Johnson noise thermometry system is in use at the Physical Measurement Laboratory in National Institute of Standards and Technology (NIST), in support of work aimed at reducing uncertainty in temperature measurements and improving the understanding of the international temperature scale, as well the development of a novel electronic method for determining the Boltzmann constant. Within the JNT project, conducted by NIST, quantum-based synthesis of the voltage waveform is applied to the precise measurement of the Boltzmann constant by developing the primary temperature standard based on the electrical measurement of the Johnson-Nyquist voltage noise of a resistor at the triple-point temperature of water. The NIST Johnson noise thermometer may eventually replace the large collection of temperature fixed points (temperature artifact standards) that define the ITS-90 thermodynamic temperature scale, providing a unique electronic measurement of the Boltzmann constant, which is important for the New International System of Units [18].
Although Johnson noise thermometry is well established in certain laboratories and used in primary thermometry and Boltzmann's constant determinations, it hasn't been used for practical devices in industrial environments. The world's first practical Johnson noise thermometer (**Figure 2**) has been made as a result of the collaboration between the National Physical Laboratory UK and Metrosol Limited. It has achieved accuracy of temperature measurement better than 1 °C and could eventually be commercialized in future [15].

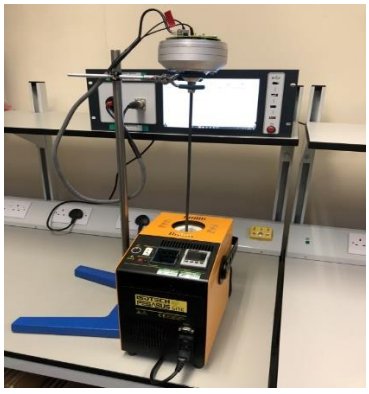

Figure 2. The first practical Johnson noise thermometer
Source: https://t.ly/QkZ1E

3. CONCLUSION

The redefinition of the kelvin will allow the accuracy of temperature measurements to gradually improve without limitations associated with the manufacture and use of water triple point cells, nor with limitations of the present temperature scales. Within a variety of alternatives, laboratories can realize a temperature standard by choosing the experimental method which is best suited to their available equipment. The aforementioned primary-thermometry methods which are recommended for the direct realization and dissemination of thermodynamic temperature are expected to eventually replace the International Temperature Scales (ITS-90 and PLTS-2000) in practical use. The most promising of them, Johnson noise thermometry, represents a breakthrough in temperature sensing, particularly in harsh environments, with the perspective of being commercialized for the needs of industrial and other measurements. By applying this method, the temperature sensor, unlike today, will no longer need calibration to ensure traceability.

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ENVIRONMENT AND SUSTAINABLE DEVELOPMENT. MECHATRONICS. OCCUPATIONAL SAFETY AND HEALTH AND FIRE SAFETY. SMART MANAGEMENT SYSTEMS. GRAPHIC ENGINEERING. DESIGN. TRAFFIC ENGINEERING. BIOTECHNOLOGY AND HEALTHCARE. MECHANICAL ENGINEERING. ECOTOURISM AND RURAL DEVELOPMENT.

ANALYSIS AND VISUALIZATION OF COVID-19 DATA SET IN PYTHON PROGRAMMING LANGUAGE

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Abstract: *This paper presents some of the ways to process and visualize data from a given data set in order to prepare data for further analysis. For this purpose, Python programming language with its libraries Pandas, Matplotlib and Plotly was used. The free Anaconda distribution is used for processing and visualization, as one of the most used programming environments for data analysis. The program editor in which the program codes of the tasks are written is Visual Studio Code.*
Keywords: Data Analysis, Data Visualization, Python Programming Language

1. INTRODUCTION

To understand the dominant role of Python programming language in data science, it is necessary to compare it with other programming languages used in this field [1]. Compared to the programming language R, which can be considered one of the main alternatives, Python is a multipurpose language and is more practical. Writing code is simple and significantly faster than in Java and C++. The languages Ruby and JavaScript are similar in nature to Python in terms of flexibility, but not in terms of open-source support. The development of Python programming language is supported by large user communities and has a huge number of libraries and tools with ready-made solutions available to the user. It is suitable for performing many operations, from data preparation, visualization, and analysis to the application of artificial intelligence and machine learning algorithms [2]. According to the programming language popularity index [3] for the year 2023, Python programming language is ranked first.

A tool that manages open-source packages for installing Python programming language [4] (in the context of data processing and visualization) and allows the isolation of different projects is the Anaconda virtual environment [5]. The advantage of Anaconda is that it allows the use of different versions of Python on different platforms and has many preinstalled packages with compatible versions, which greatly facilitates the use and avoidance of conflicts.

There are more than 700 libraries available in Anaconda. The Pandas, Matplotlib, and Plotly libraries are presented in the code examples in the paper. The Pandas library enables simple and efficient loading of tabular data, to process the data. It is built on the Numpy library and is compatible with the Scikit Learn machine learning library [6].

Libraies Matplotlib [7] and Plotly [8] enable the creation of different types of graphs, i.e., visualizations in Python programming language. Many commands can be used to create standard line charts, histograms, bar, and pie charts. To adjust the appearance of the graph, formatting is applied, which refers to the choice of colour, thickness and type of line, addition of titles and legends.

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2. ANALYSIS AND VISUALIZATION OF COVID 19 DATA SET

2.1 Data analysis and processing

The paper used data on the COVID-19 corona virus, from March 15, 2020, which was processed and analysed. The data can be found in the data set [9].
Descriptions of column names from the data set are shown in Table 1.

Table 1. Descriptions of column names from the data set
Source: *Author's paper*

The name of column	Description
Province/State	The name of province or state
Country/Region	The name of country or region
Last Update	MM/DD/YYYY HH:mm (24-hour format, in UTC)
Confirmed	The number of confirmed cases
Deaths	The number of deaths
Recovered	The number of recovered cases
Latitude	Latitude of country/region or province/state
Longitude	Longitude of country/region or province/state

For data processing and analysis, a program was written that displays the first 5 rows from the data set, prints information about the data and checks for missing values, prints the number of confirmed, deaths, recovered and active cases in relation to the country they are from, prints information about 7 countries with the highest number of confirmed cases.
The printout of the first 5 lines is shown in Figure 1.

	Province/State	Country/Region	Last Update	Confirmed	Deaths	Recovered	Latitude	Longitude
0	Hubei	China	2020-03-15T18:20:18	67794	3085	54288	30.9756	112.2707
1	NaN	Italy	2020-03-14T20:13:16	24747	1809	2335	41.8719	12.5674
2	NaN	Iran	2020-03-15T18:20:18	13938	724	4590	32.4279	53.6880
3	NaN	Korea, South	2020-03-15T18:20:18	8162	75	510	35.9078	127.7669
4	NaN	Spain	2020-03-15T18:20:18	7798	289	517	40.4637	-3.7492

Figure 1. First 5 rows from COVID-19 data set
Source: *Author's paper*

Data set information from a given data set such as number of rows, number of columns, memory space and data type are shown in Figure 2.

```
[294 rows x 8 columns]

Dataset information:
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 294 entries, 0 to 293
Data columns (total 8 columns):
 #   Column          Non-Null Count  Dtype
---  ------          --------------  -----
 0   Province/State  147 non-null    object
 1   Country/Region  294 non-null    object
 2   Last Update     294 non-null    object
 3   Confirmed       294 non-null    int64
 4   Deaths          294 non-null    int64
 5   Recovered       294 non-null    int64
 6   Latitude        291 non-null    float64
 7   Longitude       291 non-null    float64
dtypes: float64(2), int64(3), object(3)
memory usage: 18.5+ KB
None
```

Figure 2. Information from COVID-19 data set
Source: *Author's paper*

Missing values by columns from given data set are shown in Figure 3.

```
Missing data information:
Province/State    147
Country/Region      0
Last Update         0
Confirmed           0
Deaths              0
Recovered           0
Latitude            3
Longitude           3
dtype: int64
```

Figure 3. Missing values by columns from COVID-19 data set
Source: *Author's paper*

The number of confirmed, deaths, recovered and active cases in relation to the country they are from are presented in Figure 4.

```
result = covid_data.groupby('Country/Region')['Confirmed', 'Deaths', 'Recovered', 'Active'].sum().reset_index()
                  Country/Region  Confirmed  Deaths  Recovered  Active
0                    Afghanistan         20       0          0      20
1                        Albania         42       1          0      41
2                        Algeria         48       4         12      32
3                        Andorra          1       0          1       0
4                     Antarctica          0       0          0       0
..                           ...        ...     ...        ...     ...
151                   Uzbekistan          1       0          0       1
152                    Venezuela         10       0          0      10
153                      Vietnam         56       0         16      40
154             Winter Olympics 2022        0       0          0       0
155  occupied Palestinian territory         0       0          0       0
```

Figure 4. Number of confirmed, deaths, recovered and active cases from COVID-19 data set.
Source: *Author's paper*

Data set information of the 7 countries with the highest number of confirmed cases is shown in Figure 5.

```
result = covid_data.groupby('Country/Region').max().sort_values(by='Confirmed', ascending=False)[:7]
                  Last Update  Confirmed  Deaths  Recovered  Latitude  \
Country/Region
China          2020-03-15T18:20:18      67794    3085      54288   47.8620
Italy          2020-03-14T20:13:16      24747    1809       2335   41.8719
Iran           2020-03-15T18:20:18      13938     724       4590   32.4279
Korea, South   2020-03-15T18:20:18       8162      75        510   35.9078
Spain          2020-03-15T18:20:18       7798     289        517   40.4637
Germany        2020-03-15T18:20:18       5795      11         46   51.1657
France         2020-03-15T18:20:19       4499      91         12   46.2276

               Longitude  Active
Country/Region
China            127.7615   10421
Italy             12.5674   20603
Iran              53.6880    8624
Korea, South     127.7669    7577
Spain             -3.7492    6992
Germany           10.4515    5738
France            45.1662    4396
```

Figure 5. Data set information of top 7 countries from COVID-19
Source: *Author's paper*

2.2 Data visualization

Data visualization is very useful and necessary to display data. The choice of graph type is preceded by data analysis, based on which the most suitable type of visualization is chosen.

To visualize data for a given data set, a program code was written to create a line chart that visualizes data on deaths, confirmed, recovered and active cases, in countries with more than 100 deaths, which is shown in Figure 6. To obtain the graph the Matplotlib library is imported.

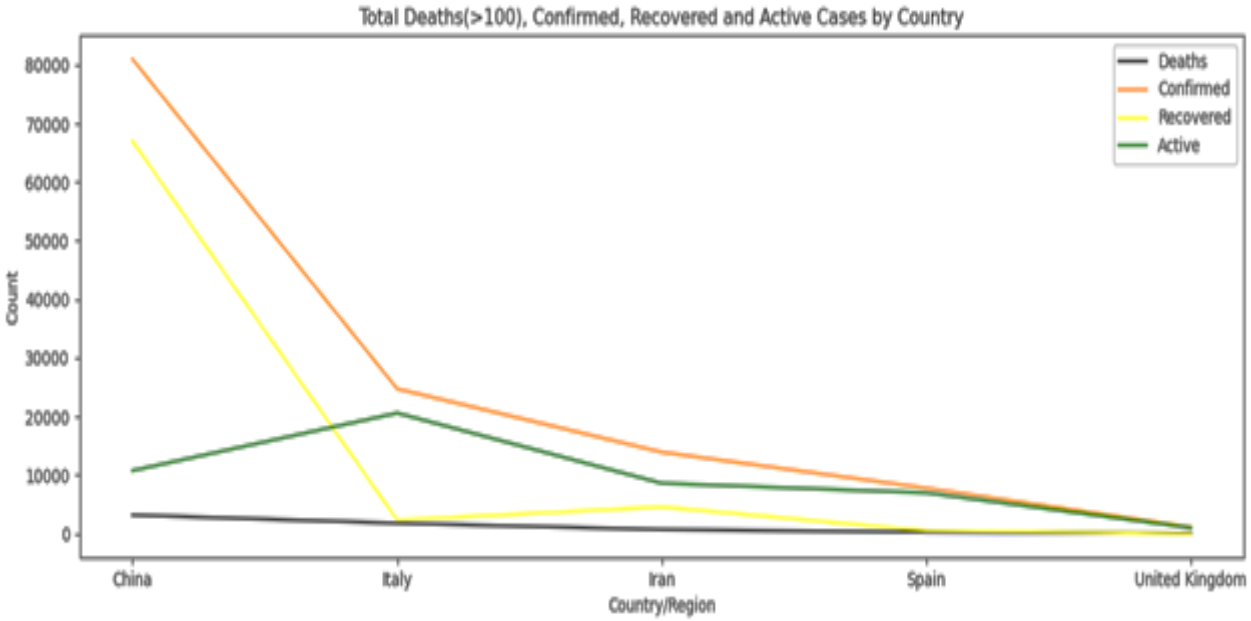

Figure 6. Line graph from COVID-19 data set
Source: *Author's paper*

Figure 7 shows a bar graph showing the frequency of different cases of the corona virus in Australians by area. On the x axis, the categories of attributive features (confirmed, deaths, recovered, active) are applied, while on the y axis, the frequency of the observed category, a numerical variable (Count), is applied. The Plotly library is imported to create graphs.

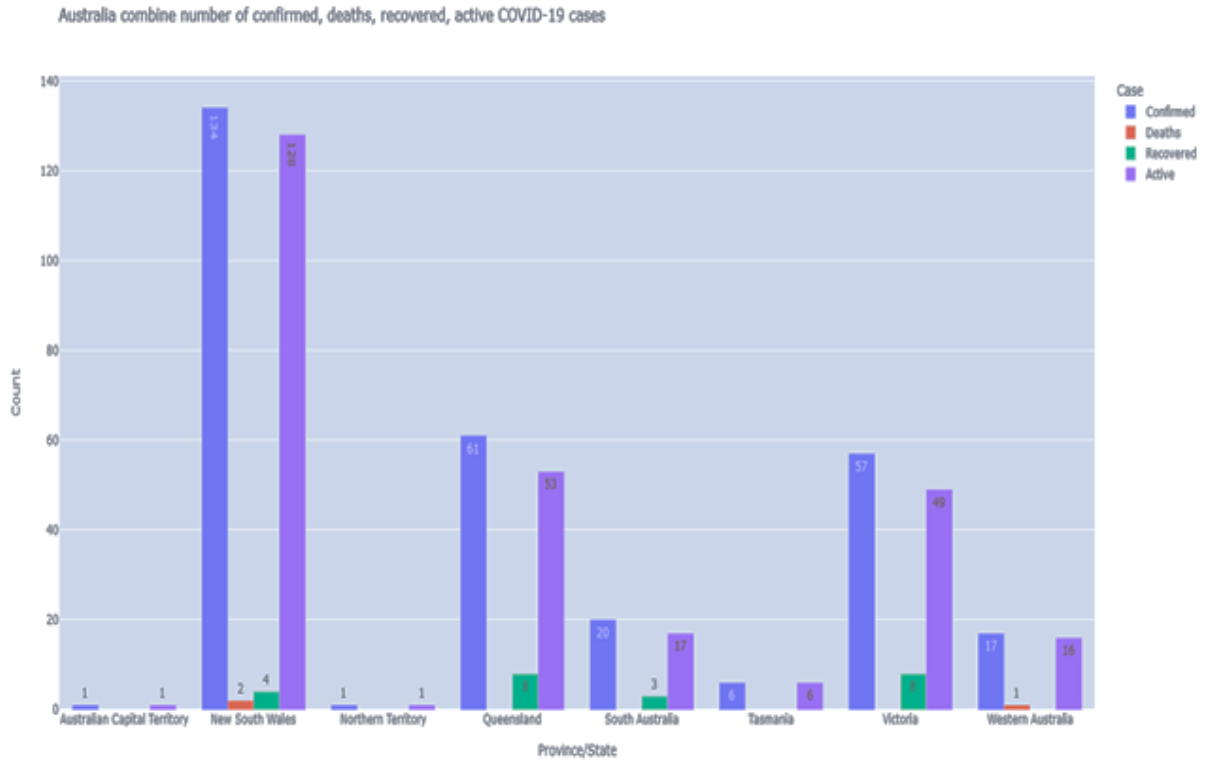

Figure 7. Bar chart from COVID-19 data set
Source: *Author's paper*

3. CONCLUSION

There are more and more programmers and researchers in the field of computer science who look at their professional development through the prism of data science. To solve practical problems, it is necessary to understand the very concept of data analysis and master at least one programming language that supports data analysis and visualization. Due to its simplicity and great programming possibilities, Python programming language is a good choice.
This paper presents the results of data processing and analysis and visualization, with the aim of adopting the skills and techniques of data visualization and processing, to illustrate the approach to problem solving in the field of data analysis. The choice of programming language is an important step in data analysis, which is also illustrated in this paper.

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EXAMINING THE ROLE OF DRONES AS EDUCATIONAL TOOLS: AN PRACTICAL TEACHING EXAMPLE IN ENHANCING LEARNING EXPERIENCES IN STEM EDUCATION

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Abstract: *In recent years, drone technology has revolutionized various industries, from photography and filmmaking to agriculture and disaster response. Now, educators are harnessing the potential of drones to enhance science and technical education. Aviation Academy in Belgrade has also recognized and introduced drones as a powerful tool in both theoretical and practical educational methods, of acquiring high-quality knowledge in aviation educational field, aiming to improve the knowledge of its students. The students of Aviation Academy learn how to observe and record the terrain situation using a drone for various agriculture purposes. Students can also learn about various drone operation technologies, including aerodynamics, aviation, programming, and data analysis, by working with drones. This article presents concrete teaching examples and students' achievements in the practical applications of drones in teaching at Aviation Academy, discussing their benefits and potential impact on student engagement, critical thinking, and problem-solving skills particularly in the fields of science, technology, engineering, and mathematics (STEM).*
Keywords: drones, education, hands-on learning, problem-solving, teacher support.

1. INTRODUCTION

With the rapid advancement of technology, educational institutions are constantly seeking innovative methods to enhance teaching and learning experiences. Drones, also known as unmanned aerial vehicles (UAVs) initially developed for military and commercial application [1], have found a niche in the realm of education. From kinematics, fluids and aerodynamics to electromagnetism, electronics, programming and data collection and analysis, drones provide an exciting and engaging platform for students to grasp abstract principles while inspiring curiosity and creativity in the world of science, technology, engineering, and mathematics (STEM) [2].
Integrating drones in STEM education contributes to better student's knowledge and has benefits in many areas of science, technology and education methods such as:

a) **Physics principle and laws**: Kinematics, Newtons laws, Bernoulli principle in flight, aerodynamics, observe and analyses drone flights, measure distances, calculate velocities, and explore motion graph, examine the effects of thrust, drag, lift, and weight on the drones' flight, balanced and unbalanced forces (**Figure 1**). Students also can learn about basic circuit concepts like voltage, current, resistance, and how they relate to drone operation, etc.
b) **Sensors:** Understand the working principle of various sensor types such as multispectral, thermal imaging, and LiDAR sensors.
c) **Drone software systems to control the flight operations and capture data efficiently:** Popular open-source platforms like ArduPilot and PX4 allow customization and integration of various

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sensors. Learn how to program the drones for autonomous flights, image processing, and data analysis using languages like C++ or Python. Fine-tune flight controls, stabilize drone stability, optimize power consumption, and integrate sensor data into actionable insights; d) **Hands-on learning and real-world application**: Students can actively engage in building, programming, optimizing and piloting drones, giving them a tangible connection to the principles they learn in the classroom, study the various components required to build a drone: flight controllers, motors, propellers, batteries, GPS modules, and sensors, research reputable drone manufacturers and their product offerings, learn how to assemble and solder drone components together [3,4]. There are numerous online resources and tutorials available that provide step-by-step guides to building drones [5,6]. They can also explore the effects of different components and configurations on the drone's performance and test drone in real-life agricultural settings, etc.

d) **Data collection and analysis**: Research their applications in agriculture for example, data collection methods, and data interpretation techniques; f) **Problem-solving and critical thinking**: Assignments involving drone missions encourage critical thinking and creativity, as students must strategize flight paths, calculate power requirements, and optimize payload distribution, all while considering the laws of physics that govern the drone's flight.

e) **Safety precautions and legal guidelines for flying drones**, including understanding airspace restrictions, privacy concerns, and proper maintenance practices.

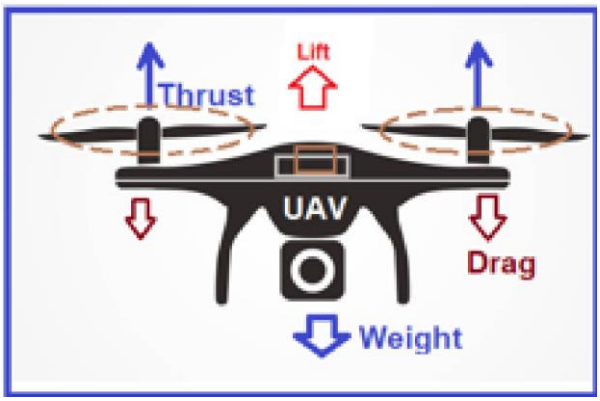

Figure 1. Major forces acting on a drone
Source: https://tinyurl.com/5dbaexrm

2. EXAMPLES

2.1 Drone flight time

In order to use drones for student education and enhance student's understanding of drone operations, teachers can, for example, assign a task to students to investigate the relationship between drone payload, battery capacity and flight duration.

In this task, students will be required to: a) demonstrate basic knowledge in physics, such as Newton's dynamics; b) apply some simpler formulas; c) think how to increase lift force; d) use an existing online calculator for drone parameters calculation [6,7]; e) think how to optimize relation between payload weight and flight time.

It can be assumed that adding payload decreases flight time. For the purpose of this article, it is also assumed that the payload is increased while the drone's components stay the same. Student need to be able to conclude that to overcome a higher weight, more thrust is required from the propellers, which requires higher RPM (rotation speed), which draws more power from the battery, thus decreasing the available battery life and flight time.

Adding mass to a UAV, the amount of thrust required to lift it off the ground is increased.

When a drone is hovering, it is in equilibrium so the thrust is equal to the weight:

$$\text{Hover thrust} = \text{Drone weigh} = \text{mass} \times \text{gravity } (9.82\ \text{m/s}^2) \qquad (1)$$

For most drones, it is necessary that their max thrust be about twice as much as is required to hover, which allows them to take-off, climb, and operate smoothly. Ultimately, greater mass means greater thrust requirements. There are a few ways to calculate thrust, but it is generally dependent on several factors, including propeller diameter and pitch, air density, velocity, and rotation speed (RPM), as demonstrated by this equation for dynamic propeller thrust [8]:

$$Thrust = 4.329 \times 10^{-8}\, RPM \frac{d^{3.5}}{\sqrt{pitch}} (4.233 \times 10^{-4} \cdot pitch - V_0) \quad (2)$$

Where: d-propeller diameter (m), V_0-propeller forward airspeed(m), pitch- displacement a propeller makes in a complete spin of 360° degree usually in inches (propeller of 40 pitch will advance 40 inches for every complete spin).

According to eq. (2), there are a couple ways we can increase thrust: we can change the dimensions of the propeller, or we can increase the RPM. Since propellers are constant, it will therefore have to increase the RPM.

So, the question for the student are how to increase RPM. To increase the RPM, we have to draw more electrical power from the battery, specifically more voltage. The more power drawn, the shorter the life of the battery. Since it will be drawing higher voltage (and therefore greater power) to reach a higher RPM, the battery life will deplete faster, and our flight time will be lower.

Students could be given the task to calculate: Flight-time vs battery capacity and flight-time vs total weight relations using some of the flight time calculators and to plot the correspondent graphs.

The simple equation below shows how battery capacity and power draw relate to the flight time of the drone. The more power you draw, the shorter the flight time will be:

$$Fligt\ time(h) = \frac{Battery\ capacity(Wh)}{Power(W)} \quad (3)$$

The battery capacity ($E_{battery}$) is equal to the weight of the battery ($W_{battery}$ in grams) multiplied by the energy density ($\sigma_{battery}$ in Wh/g).

$$E_{battery}(Wh) = \sigma_{battery}\left(\frac{Wh}{g}\right) \cdot W_{battery}(g) \quad (4)$$

The total power (Power in Watt) is equal to the weight of the drone (Wdrone (g) = W_{frame} (g) + $W_{battery}$ (g)) divided by the propeller's efficiency (propefficiency in g/W).

$$Power(W) = \frac{W_{drone}(g)}{prop_{efficiency}(\frac{g}{W})} \quad (5)$$

By combining the eqs. (3), (4) and (5) , it can be obtained that the flight time is :

$$FT = \frac{\sigma_{battery}\left(\frac{Wh}{g}\right) \cdot W_{battery}(g)}{W_{frame} + W_{battery}} \cdot prop_{efficiency}\left(\frac{g}{W}\right) \quad (6)$$

$prop_{efficiency}\left(\frac{g}{W}\right)\left(\frac{W_{frame}+W_{battery}}{Number\ of\ propellers}\right)$ - propeller efficiency is a function of total weight of the drone divided by the number of propellers on drone. From eq. (6) students should conclude that increase in the weight of the battery increases the division term in the equation above and reduces the propeller efficiency. In this way, the battery can influence the flight time in both directions. Larger batteries have a higher capacity, which can increase flight time, but they also have a higher weight, which increases the thrust required for operation, thus decreasing the flight time. Those formulas are implemented in the various existing flight time online calculators which uses the following drone parameters: weight and capacity of drone battery, total weight of your quad (without the battery), and

the number of propellers, it combines this information with propulsion data and estimates flight time [5,6].
In the previously described example, the students obtained the following results that are shown on the **Figure 2** and **Figure 3**. On **Figure 2**, students can observe the effect of varying the battery capacity on the flight time at constant drone weight . As it can be seen, increasing the battery capacity above 250 Wh increases the flight time by a few minutes, but reduces the control authority as the weight to thrust ratio decreases.

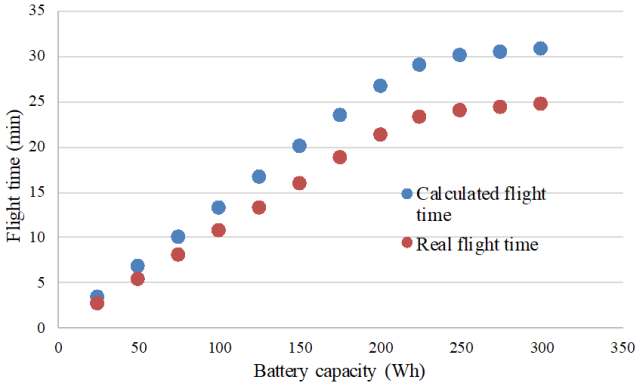

Figure 2. Calculated vs real drone flight time as a function of battery capacity.

Further increase (above 250 Wh) shows very little contribution in terms of flight time, but increases noise and reduces controllability. So, it is very important for various drone applications to optimize battery capacity in relation to required payload and flight time.
It should be noticed that time calculated with flight time calculators differ from the real flight time because they assumed that drone mostly hovers in the air – every time it performs some elaborate maneuvers, one of the motors has to work faster and hence uses up more current. If drone only moves around slightly – for example, during aerial photography – the flight time will time will be about 75% of the calculated time, or if drone flies in strong wind or moves around a lot, the flight time will decrease to around 50%, etc. On **Figure 3**, it can be noticed that with zero payload and the mass of the drone at 1.6 kg (battery included), we get a flight time of 26,6 minutes, giving more than enough time to shoot a 20-minute video. As we increase the payload by 0.2 kg increments, watch what happens to the flight time: As payload is gradually increased, flight time decreases.

2.2. Students' achievement in practical application of drones

The second task for the students was to observe, record and analyze drone images of the terrain situation [9,10]. The specific thing about the drone was a built-in multispectral camera that recorded the whole range of visible spectrum, including those outside of the visible spectrum, such as red band, near infrared, infrared and ultra-violet. (RED, NIR,IR,UV) [11]. The recording could be used in numerous multispectral analyses and a specially designed software was used for its decoding.

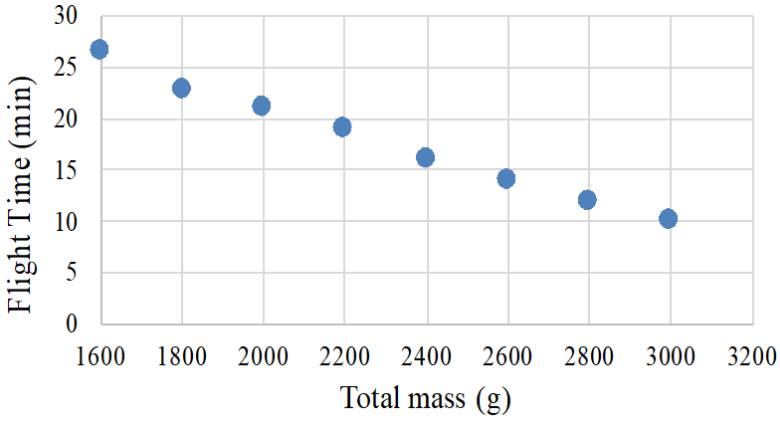

Figure 3. Drone Flight time vs. payload in hovering mode

In practice, the students were assigned an orchard as a recording terrain and they had to examine those plants general condition and target the ones that needed special treatment. The analysis of colour tracking provided information on plants (if the leaves had become dry, if they have enough water, if they suffer from certain disease or if they are damaged). The most well-known and used index map produced from multispectral imagery is NDVI (Normalized Difference Vegetation Index).
The pigment in plant leaves, chlorophyll, strongly absorbs visible light (from 0.4 to 0.7 μm). The cell structure of leaves, on the other hand, strongly reflects near-infrared light (from 0.7 to 1.1 μm).
Healthy plants reflect a smaller quantity of red light but a larger amount of near-infrared light (which humans can't detect, but multispectral imaging can), whereas the opposite is true for stressed or dead plants. The difference between damaged and undamaged planted areas, can be seen on multispectral camera image NDVI analysis (**Figure 4**).

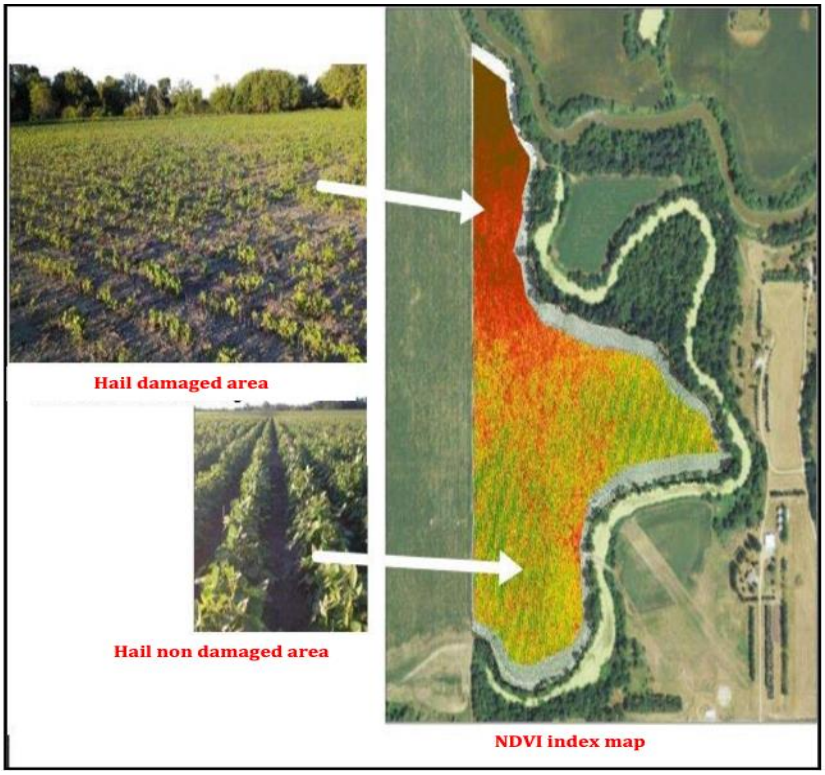

Figure 4. UAVs multispectral camera image with NDVI index map of plant condition [9]

3. CONCLUSION

Introducing students to drone technology, educators prepare them for real world application. Future careers in fields like, engineering, surveying, environmental monitoring, agriculture, and even disaster response may require drone piloting, operation and data analysis skills. By integrating drones into education, students gain practical skills that are in high demand in the job market, enhancing their career prospect. In first presented example on drone-based student assignment, student came to this conclusion: to overcome a higher weight, more thrust is required from the propellers, which requires higher RPM, which draws more power from the battery, thus decreasing the available battery life and flight time. Using the basic physics knowledge and existing flight time calculators, students learned how to optimize flight time for needed drone purpose by choosing adequate battery capacity and payload values. In the second drone application in education example student learn how to use drones in crop health monitoring and management.
These and many others diverse examples of drones as a useful tool in education demand that all future research and investment in drone-based education be focused on refining pedagogical approaches, determining the optimal student-drone ratio, expanding accessibility and exploring advanced application.

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EXPERIENCES IN TEACHING AND MASTERING MATERIALS IN WEB APPLICATIONS COURSE IN VOCATIONAL EDUCATION

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Abstract: *This paper presents the experiences in teaching and mastering the teaching contents and curricula of a representative group of students who enrolled in the first year of study in higher education in vocational engineering studies. Students originated from different high schools and have had different initial backgrounds in Informatics. After the entrance exam, a representative sample of 20 students and their success in subjects from Information Technologies and Computer Science was followed. Their work and success after the third year of bachelor studies is especially emphasized, with analysis of their results and presentation of the curriculum material they have mastered. The competencies gained and curriculum of the course in Web applications, which was taken during the third year are here presented. Parts of practical exercises performed by students are illustrated and supplied. The results of the exams taken in subject that was selected e.g. Web applications, are presented in a table, and the analysis of the data obtained is performed.*
Keywords: Teaching Experience, Computer Science, Information Technologies, Evaluation of Student's Competencies, Vocational Studies.

1. INTRODUCTION

Education at all levels should adapt to work and life during the Fourth Industrial Revolution. To prepare students adequately for the near and distant future job requirements, colleges, faculties and other higher education institutions should offer different education from the existing one [1, 2, 3, 4]. Due to increased automation and the application of new technologies, the way of working was changed, even before the Covid-19 pandemic. This made emphasis on an urgent need for mass training and reskilling of the workforce around the world [2, 3]. The Covid-19 pandemic has further strengthened and emphasized this need. The World Economic Forum announced in January 2023. [3] of more than 350 million people are being reached with better skills, jobs and education through commitments made as part of its Reskilling Revolution initiative, three years after launching at its Annual Meeting in Davos. According to *Future of Jobs Report 2023* [4] - Insight Report of the World Economic Forum published in May 2023, in the top ten of the most common labour shortages by occupations in 2022 in Europe, the second place takes "Metal, Machinery and Related Trades Workers" and the fourth "Information and Communications Technology Professionals" [4]. Labour shortage is a shortage or insufficiency of qualified candidates for employment.
Despite the fact that advanced and new technologies and methods are increasingly used in teaching, student progress does not have the expected growth trend [5]. Students were from different secondary education backgrounds. Some had graduated from high schools (gymnasiums), majority was from high schools specialized in some technical or technological field, and several students had graduated from secondary education in Economy or Social Sciences.

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During last four years a reform was introduced in which the Technical College Belgrade became the Computer-mechanical Engineering Section of the Academy of Technical Applied Studies Belgrade. This happened during here described research. At the Technical College Belgrade (now Computer-Mechanical Engineering Section of the Academy of Technical Applied Studies Belgrade), there used to be a three bachelor study programs in vocational engineering: Computer Mechanical Systems, Industrial Engineering and Energy Efficiency with Clean Energy (or with Green Energy, depending on the year of approved accreditation). The entrance exam had three forms – one consisted of questions and tasks from the Technical-Technological field, another was in Informatics and the third was in Mathematics. Students could choose between these three entrance exams with respect to the preferences of study program they were keen to be enrolled in. The results of the entrance exam showed that the best success in Informatics was made by students who graduated from high schools (e.g. gymnasiums), while in the Technical-Technological part of the entrance exam, the highest number of points had achieved graduates of high technical schools specialized in engineering.
This trend in success continued during the first and second year of study, where students took a group of Mathematical, Informatics and Computer Science subjects, namely: Mathematics I, Mathematics II, Software and Computer Tools [6], Operating Systems with User Software, Object Oriented Programming [7], Information Systems; and a group of highly specialized subjects in Technical-Technological field of study that included: Mechanics I, Mechanics II, Machine Elements I, Machine Elements II, Materials in Mechanical Engineering, Strength of Materials, Machining Technologies and others. Selected representatives of the aforementioned groups of students were monitored during the mastering of the curricular material and taking the exams in the third final year of undergraduate studies, in the first year of specialist studies and in the second year of master's studies, all taken in vocational or professional studies. One course was chosen for each of the mentioned years of study. The course in Web Applications was selected from the third year of bachelor studies in professional education and presented here. The contents of this course and fragments of code are presented in this paper, and the progress of the represented groups of students is analysed regardless of their prior knowledge (acquired before the course mentioned), as well as the success of adapting and mastering skills during the final year of undergraduate studies.
The Academy of Technical Applied Studies Belgrade cares for students' success during studies and after graduation. The Career Centre for Students of the Academy of Technical Applied Studies Belgrade [8] is dedicated to the task of career development. The Alumni organization [9] keeps track of the graduates after graduation. In order to help navigate the information gathered regarding graduate students, a database was developed [10, 11, 12].

2. WEB APPLICATIONS COURSE

The curriculum for the subject Web Applications is given briefly, and the specific projects that students performed during the attendance of this course are described in here. The introductory part of this course presents the necessary steps that need to be applied to create a web application [13]. Examples such as data conversion, ASP.NET class, as well as session and application variables are presented [14]. The next lessons show the settings that are related to the Web server. The Web server delivers the requested Web pages to users who have entered a specific URL into a Web browser. The problem of complex controls is then addressed. The Calendar control is used to select the date, usually additional command buttons are entered on the web form. In order to create dynamic sites, it is necessary to introduce validation from the very beginning of development. Errors that can occur in the application by ignoring the validation include: by-passing important fields in which it is necessary to enter data; entering data in an inappropriate format that cannot be used (as is usually the case with e-mail address); entering the wrong data type; typing errors; etc. The next topic in Web Applications course deals with complex controls. The control panel serves as a container for other side controls. It determines the appearance and visibility of the controls it contains, and allows students to create and to program controls. The following knowledge units show XML - Extensible Markup Language. This

language is widely used as an alternative to the database, as well as to store configuration information about the application. XML has a similar syntax as HTML - Hypertext Markup Language [15].
Styles and master pages are the subject of the subsequent lectures. The reason for creating a master page as well as its difference in relation to the web form is shown. The navigation through the website is presented. To move from one side to the other, a navigation system is required, which consists of several components: the XML sitemap is in charge of defining the structure, the second component provides reading data from the site map file and converting it to an object model via controls XmlSiteMapProvider and XmlSiteMapDatasource.
The final lectures deal with the notion of relational database, and structured query language. Through examples, the students master the technique of storing knowledge in or retrieving it from the database. Then the ADO.NET technique is presented, as well as the process of establishing a connection, and an example of creating an e-business web application, and the application delivery process.

2.1 Connecting the Database through the Application

In order to create a new database, students run the following script:

```
CREATE DATABASE COLLEGE
GO
```

The following script creates a new table:

```
CREATE TABLE Students
(
 StudentID int identity primary key,
 Name varchar(50),
 LastName varchar(50),
 Sex varchar(10),
 Age int,
 Address varchar(50)
)
GO
```

The data is then entered using the following script:

```
INSERT INTO Students (Name, LastName, Sex, Age, Address)
VALUES
```

The code snippets for connecting the application to the database are shown with:

```
SqlConnection connection = new SqlConnection();
SqlCommand command = new SqlCommand();
SqlDataReader reader;
connection.ConnectionString = @"Data Source=academy server;InitialCatalog=College;"
+ "Integrated Security=SSPI";
command.Connection = connection;
command.CommandText = "SELECT Name, LastName, Age FROM Students";
connection.Open();
```

In another approach to solve the same task students also use the DataAdapter class and the DataSet class, and database query can be performed without keeping an open connection. The DataAdapter object executes commands to the database and loads the results obtained by executing the query, within the table of the DataSet object. Each data can then be accessed using the Rows property of the DataTable object by specifying the column name.

2.2 XML application

In the introductory exercises on this issue, students are using classes and methods of the XML Document Object Model, and easily create a XML file. Parts of the code are illustrated as follows:

```
//Create XML document
doc = new XmlDocument();
// If there is no current file, create a new one
if (!System.IO.File.Exists(PATH))
{
 //Create necessary nodes
 XmlDeclaration declaration = doc.CreateXmlDeclaration("1.0",   "UTF-8", "yes");
 XmlComment comment = doc.CreateComment("Ovo je XML          generisana datoteka");
```

In the first phase, students create a XML file from the application made in C#, and then perform the reverse procedure, namely read the XML file. Reading content from XML files is a necessary technique that is widely used in the case of saving configuration settings that are usually stored in an XML file and then used when loading an application. The students.xml file contains data on five students. By using the navigation buttons after loading the first record, the application allows students to view the next record, return to the beginning or view the last record. The parts of the navigation code are shown here:

```
private void ShowDetails(XmlElement currentStudent)
{
 txtName.Text = currentStudent.Attributes["name"].Value;
 txtNumberIndex.Text =
currentStudent.GetElementsByTagName("NumberIndex")[0].InnerText;
 txtDepartment.Text = currentStudent.GetElementsByTagName("Department")[0].InnerText;
}
```

3. RESULTS

The students arrived from different types of secondary education to take the entrance exam to enrol to bachelor studies in vocational engineering. Students were divided into three groups: graduates from high schools, from secondary technical schools and from high schools in social sciences. At the entrance exam, part of the exam in Informatics takes 60 points, and the maximum number of points was achieved by 93% of high school students, 78% of students from secondary technical schools and 43% of students from high schools in social sciences. The success of these groups of students in the subject *Web Applications* are given in table.

The percentage results regarding the success of this group of students in learning IT subjects, and numbers of students passing these exams during the first two years of study are shown in the Table 1. The percentage success of the same students in the subject of Web Applications and numbers of students passing this exam are shown in Table 2.

Table 1. Percentage results in IT subjects and numbers of students passing these exams during the first two years of undergraduate studies

Source: courtesy of PhD Djordje Dihovicni

Secondary education type	Grades					Passed in the first term	Passed in the second term
	6	7	8	9	10		
High school	12%	15%	33%	28%	12%	76	82
Secondary technical schools	64%	17%	10%	9%	0%	64	68
Secondary Social Sciences schools	92%	8%	0%	0%	0%	48	53

Table 2. The percentage success of students in the subject Web Applications and numbers of students passing this exam
Source: courtesy of PhD Djordje Dihovicni

Secondary education	Grades					Passed in the first term	Passed in the second term
	6	7	8	9	10		
High school	11%	18%	37%	18%	16%	83	87
Secondary technical schools	58%	16%	15%	7%	4%	65	67
Secondary Social Sciences schools	84%	9%	7%	0%	0%	47	52

4. CONCLUSION

The paper provides results of following a representative group of students who enrolled in the first year of study, with different prior knowledge in informatics. This group of students was monitored during the first two years of study, and the focus was on their success in subjects in Information Technologies (IT) and Computer Science. After the first two years, IT subjects were chosen in the third, fourth and fifth year of study. Based on the analysis and tabular data presented for subject Web Applications in the third year of study, it was determined as follows. The students who originated from professional high schools in technical and technological fields made a lot of progress during their studies, and in the final years their results were very similar to students who came from high schools (gymnasiums). The progress of students who previously attended secondary schools in social sciences was also noticed. The paper presents the curriculum of representative subject, *Web Applications*, and presents practical project tasks that students have mastered over the three years of bachelor studies in vocational engineering.

LITERATURE

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INTERNATIONAL SCIENTIFIC AND PROFESSIONAL CONFERENCE
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ENVIRONMENT AND SUSTAINABLE DEVELOPMENT. MECHATRONICS. OCCUPATIONAL SAFETY AND HEALTH AND FIRE SAFETY. SMART MANAGEMENT SYSTEMS. GRAPHIC ENGINEERING. DESIGN. TRAFFIC ENGINEERING. BIOTECHNOLOGY AND HEALTHCARE. MECHANICAL ENGINEERING. ECOTOURISM AND RURAL DEVELOPMENT.

E-LEARNING: STUDY ON STUDENTS` OPINIONS

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Abstract: *New technological achievements enabled changes in all aspects of scientific systems, especially in education during the coronavirus pandemic. ICT has become an integral part of the teaching process and it represents prestige in education. Electronic learning appeared as an idea that enabled the acquisition of knowledge and certain skills through information and communications technology. The aim of the paper is to compare the theoretical basis with the opinions of the students who experienced this way of learning during the coronavirus pandemic. The research was conducted on the territory of Belgrade in the winter semester of the 2022/2023 school year. The total number of students who participated in the survey is 112.*
Keywords: Internet, e-learning, research, students and results.

1. INTRODUCTION

Electronic learning is a term that was first used in the middle of the 20th century, when the first forms of computer-based learning were created [17]. In addition to this term, synonyms such as digital learning, online learning, virtual learning, learning on the internet are also used in educational institutions [18]. Electronic learning represents the process of acquiring knowledge, competences, intellectual abilities and development of critical and creative thinking through the implementation of teaching activities with the help of computer network, electronic and modern educational technology [19]. The closure of educational institutions during the COVID-19 pandemic encouraged them and the relevant Ministry to adopt the concept of alternative teaching under an urgent procedure in order to enable pupils and students not to be deprived of learning and thus to prevent the spread of further pandemics. E-learning system was adopted. The main component of internet learning is the use of computer technology [1]. Traditional teaching methods have been replaced by e-learning since the emergence of corona virus, because social gatherings in educational institutions were considered to spread the infection further. E-learning at the time was the best option since physical distance between employees and students was kept, although students did not really benefit from this way of learning [2]. Information technologies provide great opportunities for education and also training that will improve teaching, introduce innovations in the teaching process as well as stimulation of creativity of both teaching staff and students [3,4,5]. During the implementation of this type of teaching, educational institutions devoted a lot of effort and experience related to this type of education, which can also be present in the following years. In educational institutions around the world, processes are appearing that are exclusively related to learning, and information is continuously generated in order to use the knowledge that can be used for learning [6,7,8]. Electronic learning has a serious task in the educational system not only in Serbia, but also in the world. It changes the existing system and therefore represents one of the most important topics for research by the academic community [9].

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Gaebel defines electronic learning as the use of different types of ICT and electronic devices in the teaching process [10]. Today`s students have a desire to study online and thus they are provided with the opportunity to improve their knowledge at colleges and universities around the world. A good ICT infrastructure is necessary for this type of learning. However, there are a large number of disadvantages regarding e-learning, the most important of which is acquiring theoretical knowledge, but when it comes to practical application, this kind of aspect is not feasible for certain professions. Another disadvantage is the lack of face-to-face learning which achieves a better interaction between teachers and students. Also, one of the disadvantages is that online learning is not very reliable, it can be difficult and even misused [11]. Many studies that investigated the possibilities and challenges associated with the transition from traditional to online learning came to the conclusion that the greatest lack is a good and adequate preparation for this new type of teaching. A study that examined the attitudes of students during the covid-19 pandemic, whether students are ready to learn online or not, came to the conclusion that a blended learning method must be available [12]. In addition to this study, Radha in her study investigates the process of e-learning among students who are familiar with web technology and the way to improve their knowledge, and this study indicates that e-learning has become popular among students in all educational institutions in the period of isolation caused by the virus [13]. Thus, teachers are the ones who have to design teaching activities in order for learning to be effective. In the new era of e-learning imposed on us by digitalization, e-learning will not be based on digital tools as much as on the improvement of laws for the management of content and activities related to distance learning. Any online learning functions according to the following model:

- Design, correction and distribution of teaching material,
- Evaluation of students` knowledge,
- Management of teaching and learning process.

The most famous distance learning system is Learning Management System (LMS). LMS provides program support that fully administers learning process, and the most famous are: Moodle, WebCT, Claroline, Sakai, Dokeos, Chamilo, ATutor, AHyCo and others [14].

Electronic learning today represents one of the main concepts in the development of modern education. Its special significance is reflected in its advantages and disadvantages. As it is well known, electronic learning enables teaching to take place anytime and anywhere, so there is no time, geographical or spatial limitations. With the use of the Internet, users receive constant technical support, teaching materials are always available and cost less, and everything is fast and transparent [15]. We should not ignore the fact of saving money, lower costs of organizing teaching, availability of many courses and other educational activities at any time [16].

So far, the results of the research on the attitudes of students and teachers of higher education towards e-learning show different attitudes. In his study, Dosari states that there is a positive attitude of students and teachers in higher education towards e-learning, and Bregar, Zagmajster and Radovan [20], [21] agree with him. However, Kundi and associates say that students who use e-learning are rarely satisfied with its functionality, so institutions of higher education encounter user dissatisfaction and dissatisfaction with this learning method [22]. Combined education gives excellent results in group work in which students cooperate and exchange their knowledge [23]. The research among professional nurses found that the main advantages of online learning are related to independent planning of study responsibilities (66.9%), user-friendly online environment (51.2%) and communication (20.9%) [24]. In the research by Lugonjić et al. (2021), which refers to the examination of the attitudes of nurses, the results show that 42.4% of students rated their computer literacy as high, 19.6% as very high, and 1.1% are beginners in using computers [25]. Most of the students who participated in the reseach (75%) had experience with only one subject in which they used e-learning at the time of filling out the survey [25].

2. RESEARCH METHODOLOGY

The aim of the research is to examine how electronic learning functions, what are its advantages and what are its disadvantages. The aim of the study is to examine the opinion of active students regarding

electronic learning and thus make a conclusion regarding it. The initial hypothesis is: H_0 Students are satisfied with e-learning. H_1 Students find it difficult to follow distance learning. H_2 Students find online learning content useful. The total sample consisted of 112 respondents. The research on students` opinions involved direct interviews with the students from the University of Belgrade. In order to reach the respondents more easily, the research was conducted in front of students dorms in Belgrade, and those were Košutnjak, Patris, Karaburma and Vera Blagojević. The research was conducted from the beginning of October to the end of November 2022. A research problem of this paper is what are the experiences of students using e-learning platforms.

3. RESEARCH RESULTS

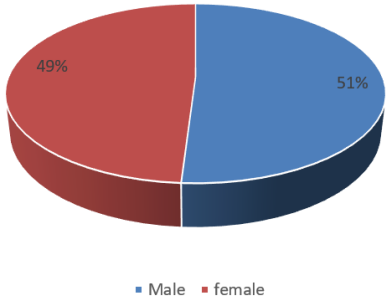

Figure 1 Sample structure with regard to the gender of the respondents
Source: Authors

Figure 1 shows the structure of the sample with regard to the gender of the respondents. In this research, only 1% more male respondents responded to the survey.

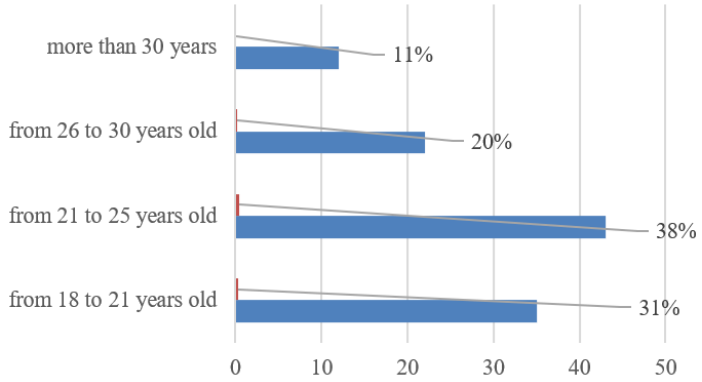

Figure 2 Sample structure with regard to the age of the respondents
Source: Authors

The highest response was among students in the age range of 21 to 25.

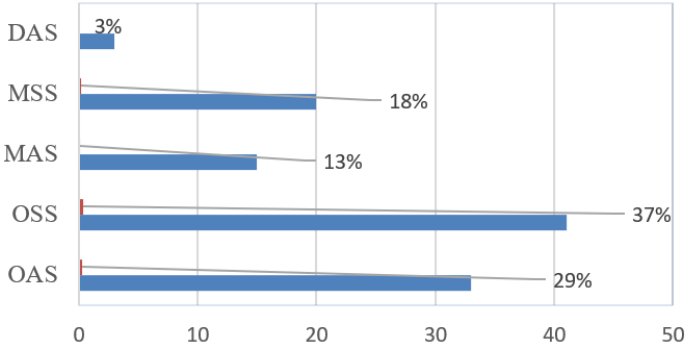

Figure 3 Sample structure with regard to the current status of studies
Source: Authors

The highest response in this research was among students at bachelor applied studies and undergraduate studies.

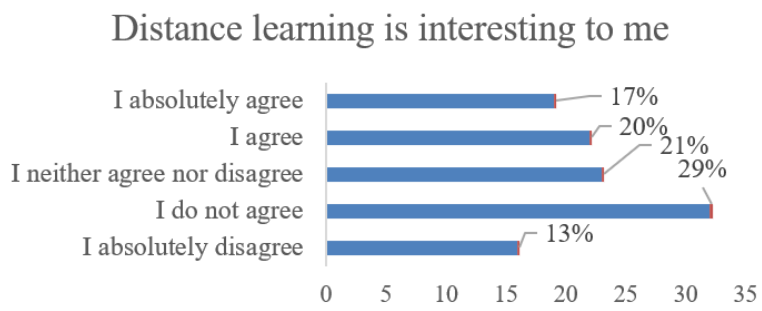

Figure 4 Distance learning is interesting for me
Source: Authors

From the above sample, we can conclude that distance learning is not interesting for students. A large number of respondents (29%) stated that distance learning is not interesting for them.

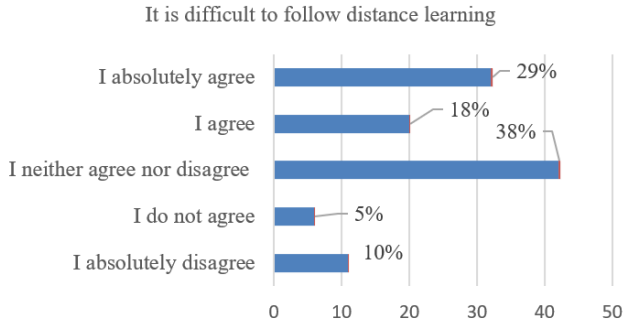

Figure 4 It is difficult to follow distance learning courses
Source: Authors

Based on the results, students expressed their opinions that they neither agree nor disagree, but a large percentage of them (29%) agree that it is difficult to follow lessons.

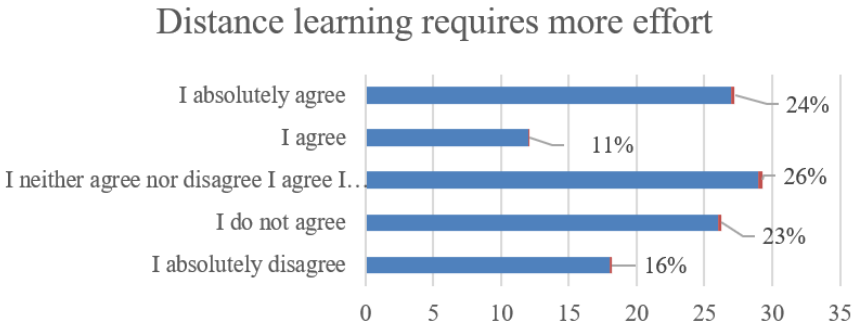

Figure 5 Distance learning requires more effort
Source: Authors

We can conclude that 24% of students think that distance learning requires greater commitment and more effort.

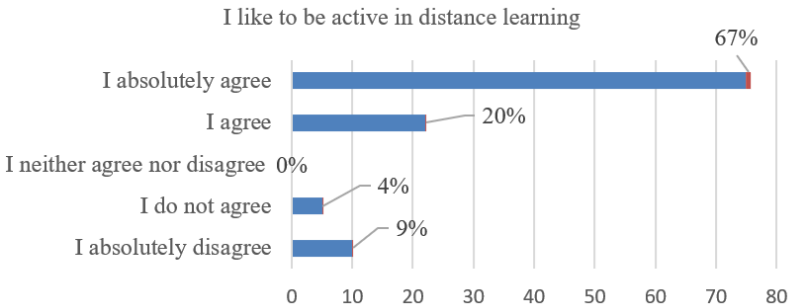

Figure 6 I like to be active in distance learning
Source: Authors

Regarding the online learning content, 87% of the respondents confirmed that they understand it. When asked whether independent work in distance learning suits them, 27% of students confirmed that this method suits them. When asked whether distance learning is stressful, the largest number of respondents answered that they neither agree nor disagree, while 20% of them answered that they absolutely disagree and that this way of learning is not stressful for them. In further research, 43% of respondents said that they use the Internet as an additonal source of teaching and learning material. While 55% of respondents would like to communicate with their teachers and colleagues via e-mail, 45% of them said that they sent their exam assignments (seminar papers, essays, etc.) via e-mail. 89% of students took their exams in the traditional way. 49% of students most often had consultations with their teachers and colleagues via Zoom and the Moodle application. During the pandemic, 90% of respondents used e-learning, but immediately after the pandemic students returned to their amphitheatres, workshops and laboratories. During the pandemic, students used the following platforms for online learning: Google Meet (38%), Zoom (32%) and Microsoft Teams (30%). When asked whether they are satisfied with e-learning, 58% of respondents answered with I neither agree nor disagree.

4. CONCLUSION

The obtained results indicate that students use the Internet as a source of learning and that it was their only way of learning during the pandemic. Moreover, they had communication with their teachers and colleagues and actively participated in the learning process. In most educational institutions, the following platforms were used: Google Meet, Zoom and Microsoft Teams. For some subjects, even after the pandemic, this type of learning is still used because there are only a small number of students who attend the same classes. Therefore, e-learning is successfully applied at all education levels, all ages and subjects. Students became aware of the importance of e-learning activities for their further development. Electronic learning is the future in educational institutions, so it is important to work on its further modernization and popularization. Based on the obtained results, it is recommended that institutions of higher education use a blended learning method. The hypotheses in this research: initial H_0 Students are satisfied with e-learning was partially confirmed. 58% of respondents confirmed it, although a large number of them did not express a positive attitude. H_1 Students find it difficult to follow distance learning was partially confirmed, as can be seen in Figure 4. H_2 Online learning content is useful for students was confirmed in the research, as seen in Figure 7.

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GRAPHIC ENGINEERING

INTERNATIONAL SCIENTIFIC AND PROFESSIONAL CONFERENCE
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ENVIRONMENT AND SUSTAINABLE DEVELOPMENT. MECHATRONICS. OCCUPATIONAL SAFETY AND HEALTH AND FIRE SAFETY. SMART MANAGEMENT SYSTEMS. GRAPHIC ENGINEERING. DESIGN. TRAFFIC ENGINEERING. BIOTECHNOLOGY AND HEALTHCARE. MECHANICAL ENGINEERING. ECOTOURISM AND RURAL DEVELOPMENT.

PRINTING PARAMETER IMPACT ON PLA MATERIAL FRACTURE TOUGHNESS RESULTS

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Aleksandar Sedmak[3], Faculty of Mechanical Engineering, University of Belgrade
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Abstract: *The structural life of a functional component includes the period when the component has developed some sort of defect (e.g., crack). In such cases, damage-tolerant design utilizes fracture mechanics parameters for the assessment of the component's structural capability to withstand loads expected in the exploitation. One of the most fundamental parameters is the stress intensity factor, which characterizes the stress state near the crack tip. The critical value of this parameter is called fracture toughness, and it is the most suitable failure criterion for brittle materials. One of the most used materials in fused deposition modeling (FDM) technology is PLA polymer, known for its brittle behaviour. Due to good mechanical properties in comparison with other FDM polymers and excellent biocompatibility, the PLA material is not just a material for prototyping purposes but may also serve as a material for functional applications in medicine, food packaging, etc. The FDM printing parameters influence the final component's mechanical properties. The aim of this paper is to assess the impact of printing parameters, such as layer height, infill density, and raster orientation, on fracture toughness values.*
Keywords: PLA, Fracture toughness, Fused Deposition Modeling, Printing parameters.

1. INTRODUCTION

PLA (PolyLactic Acid) is a thermoplastic polymer derived from natural sources and is best known for its applications in Additive Manufacturing (AM) [1,2], namely, Fused Deposition Modeling (FDM), which is an extrusion-based AM technology. As a bio-based polymer, PLA represents a good substitute for other petroleum-based synthetic polymers, both for certain functional applications and for AM prototyping purposes. Due to the good mechanical properties investigated in [1,3] and proven biodegradability, PLA material is utilized in the food packaging industry and may serve in load-bearing biomedical applications, e.g., sutures, short-term screws, and resorbable fracture fixation plates [3-5].
Previously conducted tensile tests on FDM-prepared PLA specimens have shown a substantial influence of printing parameters on the mechanical responses of the material [1,2,6-9]. Lower layer heights improve the Ultimate Tensile Strength (UTS) but one has to keep in mind not to over-compress the layers [1,6]. Infill density influence was a subject in [7], showing the density influence from 10 up to 100 % infill with a 10 % increment. Raster orientation impact was a subject in [8], and the influence of nozzle temperature and printing speeds was examined in [9]. Thus, from papers [6-9] it is obvious that layer height, infill density, and raster orientation have the highest impact on the tensile properties of PLA material.

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According to fracture mechanics fundamentals, there are three Modes of loading that can be applied to a developed crack. Mode I tends to open a crack, Mode II slides one crack face with respect to the other, and Mode III tears both crack faces (Fig. 1). In real-life conditions, these three Modes act together with Mode I being the most influential, [10]. Thus, the critical stress intensity factor in Mode I is usually referred to as fracture toughness (K_{IC}).

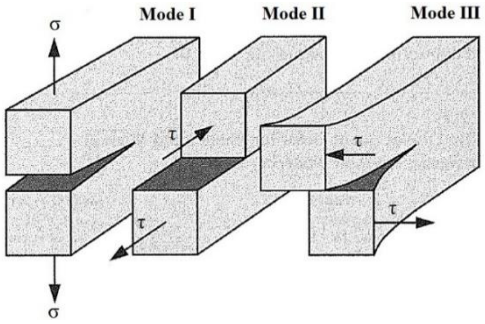

Figure 1. Three possible loading Modes on a crack.
Source: [10]

Fracture toughness assessment is a regular procedure for AMed materials, both for Mode I and II, [11-16]. The principal difference between Mode I and II fracture toughness is the testing setup, i.e., the number of supporting points on the specimen during the test: Mode I uses a three-point bending test procedure while Mode II uses a four-point bending setup. For example, there is thorough data on the fracture toughness values (both Mode I and II) of Selective Laser Sintered (SLS) materials, [11-14]. In FDM, except for securing the plane-strain state (described in detail in [10,17]), there are also a few more requirements, as explained in [15]. Except for regular fracture toughness tests, the addition of a set of cameras in order to capture crack opening displacement at the notch mouth and crack tip, and full-field strain states at the front side of the specimen ligament provides valuable information about the material, [16].

2. MATERIALS AND METHODS

Fracture toughness values can be calculated using different specimen geometries (see [13]), and the most utilized designs are SENB (Single Edge Notched Bend) and CT (Compact Tension). Standard [17] covers both these specimen geometries. The selected specimen design here is SENB, with 13 x 26 x 114 mm in bulk. Tests were conducted on a regular tensile testing machine, with a mounted three-point bending test rig. The test scheme with specimen geometry is shown in Fig. 2. Notch (see detail C, Fig. 2) was AMed, and pre-crack (3 mm long) was created via hammer tapping onto a razor placed in the notch- as suggested in the standard [17].
The fracture toughness value is calculated according to the formula in [17]:

$$K_Q = \left(\frac{P_Q}{BW^{1/2}}\right) f\left(\frac{a}{W}\right) \tag{1}$$

In (1), P_Q is the maximal detected load, B and W are specimen dimensions, and $f\left(\frac{a}{W}\right)$ is a formula which depends on the ratio between crack length and specimen width (see the full formula in [17]). Index ''Q'' in (1) signifies the conditional state of a calculated value, since load-displacement response must follow a linear trend and plane-strain condition at the crack front must be met. Namely, a specimen has to reach a certain thickness in order to obtain the plane-strain condition. In [17], the following size criterion must be satisfied:

$$B, a, (W - a) > 2.5\left(\frac{K_Q}{\sigma^y}\right)^2 \tag{2}$$

In (2), σ^y represents yield stress. For this particular case, the values are stored in [1].

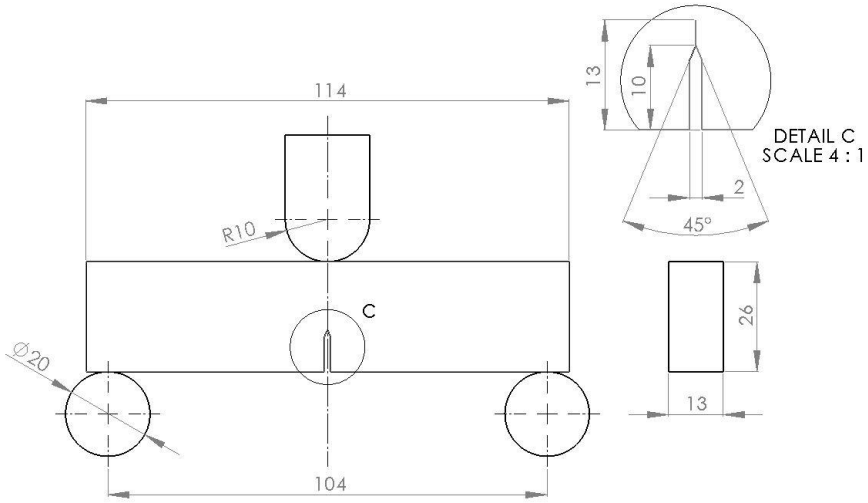

Figure 2. Three-point bending test scheme with loaded specimen geometry (units in [mm]).
Source: Personal image

To estimate the layer height, infill density, and raster orientation influence, the SENB specimens were sorted in four batches according to [1], with three specimens per batch:

- 1st batch: 0.1 mm layer height, 50% infill density, rectilinear raster orientation,
- 2nd batch: 0.1 mm, 100%, rectilinear,
- 3rd batch: 0.1 mm, 100%, circular,
- 4th batch: 0.2 mm, 50%, rectilinear.

The fifth batch from [1] was excluded since material drying is not a subject of this research. Fracture surfaces were observed using a scanning electron microscope LYRA 3 XMU FEG/SEM (SEM) operating at 2 kV. The images were taken in secondary electron contrast.

3. RESULTS AND DISCUSSION

In FDM, outer and inner layers are differently deposited as can be seen from the fracture surface SEM images in Figs. 3 and 4. Brittle fracture is more obvious in the outer layers (see Fig. 3). Inner layers exhibit a slight straining at ruptured ends (see Fig. 4), but this phenomenon probably appeared after the reached maximal load, since load-displacement linearity until reached maximal load was satisfied.

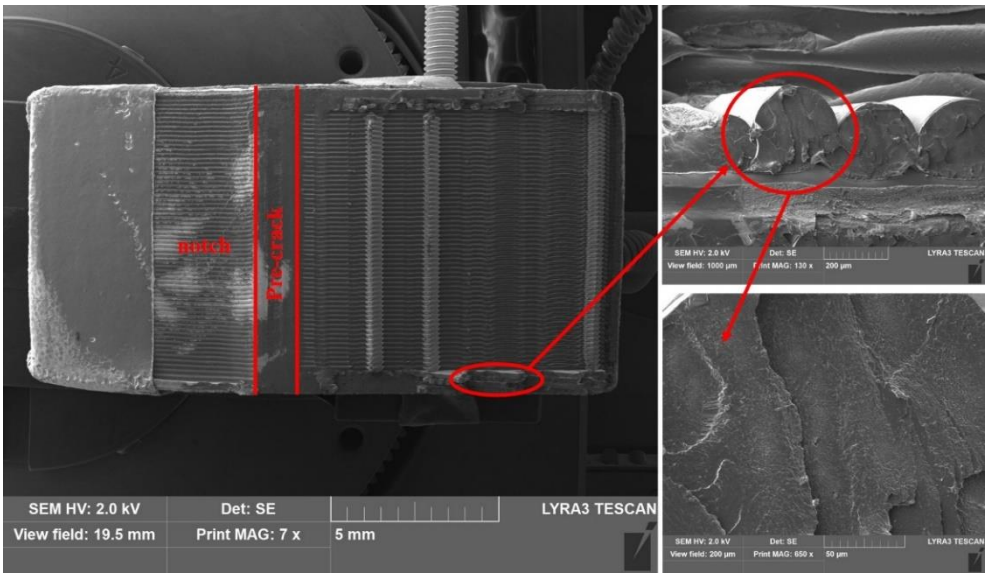

Figure 3. SENB specimen fracture surface with magnified outer layers.
Source: TESCAN LYRA3 SEM device, Institute of Physics of Materials, Brno, Czech Republic

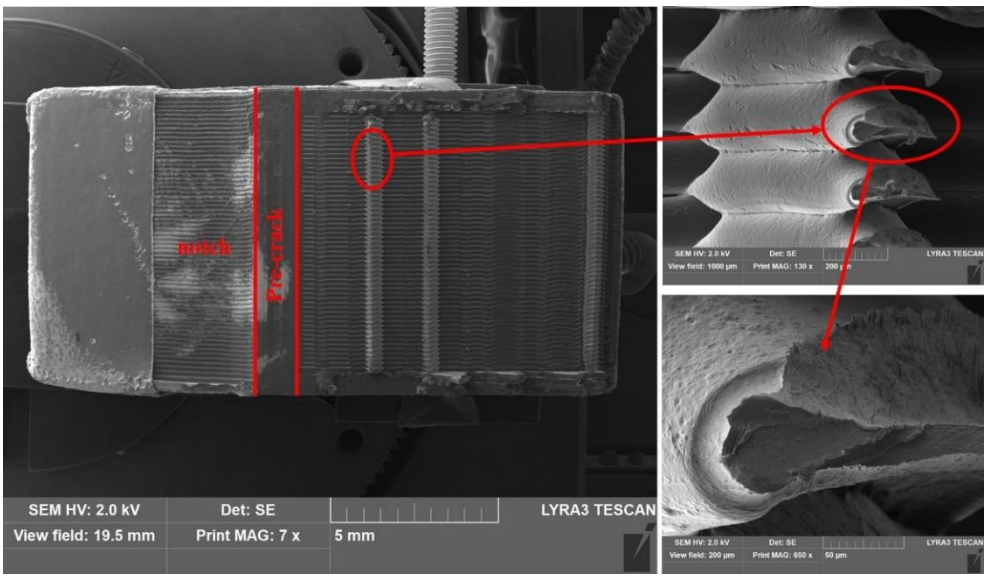

Figure 4. SENB specimen fracture surface with magnified inner layers.
Source: TESCAN LYRA3 SEM device, Institute of Physics of Materials, Brno, Czech Republic

Before fracture toughness tests, the specimens were measured in width (W) and thickness (B) via a vernier caliper in three points, and the average values were used for K_{IC} calculation. Crack length (a) is set to 13 mm, and the ratio a/W is used for the calculation of f (a/W)- the exact formula is shown in the standard [17]. Maximal detected load (P_Q) is the highest in full-infill density batches, with rectilinear raster orientation specimens reaching values of almost 1 kN. Hence, all the data needed for fracture toughness calculation are stored in Table 1.

Table 1. Measured specimen dimensions and maximal detected load.
Source: personal data

PLA data	B [cm]	W [cm]	a/W	f (a/W)	P_Q [kN]
1.1	1.315	2.649	0.491	10.32	0.267
1.2	1.308	2.663	0.488	10.32	0.264
1.3	1.312	2.649	0.491	10.32	0.268
Average	1.312	2.654	0.490	10.32	0.267
2.1	1.314	2.632	0.494	10.48	0.739
2.2	1.317	2.633	0.494	10.48	0.938
2.3	1.318	2.628	0.495	10.48	0.929
Average	1.316	2.631	0.494	10.48	0.869
3.1	1.320	2.594	0.501	10.65	0.507
3.2	1.318	2.592	0.502	10.65	0.527
3.3	1.322	2.590	0.502	10.65	0.545
Average	1.320	2.592	0.502	10.65	0.526
4.1	1.299	2.599	0.500	10.65	0.242
4.2	1.295	2.596	0.501	10.65	0.267
4.3	1.293	2.597	0.501	10.65	0.260
Average	1.296	2.597	0.501	10.65	0.256

The first calculated fracture toughness value is conditional (K_Q) and has to meet the size criterion, which evaluates whether the specimen has reached the required plane-strain condition. From Table 2, one can see that K_Q falls between 1.526-5.672 MPa*m^1/2. The size criterion shows that all the specimen batches meet the plane-strain condition, except for the 2nd batch (100 % infill, rectilinear raster orientation), where the thickness needed to reach the plane-strain condition is around 26 mm,

on average (as a reminder, SENB specimen thickness here is around 13 mm). Hence, the 1st, 3rd, and 4th batches meet the size criterion, and the conditional K_Q value there is actually the real fracture toughness value K_{IC}.
The K_{IC} value range in this research is between 1.526-3.388 MPa*m^1/2. The difference between the 1st and 4th batches suggests that layer height does not have a significant influence on K_{IC} value. An interesting conclusion can be drawn from full infill density batches, namely: in tensile tests, the highest UTS values were present in circular raster batch, where raster lines are parallel to the load direction (see [1]). But, in fracture toughness tests, using a three-point bending setup, the rectilinear orientation batch holds the highest load values even though the size criterion was not met. This is due to raster lines being at -45/+45° angle relative to the applied load. The conclusion from this research is in agreement with [18].

Table 2. Fracture toughness values and size criterion.
Source: personal data

PLA data	K_Q [MPa*m^1/2]	σ^y [MPa]	Size criterion, Eq. (2) [mm]	B, a, (W-a) [mm]	Size criterion Satisfaction [YES/NO]
1.1	1.584	32.924	5.790	13 - 13.49	YES
1.2	1.566	32.924	5.653	13 - 13.63	YES
1.3	1.592	32.924	5.842	13 - 13.42	YES
Average	1.580	32.924	5.761	13 - 13.51	YES
2.1	4.481	51.363	19.029	13 - 13.32	NO
2.2	5.672	51.363	30.488	13 - 13.33	NO
2.3	5.619	51.363	29.923	13 - 13.28	NO
Average	5.258	51.363	26.199	13 - 13.32	NO
3.1	3.151	54.36	8.402	12.86 - 13.13	YES
3.2	3.283	54.36	9.117	12.92 - 13.18	YES
3.3	3.388	54.36	9.710	12.9 - 13.22	YES
Average	3.274	54.36	9.069	12.89 - 13.18	YES
4.1	1.526	31.5	5.868	12.99 - 13	YES
4.2	1.690	31.5	7.200	12.95 - 13	YES
4.3	1.648	31.5	6.843	12.93 - 13	YES
Average	1.621	31.5	6.623	12.96 - 13	YES

4. CONCLUSION

Fracture toughness tests were conducted on SENB specimens, made from FDM-prepared PLA material, according to the standard [17]. There are four specimen groups in total, with three specimens per batch. Batches differ in printing parameters, i.e., there are three variables: layer height, infill density, and raster orientation.
The infill density has proven to be the most influential parameter on K_{IC} values, then raster orientation, and lastly, the layer height was the least impactful.

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ENVIRONMENT AND SUSTAINABLE DEVELOPMENT. MECHATRONICS. OCCUPATIONAL SAFETY AND HEALTH AND FIRE SAFETY. SMART MANAGEMENT SYSTEMS. GRAPHIC ENGINEERING. DESIGN. TRAFFIC ENGINEERING. BIOTECHNOLOGY AND HEALTHCARE. MECHANICAL ENGINEERING. ECOTOURISM AND RURAL DEVELOPMENT.

APPLICATIONS OF REAL-TIME RENDERING GAME ENGINE IN EDUCATION THROUGH PRACTICES AND INITIATIVES

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Abstract: *Games should enrich leisure time and provide a sense of advancement and fulfilment by following specific rules and overcoming obstacles to reach a particular goal. By analogy to games, our educational system is comprised of various sets of rules that participants are meant to obey. If it is looked through that prism, students can be perceived as players that acquire a different set of knowledge and skills that can be useful further in their careers. On the other hand, educators can be perceived as someone who design and imposes various challenges and obstacles for students to solve and overcome. Today, real-time rendering game engines provide accessible toolboxes for learning and implementing a different set of technical skills such as programming, solving logical problems, writing shader codes for different visual styles, and also set of artistic skills such as 3D modelling, painting, sculpting, and animating to name a few. Therefore, this paper aims to give insight into the theoretical background of what real-time rendering and game engines refer to and to describe some practices and initiatives promoting the implementation of real-time rendering game engines in the educational curriculum through different courses and workshops.*
Keywords: Real-time rendering, game engine, video games, education, gamification, edutainment

1. INTRODUCTION

The term ‘play’ refers to an activity usually not bound by externally imposed rules and is more casual, creative, and liberating. The term ‘game‘ refers to an activity that should enrich leisure time and provide a sense of advancement and fulfilment by following specific rules and overcoming obstacles to reach a particular goal. By analogy to games, our educational system is comprised of various sets of rules that participants are meant to obey. Both students and teachers. If it is looked through that prism, students are players who acquire a different set of knowledge and skills that can be useful further in developing their careers. On the other hand, educators can be perceived as someone who designs and imposes various challenges and obstacles for students to solve and overcome. Today, real-time rendering game engines provide accessible toolboxes for learning and implementing a different set of technical skills such as programming, solving logical and mathematical problems, writing shader codes for different visual styles, and also set of artistic skills such as 3D modelling, drawing, painting, texturing, sculpting, and animating to name a few.
Dempsey and his colleagues as well as Malone [1,2], define a game as ‘usually a contest of physical or mental skills and strengths, requiring the participant(s) to follow a specific set of rules to attain a goal‘. According to Suits ‘playing a game is a voluntary effort to overcome unnecessary obstacles’

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[3]. In his book ‘Level Up – The Guide to Great Video Game Design‘, Rogers [4] ultimately concluded that ‘a game is an activity that requires at least one player, has rules, and has a win and/or lose conditions‘. Chris Crawford [5], one of the game designer pioneers stated that - ‘The computer game is an art form because it presents its audience with fantasy experiences that stimulate emotion.‘ and that games are ‘intrinsically participatory in nature‘ which gives players ‘not the experience itself but the conditions and rules under which the audience will create its own individualized experience’. But, what is a video game? Maybe the simplest definition that gave Rogers is: ‘a video game is a game that is played on a video screen’ [4]. Academics and especially game designers also consider one of maybe most important factors of a video game – fun. The fun can not be looked upon solely as something amusing or as the result of a leisure time activity. Fun can be also achieved while working on something that may not be so interesting when one starts doing it. Csikszentmihalyi in his book ‘Flow: The Psychology of Optimal Experience‘ talks about the state – called flow state - in which we can merge ourselves when doing something interesting to us or when something becomes interesting to us by doing it [6]. This paper aims to give insight into the theoretical background of what real-time rendering and game engines refer to and to describe some practices and initiatives promoting the implementation of real-time rendering game engines in the educational curriculum through different courses and workshops.

2. REAL-TIME RENDERING AND GAME ENGINES

2.1 Real-time rendering

Akenine-Möller et al. describe real-time rendering as a process of rapidly making images on the computer and as the most highly interactive area of computer graphics [7]. Interactivity comes from the viewer‘s action and reaction through their feedback when the image appears on the screen which further affects generated real-time content. Besides interactivity, producing three-dimensional images is another condition to call the sequence of images rendered in real-time. These two conditions are sufficient conditions for real-time rendering but more than ever the third element became essential for real-time rendering, and that is graphics acceleration hardware [7]. The core component of real-time graphics is called the graphics rendering pipeline. An in-depth discussion on this topic is out of the scope of this paper, but the main function of this pipeline is to generate (or render) a two-dimensional image based on three-dimensional objects, virtual cameras, lights, etc. [7] Figure 1.

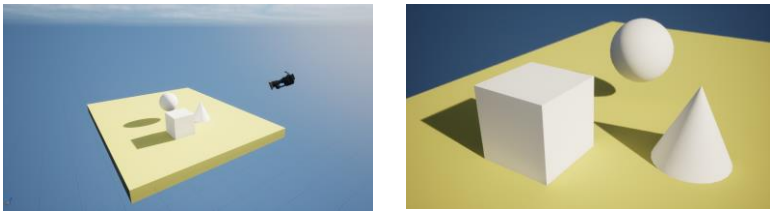

Figure 1. Locations of basic geometry shapes and camera in the environment (left), and 2D appearance of the shapes and environment through the camera lens (right)

2.2 Game engines

To discuss what a game engine is in its broadest meaning it must be separated from a specific game, genre, or hardware system. Sherod [8] describes a game engine as ‘a framework comprised of a collection of different tools, utilities, and interfaces that hide the low-level details of the various tasks that make up a video game‘. Lewis and Jacobson mention that the engine includes modules handling input, output (3D rendering, 2D drawing, sound), and generic physics/dynamics for game worlds [9]. According to Andrade, a game engine represents a reusable software layer allowing the separation of common game concepts from the game assets (levels, graphics, characters, etc.) [10]. The main goal of a game engine is to separate the game-making process into common video game features enabling

the use of code and game assets not just for one game but for reuse in different games. Today, there is a tendency to have a single game engine for different types of games, and not only games but also for animated movies, geographic and architectural visualizations, and ICVFX (In-Camera Visual Effects) used in the movie industry. Such an engine - ‚Überengine', according to Anderson et al., could potentially offer large benefits for the development of games, and apart from financial savings, such an engine would facilitate the transfer of programmers and artists across projects [11].

3. FINDINGS

3.1 Game engines in education curriculum

At the University of Novi Sad, Faculty of technical sciences, a couple of Departments started using game engines in their education programme. For example, at the *Department of Graphic Engineering and Design* [12], real-time graphics and game engines are used in two subjects: *Basics of Computer Games* [13] and *Computer Games* [14]. On those two subjects two game engines are being studied: Unity [15] and Unreal Engine [16]. The first one is introduced to students in first semester of the third year on the *Basics of Computer Games*, where the main goal of the subject is to give an introduction to and basics of game development and the game industry and basic terminology while simultaneously working on teaching students to develop their first 2D game. This subject also covers the basics of C# scripting language. Further on, in their second semester of the third year of studies on the subject named *Computer Games*, students continue to learn about game development by getting familiar with the concept of real-time rendering, introduction to game and level design, and concept of game engines, particularly Unreal Engine. In parallel students work in Unreal Engine on developing their first 3D environment by tackling basic concepts of level design, lighting, post-processing, animating cameras, modelling, and rendering.
Chair of Animation in Engineering, in the Department of Fundamental Sciences, at the Faculty of Technical Sciences in Novi Sad also implemented the Unreal game engine in their curriculum programme. In the subject named *Spatial Design and 3D Environments*, students learn to design immersive virtual spaces and environments in different disciplines [17]. Besides this subject Unreal Engine is implemented also in subjects such as *Simulations in Digital Animation*, *Advanced Simulation in Digital Animation*, and *Engineering Animation and Other Media* [18].
Faculty of Dramatic Arts in Belgrade also successfully implemented the utilization of real-time rendering techniques and technology through a four-year programme in the *Visual Effects, Animation and Game Art Department.* During their study, students are trained in the fields of animation, visual effects video games, and interactive media [19].

3.2 Educational and training courses, programmes and initiatives

Together with industry specialists, university educators have worked on various programmes where the implementation of real-time rendering graphics can help to tackle some of the modern technology challenges. One such project is conducted by educators and researchers from the *Mechatronics, Robotics and Automation Department* (Faculty of Technical Sciences in Novi Sad) [20] with the help and support of industry specialists from company *3Lateral* [21] through the EpicMega Grants programme [22] in 2021. The project is called *MetaCobots* which demonstrated the ability to design and deliver a framework for training and validation of human-to-robot interaction within the synthetic environments empowered by runtime simulations [23].
In February 2021, a team specialized in VFX and education courses – *Crater Training Center* [24] initialized together with *3Lateral*, the training programme called *Train The Trainers* [25] for university educators with the aim of implementing real-time rendering by using Unreal Engine, in curriculum programmes at their institutions. More than 40 university professors coming from Belgrade, Novi Sad, Kragujevac, Niš, and Zrenjanin successfully finished this educational course.

Further, the *Nordeus Foundation* situated in Belgrade, Serbia [26] started the *Gejmlab* platform [27] where the domestic public can learn all about gaming and game development from successful industry specialists. This platform aims to help people start their careers in the gaming industry by honing their love and interest in the world of games through a series of articles, courses, and tutorials.
One can not talk about the gaming industry in Serbia not to mention *The Serbian Games Association (SGA)* [28], a non-governmental, non-profit organization dedicated to the development of the Serbian gaming industry. Their main goal is 'to increase the competitiveness of their members on the global market, to create the best possible conditions for creating and publishing video games in Serbia, as well as to improve the talent and creativity of people involved in the sector.' One of their programmes includes ones such as *Playing Narratives* [29], a mentorship cohort with the aim of lifelong learning and exchange of knowledge between mentor and mentee creating an environment in which they can develop on a personal as well as professional level. Another of their initiatives is one called *Shift2Games* [30] which aims to popularize gaming professions and the creative industry as a whole, especially among the young population who are in the final stages of their education as well as professionals active in other relevant industries. *SGA* also provides a place where the public can search for job offers in the games industry.
The important role in implementing new technologies from the gaming and IT industries into education and vice versa plays *3Lateral* and *Materriya Talent Development* team through *Epic Games Community Lab* activities held in *Science & Technology Park in Novi Sad*, Serbia [31]. Through a series of lectures from industry specialists and university professors, they aim to bring together the gaming and education community, bring the audience novelties from creative industries and organize different education programmes such as *Fortnite Creative Fundamentals* [32], *Game Crafting: Unreal Editor for Fortnite* [33], and now renowned *Epic Games Fellowship programme* designed for the domestic public. Fellowship programmes (such as *Storytelling Fellowship* [34] and *World Building Fellowship* [35]) have a goal to gather specialists from gaming, VFX, animation industries, and education and through a series of lectures and practical workshops train them in using Unreal Engine for their further projects and researches.

4. DISCUSSION

With the advance of game engines and real-time rendering, it can be seen that these technologies are finding their way into the curriculum programme of different departments and different subjects. The tendency toward 'Überengine' is now evident more than ever. Game development is intrinsically interdisciplinary area gathering people from different professions to work collaboratively on the same project. From the game engine of today, it is required to be able to tackle various kinds of jobs, from modelling, texturing, shading, lighting, and post-processing to scripting, animating, and even movie and art direction and all of that in real-time.
There is a lot of research on the advantages and disadvantages of implementing games in education and teaching pupils and students about game development. There are usually two very different approaches in designing games in curriculum according to Klopfer et al. [36]. The first approach is to use commercial games (e.g. World of Warcraft and Civilization) to bring close the subject of research or develop certain skills. The second one generally avoids commercial games and focuses on educational games that help supplement traditional academic subjects. Klopfer and colleagues pointed out that 'while the first group embraces games and abandons school, the second group often embraces school to the detriment of anything that looks like real gaming.' The two approaches mentioned above tend to be more instructional in the way that teachers want to have a finished, downloadable teaching product as the party responsible for teaching the child [36].
Apart from this 'instructional approach', Kafai and Burke [37] adopted and wrote about the so-called 'constructivist approach' to using games in education. Kafai and Burke (2015) emphasize the idea that knowledge about rules, worlds, and interactions is, in this way, represented in a public entity (which is the game) and that playing and making games highlights the personal, social, and cultural dimensions of constructionist learning. They stated that making video games could help understand

the social, economic, and civil power of making and sharing. This is also supported by much earlier Piaget's work [38] who stated that games of construction are considered the highest form of gameplay, as games require children to build representations of the world according to their understanding.

5. CONCLUSION

From the findings represented in this paper one can not argue that implementation of real-time rendering through game engines is present to a large degree and probably will continue to be researched to a great extent in different departments as part of different subjects. These subjects and even departments intertwine each other in their findings to be part of a much larger whole wrapped in one common denominator called game development, animation, simulation, architecture, or even movie projects.

Application of game engines through different curriculum programmes can grow the community which is connected through different initiatives and joint projects directly with the professionals from the industries giving even more credibility to the educational institutions and their subjects as well as research projects. On the other hand, students can be prepared to work in team with people from different professions during their studies as well as on their tomorrow jobs.

And last but certainly not least, research done by academia when connected through community-driven and industry-supported events and programmes can give back to the industry by providing new research findings and vice versa. This started to show great possibilities for creatives not only who are part of a great team but also for individuals; not only for industry workers but also for researchers, students, and their professors.

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ENVIRONMENT AND SUSTAINABLE DEVELOPMENT. MECHATRONICS. OCCUPATIONAL SAFETY AND HEALTH AND FIRE SAFETY. SMART MANAGEMENT SYSTEMS. GRAPHIC ENGINEERING. DESIGN. TRAFFIC ENGINEERING. BIOTECHNOLOGY AND HEALTHCARE. MECHANICAL ENGINEERING. ECOTOURISM AND RURAL DEVELOPMENT.

EXAMINATION OF THE POSSIBILITY OF DYEING PRINTING PAPERS WITH PLANT EXTRACTS

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Abstract: *In this study, aqueous and alcoholic extracts of red cabbage were initially prepared, and offset paper sheets were dyed using the immersion technique. The sheets were dried under various conditions, both at ambient air temperature and elevated temperatures. The color change of the paper sheets was determined based on spectrophotometric measurements of the uncolored offset paper (reference value) and the dyed sheets were dried by two methods immediately after coloring, as well as at intervals of two and six days. The color fastness to distilled water and alcohol was also examined, and the impact of these agents on different samples was assessed over specific time intervals.*
Keywords: red cabbage, plant extracts, printing papers, paper dyeing, ink resistance to moisture

1. INTRODUCTION

The constant pursuit of ever-increasing profits, coupled with decades of neglect for environmental preservation, has resulted in pollution that is evident at every turn. Industries have surged in innovation and hyperproduction, prioritizing their capital without regard for the environment. Year after year, the environment has borne the increasing burden of various types of waste, which it can absorb less and less. Such behavior has led to a point where sustainable development must be the guiding principle in all aspects of prosperity. In nature, materials are found from which various products can be made, both synthetic ones that often have a detrimental impact on the environment, and recyclable and biodegradable ones with minimal adverse effects on the environment. Plant life is rich in substances that can be used to create various products, including dyes. Such plant-based dyes have been used since prehistoric times in various civilizations around the world [1].
Plant-derived dyes can be classified into groups of chemical compounds, or pigments, found in the plants from which they are extracted (Table 1).

Table 1. Classification according to colors and chemical compounds found in plants [2]

Color	PIGMENT	FRUIT AND VEGETABLES	FORMULA
Red	Anthocyanin	Strawberry, Blackberry, Cherry, Apple	
	Lycopene	Tomato, Watermelon	
	Betacyanin	Beet	

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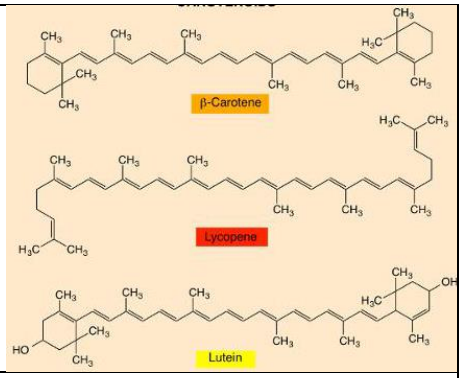
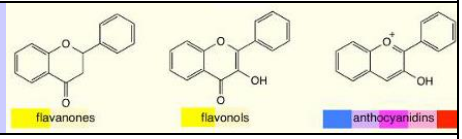
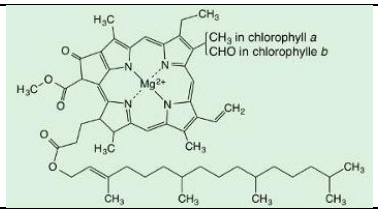
Orange	Beta-carotene	Carrot, Mango, Apricot, Pumpkin	
	Beta-cryptoxanthin	Oranges, Tangerine	
Blue/Purple	Anthocyanin	Plums, Eggplant, Red Cabbage	
Yellow	Lutein, Zeaxanthin	Corn , Avokado	
	Kurkumin	Tumeric	
Green	Chlorophyll	Broccoli, Spinach, Cabbage, Green tea	
Black	Thearubigens	Black tea	
	Antocyanin	Blackberries	

In this study, the possibility of coloring printing paper with extracts of compounds from the anthocyanin group will be examined. The chemical formula of anthocyanin is provided in Figure 1.

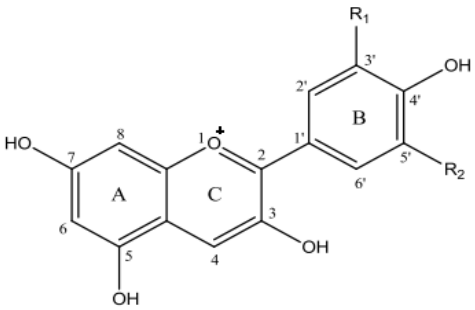


Figure 1. Structural formula of anthocyanin [3]

According to the groups R1 and R2, anthocyanins are divided into several subgroups, as shown in Table 2.

Table 2. Basic structure of the main anthocyanins commonly found in nature [3]

Anthocyanins	R1	**R2**	**Produced color**
Pelargonidin	-H	-H	Salmon orange
Cyanidin	-OH	-H	Crimson red and burgundy
Peonidin	-OCH_3	-H	Crimson red
Malvidin	-OCH_3	-OCH_3	Purple
Petunidin	-OCH_3	-OH	Purple
Delphinidin	-OH	-OH	Purple, lavender, and blue

Red cabbage contains cyanidin in its composition, which is reflected in its purple-blue color (Figure 2). Characteristic of red cabbage, specifically cyanidin in it, is its ability to change color with a change in the pH value of the environment. This property is interesting when coloring packaging paper, where a color change could indicate the condition of the packaged product.

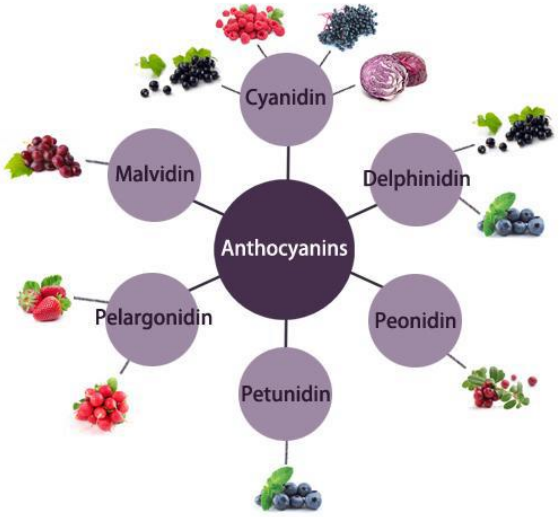


Figure 2. Graphic representation of anthocyanins, their classification, and the plants in which they are found [4]

In this study, printing paper will be colored using water and alcohol extracts of red cabbage. The coloring obtained with different extracts and under different operating conditions will be examined, as well as the stability of the coloring over time and under the influence of moisture and alcohol.

2. EXPERIMENT

The aqueous extract was prepared by blending 400 g of red cabbage for 3 minutes. The blended mass was immersed in 600 ml of distilled water and kept at a temperature of 150°C for 25 minutes with occasional stirring. After 24 hours, the mass was filtered through a triple-layered gauze. The alcoholic extract was prepared by blending 400 g of red cabbage for 3 minutes. The blended mass was immersed in 600 ml of 96% ethyl alcohol. After 24 hours, the mass was filtered through a triple-layered gauze. The leaves were dyed using the immersion method. A shallow container was filled with 100 ml of the aqueous extract. Prepared sheets of offset paper IQ MASTERPRINT, manufactured by MONDI, with a weight of 80 g/m2, were immersed in the extract for 15 minutes, with occasional stirring. The sheets were then removed and drained naturally (gravitationally). One group of sheets was air-dried at room temperature, and the other in the laboratory paper sheet former (blatbildner) between two sheets of dry paper at a temperature of 85°C for 5 minutes. Dyeing of sheets with alcoholic extract and drying was performed in the same manner as with the aqueous extract. The color of reference and dyed sheets was measured after 40 minutes, sufficient for sample drying, using the SpectoEye spectrophotometer from GretagMacbeth, under the following measurement conditions: D50, 2°, without optical filter, calibration on an absolute white standard, white background. On each sheet, color was measured at five points to examine uniformity and obtain the average value as a representative indicator. The measured color values are presented in the CIELab system (L*-lightness, a* green-red axis, and b* blue-yellow axis), and the color difference was calculated as.

$$\Delta E = [(L_2 - L_1)^2 + (a_2 - a_1)^2 + (b_2 - b_1)^2]^{1/2} \quad (1)$$

The colorfastness over time was determined based on color measurements of leaves left in the dark, exposed to air, after two and six days. The second group of leaves was subjected to the action of

distilled water and alcohol for 11 minutes and air-dried to investigate color resistance to these liquids. Measurements were taken after drying for 40 minutes, which was sufficient for the samples to completely dry naturally.

3. RESULTATS AND DISCUSSION

The extracts were monitored for 6 days, and in the aqueous extract, there was a change in color from purple to blue-green, while in the alcoholic extract, a slight change occurred from light purple to a darker shade. The results of color change measurements of dyed sheets compared to the clean sample of offset paper, measured on the same day as they were dyed, are presented in Table 3.

Table 3. Color change of offset paper dyed with aqueous and alcoholic extracts of red cabbage

Extract – drying conditions	L_{sr}	a_{sr}	b_{sr}	ΔE
Reference paper	93.90	1.09	-7.99	**0**
Distilled water – desiccant	81.93	3.22	-13.94	**13.6**
Distilled water – natural	83.40	1.00	-12.18	**11.3**
Alcohol – desiccant	84.45	7.05	-13.10	**12.3**
Alcohol – natural	84.86	3.39	-13.04	**10.6**

The most intense coloration is exhibited by the aqueous extract dried in the paper sheet former. The alcohol solution, air-dried naturally, has the least impact on coloring the offset paper. The difference between the best and the least intense coloring is 2.6. According to Table 4, this value is defined as the mean difference.

Table 4. Visual difference between two colors [5]

Value ΔE	Description of color difference
ΔE between 0 i 1	Generally, the difference cannot be applied.
ΔE between 1 i 2	Very slight difference, noticeable only to an experienced eye.
ΔE between 2 i 3.5	Moderate difference, noticeable to an untrained eye.
ΔE between 3.5 i 5	Substantial difference.
ΔE over 5	Massive difference.

The colorfastness over time was examined by monitoring the color of the sample after two days and after six days. The values of the color difference of the sample after two and after six days, compared to the color of the initial dyed sample, are presented in Table 5.

Table 5. Color change after the second and sixth day following dyeing

Extract – drying conditions	ΔE_{0-2}	ΔE_{0-6}
Distilled water – desiccant	0.8	1.4
Distilled water – natural	1.3	0.6
Alcohol – desiccant	0.7	1.8
Alcohol – natural	1.2	1.2

The color change after two days was smaller for samples dried on the paper sheet, regardless of the type of extract. After six days, the most significant color change was observed in the sample dyed with alcohol extract and dried on the paper sheet, while the smallest change was noted in the sample dyed with distilled water and air-dried. However, all identified differences are small and fall into the category of changes that are not noticeable to the naked eye or are very slight.

Testing color resistance to water and alcohol yielded the following results (Table 6):

Table 6. Color change due to the effects of water and alcohol on dyed samples

Extract – drying conditions	$\Delta E_{\text{destilled water}}$	$\Delta E_{\text{alcohol}}$
Distilled water – desiccant	9.6	2.2
Distilled water – natural	9.0	2,0
Alcohol – desiccant	10.7	1.6
Alcohol – natural	9.9	1.8

According to the results, it can be observed that the sample dyed with water extract and air-dried is the most resistant to the effects of distilled water. The sample dyed with alcohol extract and dried in the paper sheet former shows the least resistance to distilled water. Color differences between samples tested for water resistance are very small, below the threshold of human eye perception or barely noticeable. The sample dyed with an alcohol solution and dried in the paper sheet former is the most resistant to alcohol, while the sample dyed with water extract and dried in the paper sheet former is the least resistant. Again, the differences between them are below the threshold of human eye perception. Comparing the color change of samples, it is evident that all samples are significantly more resistant to the effects of alcohol than to the effects of distilled water. This significant difference in color change arises from the fact that the extracts are more soluble in water, as evidenced by the color change in distilled water after removing the sample. There was almost no change in color in alcohol.

4. CONCLUSION

The most intense coloring was achieved by dyeing with a water extract and air-drying in the paper sheet former ($\Delta E = 13.6$). Similarly, when dyeing with an alcohol extract, more intense coloring was achieved in the sample dried in the paper sheet ($\Delta E = 12.3$).
Comparing samples dyed with water and alcohol extracts and dried in the same way, it can be noted that slightly more intense coloring is achieved with dyeing from the water extract, although the differences between these samples fall into the category of those not noticeable to the naked eye.
The most colorfast dye after two days from the drying moment is the sample dyed with alcohol extract and dried in the paper sheet former ($\Delta E_{0\text{-}2} = 0.7$), while after six days, the most colorfast sample is dyed with a water extract and air-dried ($\Delta E_{0\text{-}6} = 0.6$). Given that these changes are imperceptible to the naked eye, it can be concluded that the color is stable within the observed time interval.
The most resistant to the effects of distilled water is the color of the sample dyed with a water extract and air-dried ($\Delta E_{\text{distilled water}} = 9.0$). However, this can still be considered a significant change, indicating that the color of the paper dyed with a water extract is not inherently resistant to moisture.
The most resistant to the effects of alcohol is the color of the sample dyed with an alcohol extract and dried in the paper sheet former ($\Delta E_{\text{alcohol}} = 1.6$), while the least resistant is the sample dyed with distilled water and air-dried ($\Delta E_{\text{distilled water}} = 2.2$). It can be concluded that the color resistance to alcohol is much greater than the resistance to water.

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DESIGN

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SOCIETY, ECOLOGY AND DESIGN EDUCATION: TRANSFORMATIVE LEARNING FOR FUTURE SUSTAINABLE AND HEALTHY ENVIRONMENTS

Jelena Ristić Trajković[1], Faculty of Architecture, University of Belgrade

Abstract: *To effectively tackle the complex socio-ecological challenges of our time, it is imperative to utilise design approaches that are both transformative and broadly applicable. Such design approaches must transcend traditional boundaries of fields, domains, and disciplines and foster cross-cutting collaboration and innovation. By adopting a holistic and inclusive perspective, we can work towards meaningful and sensitive solutions that address the multifaceted challenges facing our society and environment. Failure to do so could result in a lack of understanding of environmental values and problems, leading to a significant lack of progress and understanding in these critical areas of our lives. In line with that, design education can play a central role in creating more sustainable, equitable and healthy urban environments. Transformative learning can provide "a qualitative shift" in our living spaces at all spatial scales. It calls for dialogue, reflection, and action, whereas it addresses multiple ecological, societal, and health crises. This presentation aims to share lessons learned from international cooperations and projects, offering examples to enrich design education and practice development.*
Keywords: socio-ecological challenges, transdisciplinarity, holistic design, environment-behavior relations, living spaces

1. THE IMPERATIVE FOR CHANGE

As we progress through the 21st century, the relationship between human societies and natural environments becomes increasingly endangered. With the rapid advancement of science, technology, urbanization, and climate challenges, humanity's aspirations with regard to ecological imperatives are being fostered toward domination and disconnection. Addressing this re-examination demands an interdisciplinary approach recognising that our collective actions simultaneously affect both social structures and ecological systems [1]. Understanding the interconnections between these complex challenges is crucial to creating a regenerative, equitable, and harmonious future for all. The current epoch is recognised as the epoch of the Anthropocene, in which humans and our societies have become a global geophysical force [2]. Human influence has become the primary driver of change, surpassing natural processes [3]. Science and technology have transformed the human experience on Earth by compressing time and space, offering novel opportunities and perspectives of action, resulting in multiscale and rapid global transformation [4]. Biodiversity and cultural loss, resource depletion, social disparities, and degradation of health and well-being are just some of the crucial topics in this context. As Kolbert observes over the last half a billion years, there have been five mass extinctions, when the diversity of life on earth suddenly and dramatically contracted. The sixth extinction is likely to be mankind's most lasting legacy, and it compels us to rethink the fundamental question of what it means to be human [4]. As the global population grows and urban areas become more crowded, there is increasing pressure on resources, leading to complex issues that require new solutions. Addressing these challenges demands a collaborative effort, combining knowledge and expertise from various disciplines such as ecology, sociology, economics, and many others.

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In this context, design can serve as a bridging discipline, providing a framework to conceptualise and implement solutions considering both human and environmental well-being. The complexity of prevailing socio-ecological crises highlights the limitations of conventional design methods, emphasising the imperative for a shift in design practices [5]. The present situation underscores the imperative for design practices to shift towards more socially and ecologically responsible approaches [6]. To address the intricate socio-ecological issues of our time, we must employ design methodologies that should be adaptable across different contexts, promoting a holistic approach to regeneration and societal well-being. It implies creating a profound change in perspective, encouraging designers to integrate knowledge across various disciplines and topics, and critically assess their own beliefs and experiences. By embracing a holistic and transformative perspective, design education can pave the path for training professionals who are not only capable of creating visually appealing and functional spaces and objects but also profoundly considerate of the broader environmental, societal, and ethical implications of their projects. Such a systematic framework is often referred to as transformative learning. Emphasising systemic change and holistic understanding, transformative design is more than just an option. It's a critical necessity.

2. DESIGN EDUCATION AS A CATALYST FOR REGENERATIVE URBAN ENVIRONMENTS

2.1 Breaking Barriers: Transcending Traditional Disciplinary Boundaries

The traditional boundaries of individual subjects should not confine education. Schools and universities should encourage an interdisciplinary approach to help students understand the interconnectedness of human societies, natural environments, and built environments [7]. While providing in-depth knowledge and expertise in a particular field, discipline-specific approaches have limitations, especially when addressing complex, multi-faceted challenges. This narrow perspective can obstruct understanding and detecting expansive, interconnected systems and settings crucial for thorough problem resolution. Consequently, it might induce shortcomings like a limited scope of understanding, difficulty adapting to swift changes, susceptibility to repetitiveness, a restricted skill range, inherent biases, and disjointed communication. Merging varied expertise, viewpoints, and approaches through interdisciplinary collaboration often paves the way for groundbreaking solutions. In our rapidly changing world, an overly specialised focus can inhibit adaptability to fresh insights or novel technologies from different domains. A deep commitment to one discipline can introduce biases, causing professionals to overly favour their specific methods and perspectives, which might distort results and lead to miscommunication and lost opportunities. Depending solely on specialised training may not provide professionals with the broad skill set essential for diverse teams or ventures. In line with this, we must encourage ongoing dialogue, reflection, and action among all sectors and disciplines involved in environmental design and policy. Transformative learning has already marked notable successes, serving as a standpoint of optimism for educators and learners. Current achievements in this area not only validate the effectiveness of such an approach but also illuminate a promising path forward, especially in terms of its potential to reshape educational paradigms.

2.2 Transformative Learning: A Paradigm Shift

Transformative learning is a deep form of learning where individuals change their frames of reference, including belief systems and behaviour. Learning as transformation goes to the heart of human experience: our quest for meaning, our pursuit of growth, and our role as agents of change in an ever-evolving world. The interplay between individual development and societal change and how we change ourselves to adapt to or challenge the circumstances that surround us, is crucial, as it shapes not only our personal growth but also the evolution of our communities and societies [8]. In practice, transformative learning can happen in various settings – in formal education, professional development, or personal life experiences. It is crucial that it involves not just the individual learner but also the social and relational contexts in which they are embedded [9]. This concept has

exceptional potential for design education for a variety of reasons. It provides understanding and grappling with the complexity of contemporary multifaceted design challenges, cultivating critical and adaptive thinking, promoting empathy and ethical consideration, going beyond disciplinary boundaries, fostering lifelong learning, enhancing collaborative skills, and constantly questioning established norms.

Today's design problems, from urban planning to product innovation, are more complex than ever. The speed and nature of change in the contemporary world mean that designers must constantly adapt [10]. Transformative learning gives designers the skills to assess and understand their pre-existing beliefs and experiences critically, allowing them to address these multifaceted challenges holistically. Transformative learning fosters an adaptive and reflective mindset, enabling designers to evolve alongside the rapidly shifting landscapes of technology, society, and the environment. It highlights the importance of empathy and ethical reflection, ensuring designers consider their work's broader implications and responsibilities [11]. Design directly impacts users, communities, and environments. Traditional educational models can sometimes perpetuate linear, compartmentalised thinking. On the other hand, transformative learning challenges learners to break out of these barriers, promoting interdisciplinary thinking vital for innovative design solutions [12]. It continuously provokes a lifelong commitment to ensuring designers remain current, relevant, and effective. Design projects often involve teamwork and collaboration with professionals from diverse fields. Transformative learning equips individuals with the skills to understand and value diverse perspectives, fostering more effective and harmonious collaborative efforts. At its core, design is about envisioning and creating the future. Transformative learning encourages challenging the status quo and reimagining possibilities, which is fundamental for forward-thinking design.

Traditional design education often focuses on aesthetic and functional aspects, sometimes overlooking the broader environmental implications of design choices. Integrating social and ecological considerations from the outset helps designers to become advocates for environmental stewardship, ensuring that they consider the entire lifecycle impacts of their designs on ecosystems, societies and resources. Designers play a crucial role in shaping communities. By emphasising social aspects and human-centred design, future designers will learn to create spaces that support community, equality, and inclusivity. By fostering a deep, critical understanding of existing norms, this educational approach equips urban planners, architects, and designers with the tools to envision and create spaces and objects that are more sustainable, regenerative, equitable, and health-focused. Designing regenerative environments often demands challenging existing paradigms and rethinking established practices that might be detrimental to the environment and well-being, both in terms of personal well-being and the broader well-being of communities and the environment.

This educational approach emphasises the intricate connections between environmental sustainability, social systems, economic models, and cultural shades in urban design processes. Questioning existing power structures and societal norms leads to a design that prioritises social justice and equity, ensuring that urban spaces are accessible, inclusive, and beneficial to all, regardless of socioeconomic status. A heightened focus on health, encompassing both psychological and physical aspects, is also essential.

The concept of "transformative" in design and education denotes a profound shift in how we perceive, understand, and address challenges. It nurtures a culture of reflection. This reflective practice is crucial for continuous personal and professional development, fostering a mindset of lifelong learning and adaptation to new challenges and information. Rather than simply tinkering at the margins or making incremental improvements, transformative approaches seek profound, foundational changes in how we think and act [8].

3. INTERNATIONAL COOPERATION: LESSONS LEARNED

This section opens a discussion on various experiences, challenges, and gaps in the application of transformative learning realised within the framework of international scientific projects and expert networks:

1) SHiFT - *Social Sciences and Humanities for Transformation and Climate Resilience* – COST Action CA21166, European Cooperation in Science and Technology (2022-2026) [13].
2) HERSUS - *Enhancing of Heritage Awareness and Sustainability of Built Environment in Architectural and Urban Design Higher Education*, Erasmus + Programme of the European Union (2020-2023) [14].
3) sUser - *Introducing User-Driven Design and Agile Development Skills in the Case of Sustainable Service Housing for Elderly*, Erasmus + Programme of the European Union (2022-2025) [15].

3.1 Urban imaginary - Transdisciplinary time traveler's guide to our shared future(s)

This chapter shares experiences from an international summer school Urban Imaginary - Exploring our Urban Futures" which was hosted under COST action SHiFT - Social Sciences and Humanities for Transformation and Climate Resilience. The 5-day course took place in the National Museum of Science and Natural History and the Botanical Garden of Lisbon, Portugal, 3-7 July 2023.
The summer school was envisioned as a creative co-learning and transformative environment. It was conceptualised as an educational setting that intertwined both intellectual and experiential knowledge to enrich the body and mind simultaneously and synergistically. With 48 trainers and participants from varied disciplines across 20 countries, both from Europe and beyond, the program adopted a transdisciplinary and transformative methodology. This approach facilitated the exploration of various dichotomies, conflicts, and urban challenges and spurred discussions on innovative, regenerative visions for the future. Participants were immersed in a blend of theoretical lectures, interactive discussions, guided explorations, and integrated embodied and experiential learning sessions, consistently emphasising experiential and hands-on learning. The selected fusion of art and science in a transdisciplinary manner aimed to endow learners/travelers with both a tangible experience and a theoretical grasp of transdisciplinarity, demonstrating how to address real-world challenges holistically. Every morning of the course was initiated with an embodiment session in the Botanical Garden, tapping into the profound insights of embodied knowledge and the body's wisdom. As the sessions progressed, trainees grew more expressive, harmoniously aligning with fellow participants and nature, seemingly converging as a singular entity. The culmination of this learning journey was group presentations showcasing visionary urban design ideas for various Lisbon locations. These showcases amalgamated performance art, narratives, poetry, innovative design strategies, and visual illustrations, all underpinned by core values like kincentric futures, well-being, care, community bonds, utopian visions, transformative evolution, and heritage preservation. Participants' varied disciplinary and geographical origins brought a unique knowledge spectrum and experiential richness to their collaborative groups.
This summer school opened a spectrum of emotions and experiences for both trainers and trainees. The most crucial impression was the strength of creativity, embedded experience and wisdom in feeding scientific and technological innovations. Participants stated that the integrative approach creatively inspired even groups not primarily rooted in creative disciplines. They, in particular, acknowledged the transformative learning liberating potential to tackle serious matters with a light-hearted attitude, as it not only infuses hope but also makes it easier to deal with topics that might otherwise feel insurmountably difficult. It underscores the need for optimistic approaches when confronting with very daunting topics.

3.2 Reprogramming perspectives of architectural heritage

The built environment is more than just physical structures. It's a cultural narrative where interpretative and discursive methods frequently transcend traditional disciplinary ways of perceiving and comprehending space and culture. In recent years, there's been a clear imperative to incorporate heritage sustainability elements into design research, practice, and education. International Project *Enhancing of Heritage Awareness and Sustainability of Built Environment in Architectural and Urban Design Higher Education* (HERSUS) strives to contribute to this aim raising 1) a new profile of an architect/urban designer, a professional who is trained in the broad architectural domain, who

owns technical, technological, socio-humanistic and artistic skills and, therefore, equipped to contribute to the socio-environmental challenges, and (2) a new profile of architectural educator capable of assuming responsibility for the improvement of education and training of the future architects to enable them to meet the expectations of 21st-century societies worldwide for sustainable human settlements in every cultural heritage [14].
The objects and spatial wholes represent a legacy of a specific period or culture, characterised by the environmental, human, social, systemic, temporal, economic, and aesthetic values that form the basis for generating an architectural program. Contemporary design research, education and practice search for novel analytical tools and design strategies for understanding these values and addressing design issues. Architectural programming methodology assists in unravelling and steering through these complex design dilemmas. It advocates for an all-encompassing interdisciplinary method, striving to tackle the diverse aspects of our holistic environment, including the natural, built, social, cultural, and economic realms [16]. Such an approach also aims to foster a creative and cohesive link between the past, present, and future. The emphasis is placed on the design process, indicating that design isn't just the product and piece of art but a tool for challenging the current state and navigating the future.

3.3 Introducing System Thinking in the Case of Sustainable Service Housing for the Elderly

Europe's increasing elderly population urgently demands rethinking specific needs for housing and services. To provide a built environment that meets the demands of the residents, it is critical to introduce user-centred design and system thinking in the design process. In the design phase, many decisions are of great importance for ecological as well as social, and economic sustainability. Future professionals must have knowledge and competence on the adequate methods and tools that can be transferred to broader co-creation and user-centred design and enhance awareness of the importance of sustainability in environmental, economic, and social contexts. From this standpoint, this project develops a future-oriented teaching material and an integrated methodological framework developed by an interdisciplinary team of researchers. The project also considers behavioural changes for individual preferences, cultural values, and awareness to support active engagement for sustainable development. This is done by stimulating innovative learning and teaching practices to increase the quality and relevance of the curricula and by promoting inter-connected higher education systems to build the partner’s capacity to work transnationally and across sectors.
By breaking away from traditional silos of knowledge and embracing a more interdisciplinary and systematic educational approach, students can innovate more effectively. They learn to recognise systems at different spatial scales and complexities, understanding the interconnectedness of various elements of the system. This systemic view is a prerequisite for sustainable innovation, aiming to inspire students to find novel solutions that have multiple positive effects across the system.

4. CALL TO ACTION: ENRICHING DESIGN PRACTICES

Fostering a culture of perpetual learning and adaptability within the design profession is essential for design innovation and effectiveness. O'Sullivan highlighted the importance of embodied learning, a coming into ecological consciousness [17]. Transitioning to a transformative design approach should transcend traditional classroom confines. It is crucial to encourage students to challenge existing paradigms and introspect on their academic journeys. They should be prompted to consider the ethical, environmental, and social consequences of design and technology, cultivating a sense of responsibility and ethical citizenship. Engaging in community endeavours offers students a unique opportunity to witness collaborative problem-solving and grasp the tangible societal repercussions of ecological choices. Such hands-on experiences anchor their theoretical knowledge, illustrating the real-world consequences of both policy and design decisions. Developing emotional intelligence and fostering empathy is essential to comprehend and weigh environmental and design choices' emotional and societal consequences.

However, there are numerous obstacles in the transition to transformative design education. Starting from institutional inertia, where established systems and mindsets resist change, to the challenge of integrating positive experiences systematically. Furthermore, real-world application of design solutions often encounters technical, economic, and policy constraints. The balance between visionary design and practical implementation requires a deep understanding of these challenges. In line with that, interdisciplinary and multistakeholder educational partnerships could be vital in responding to the urgency of addressing socio-ecological challenges through transformative design. They can foster awareness of the broader impacts of design decisions and innovate responsibly, ensuring the health and sustainability of environments and communities for the future. Embracing a transformative learning model transcends mere academic knowledge—it's about driving impactful change and constructive action.

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THE EFFECTS OF STYLE ON AN AESTHETIC ASSESSMENT OF DESIGN

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Abstract: *This article describes the impact of artistic style on an aesthetic assessment - its effect on the complexity, noticeability and interestingness of an aesthetic object. In this research, the vases of different styles have been chosen as stimuli and the subjects estimated their aesthetic impressions. Research in experimental aesthetics showed that the perception and aesthetic value of a piece of art depends on many formal characteristics. The style was described as a set of important aesthetic characteristics, specific to a particular set of artworks. It has been approved that the impact of style increases with sensibility and education level of subjects. The research included 40 subjects, students of Art Academy. They were assessing 12 black-white photos of vases, using 7-degree scales for different criteria: beauty, complexity, interestingness and noticeability. Vases differed by style (Art Nouveau, abstraction, minimalism, postmodern art). The results indicate that all examined characteristics representing the style: complexity, prominence and interestingness, affect the aesthetic assessment of vases. Vases of Nouveau Art style were preferred, while the lowest scores were found for minimalistic-styled vases. Nouveau Art vases were seen as the most complex, most interesting and noticeable. For this group of subjects, interestingness appeared as the most important characteristic in aesthetic assessment. These findings are in concordance with Eysenck's finding of a linear connection between aesthetic noticeability and complexity and Berlyne`s idea of collative variables.*
Keywords: style, aesthetic assessment, complexity, interestingness, noticeability

1. INTRODUCTION

Effects of style on an aesthetic impression is one of the few focal issues in the field of psychology of art. Many pieces of research demonstrated the fact that the style of artwork plays an important role in the process of forming the aesthetic impression and aesthetic assessment. Style strongly influences the assessment in visual arts [1,2]. According to some authors, style as a factor is a stronger predictor of aesthetic value than excitement [3].

The effect of style becomes visible and measurable observed in the process of assessment of visual art objects which differ in the levels of realism or abstraction [1,2]. Realistic art objects are more frequently observed as beautiful and pleasant compared with abstract visual art objects [2,4,5,6,7]. The effect of style becomes stronger in observers with higher levels of art education and experience in art [1,8]. Many studies show that in general, artists tend to highly evaluate abstract art, while other groups prefer representational art [6,7,9,10,11,12]. Fine analysis of the responses shows that the differences between the responses were based on different constellations of various aspects of the work of art participants paid their attention to [13,14,15,16,17,18]. The group of non-artists was more attracted by bright colours, content and realism, while artists based their assessments on elements of composition (lines, forms and colours) and their relations [17,19,20]. The non-artists were attracted by the meaning and semantics, while artists estimated formal characteristics of paintings, style and relations of elements [13,21,22].

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At the same time, there are some gender differences registered, female observers preferred impressionism and rococo styles, while male observers preferred expressionism, cubism, pop art and abstractions [6,23,24,25]. Polzella [24] found that female observers described the painting of impressionism as more pleasant and relaxing than other works of art. Furham and Voker [7] found lower estimations in female subjects for traditional, pop-art or Japanese paintings in their life space than male subjects. Pop art has been seen as less valuable, and pop artists as less talented by subjects. Style, as a constellation of characteristics, appeared as an important aspect in the classification of works of art. Aesthetic assessment of everyday objects, such as buildings [26], furniture [27], the phones [28], showed that the style of the object appeared as the most important factor of aesthetic decision. Whitfield and Slatter [27] asked their subjects to create a living room and found that subjects chose elements according to style, not according to their personal preferences. The style has been seen as the most important criterion.
Considering such findings, the aim of this research is to observe the effect of style on an aesthetic assessment of everyday objects. The focus of this research is on the effects of style – its complexity, salience and interestingness.

2. METHOD

2.1. Subjects

A total of 40 subjects were included, they were the students of visual arts from Academy of Arts Novi Sad. There were 75% female and 25% male included. They were students from the groups: painting, sculpturing, graphic arts, new media and design. This group was expected to be sensitive to formal aspects of an aesthetic experience and familiar with art history.

2.2. Stimuli

There were 12 black-white photos of vases presented, representing 4 art styles: Art Nouveau, abstract art, minimalism and postmodernism (Figure 1). Each style has been represented by 3 examples. In order to simplify the procedure and avoid the effects of colours, black-and-white photos have been used. Vases as objects have been chosen because they are at the same time works of art and everyday objects.

Figure 1. Vases of different styles
Source (from left to the right)**:** https://www.pinterest.com; https://www.etsy.com; https://www.pinterest.com; https://www.dezeen.com

Art Nouveau style is ornamental, representing natural forms such as a leaf, a flower, human or animal body shapes, unusual colours, curved lines, and strict lows of harmony and contrast. The abstract style uses forms in a non-traditional way, symbols, simplicity, asymmetry, and geometry. Minimalistic vases are simplified, with reduced lines, high symmetry and reduced expressiveness, they are focused on geometric forms. Post-modernistic vases are disproportional, and asymmetric, with oblique forms, focused on details and decoration, they represent the combination of typical styles.

2.3. Instrument

The list of four seven-grade scales has been used. The scales were: beautiful - ugly, simple – complex, uninteresting – interesting and non-noticeable – noticeable.

2.4. Procedure

The subjects assessed their impressions using the list of scales. Their task was to note one of the numbers representing their impression. Grades on the scales varied from –3 (least present characteristic) to +3 (most present) with 0 in the middle. Stimuli have been presented in random order. There was no time limit. The research was organized in groups.

3. RESULTS

The analysis of variance showed a statistically significant effect of the style on all the scales included: scale ugly-beautiful, $F(3)=8,76$, $p<.001$; scale simple – complex, $F(3)=105,39$, $p<.001$; scale uninteresting – interesting $F(3)=48,97$, $p<.001$ and scale non-noticeable – noticeable $F(3)=37,26$, $p<.001$.
Regarding the impression of beauty, the highest scores have been registered for the vases of Art Nouveau style, next were abstract vases, while post-modernistic and minimalistic styles were assessed as less beautiful (Figure 2). Regarding complexity, the higher scores have been related to Art Nouveau and post-modernistic styles, lower scores have been related to abstract and minimalistic styles. Scales of interestingness (Figure 3) and scale of noticeability (Figure 4) showed similar results, the higher scores were given to Art Nouveau and post-modernistic styles, and the lower scores were given to abstract and minimalistic styles.

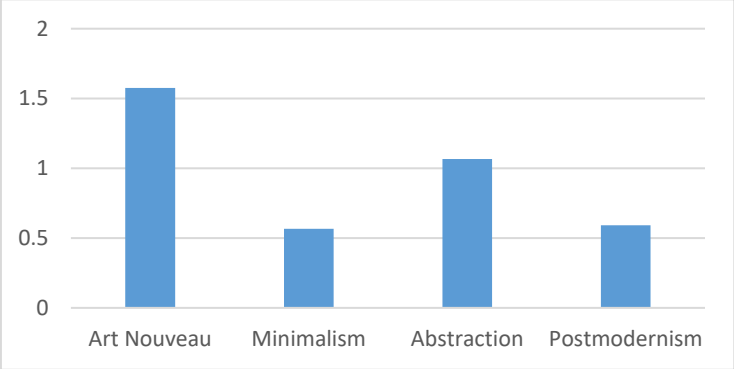

Figure 2. Scores on the scale of Beauty

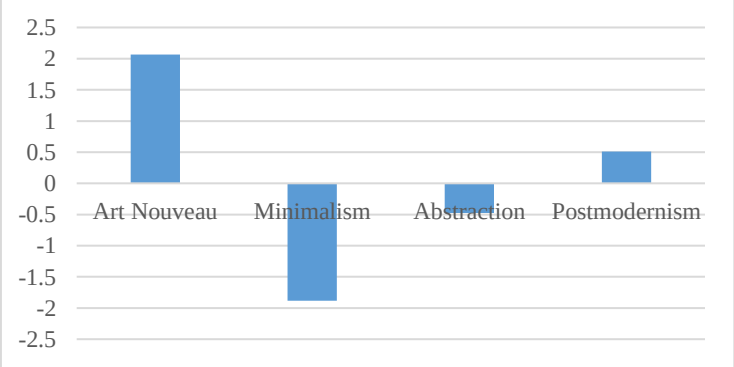

Figure 3. Scores on the scale of Complexity

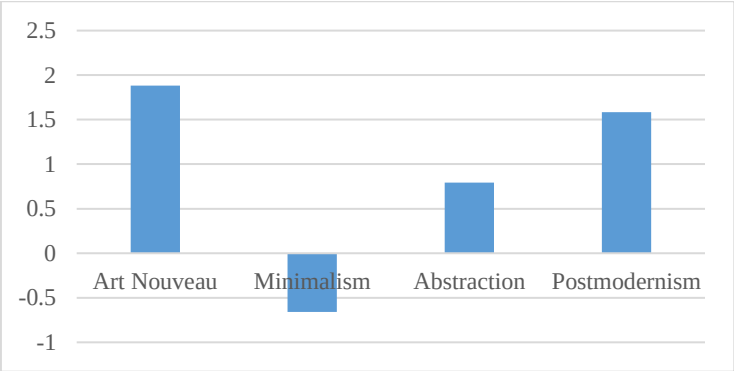

Figure 4. Scores on the scale of Interestingness

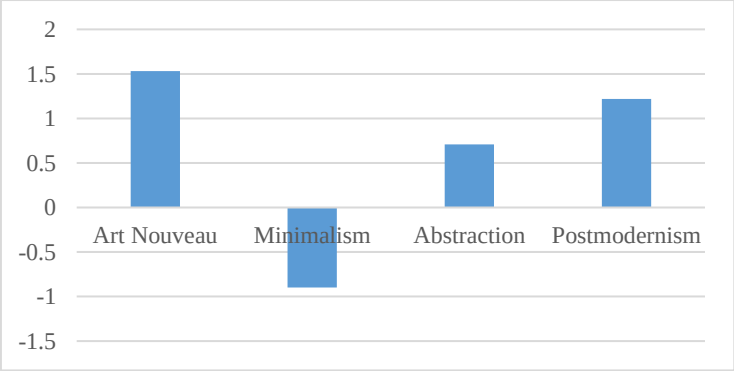

Figure 5. Scores on the scale of Noticeability

The analysis of correlations showed a positive relation between the scale of Beauty and all other scales. The correlation between Beauty and Interestingness was significant and high ($r=.507$, $p<.001$), the correlation between Beauty and Noticeability was significant and moderate ($r=.391$, $p<.001$), while the correlation between Beauty and Complexity was significant and low ($r=.240$, $p<.001$).

4. DISCUSSION AND CONCLUSIONS

The results confirmed the effects of the style on an aesthetic impression of objects. It is congruent with many previous findings and research done [1,2]. Also, it is noticeable that characteristics such as complexity, noticeability and interestingness are important aspects influencing the process of aesthetic evaluation.

In this research, the Art Nouveau style has been estimated as the most beautiful. The reason for that could be found in style characteristics, rich decoration, curved lines, and exaggerated lows of harmony and contrast, which are typical for this style. These vases were also estimated as complex, interesting and noticeable. At the same time, the minimalistic style has been recognized as less beautiful, very simple, boring and not noticeable. The characteristics of this style (simplification of forms, symmetry, subtle forms, clear lines) were seen as less beautiful by subjects. It is in accordance with many previous researches which have found a close relation between an aesthetic impression and the complexity of visual objects in the fields of art and design. As it has been shown by Berlyne [29], the correlation between the complexity and aesthetic value is strongly positive but not linear, it appeared always in interrelations with other aspects of aesthetic objects.

Post-modernistic style showed low scores on the scale of Beauty and high scores on scales of Noticeability and Interestingness. At the same time, the abstract style showed high scores on the scale of Beauty and lower scores on all other scales. This finding deserves more interest and requests further clarification. That shows that aesthetic impression is a complex phenomenon based on interrelations between formal aspects of the object. In this research, asymmetry, simplification and reduced forms of objects have been highly valued when applied in an abstract style but less valued when applied in a post-modernistic style. Having in mind that the subjects were students of visual arts who were

educated in art history and highly sensitive to the aesthetic values of objects, it could be expected that abstract and minimal art would be even less accepted by standard audiences. As has been shown by many pieces of research, abstract art is a powerful cultural tool but is accepted only by selected groups of audiences and is generally rejected by standard, less educated and less sensitive audiences who prefer decorated and realistic objects [6,7,9,10,11,12]. Regarding ornaments and decoration, they appeared as the main criteria in non-artistic audiences. In this study, it was noticed that complexity and decorations were not the main criteria as would be expected for the standard audience. For this group of subjects interestingness and noticeability (salience) were more powerful factors in forming aesthetic evaluation. The analysis of responses of the audience to abstract art and potential differences between artistic and standard audiences deserve the future interest of psychologists.

The main restriction of this research is the small sample of visual stimuli, conclusions regarding style should have been based on a much bigger sample of style representatives. However, the findings lead us toward new insights into the complex and subtle process of aesthetic reception.

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FAMILIARITY AS AESTHETIC CATEGORY IN DESIGN

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Abstract: *This article is focused on the impact of familiarity on the aesthetic assessment of vases. Vases are chosen as research objects because of their artistic and functional value and are rarely used in experiments. Familiarity is seen as a subjective category closely related to closeness. It was of interest to test the relation between familiarity as a category and the aesthetic value of objects. The subjects were 40 students of Art Academy, a visual art course. They were assessing 15 black and white vase pictures, using 7-degree scales by criteria: beauty, familiarity and closeness. The vases shown were balanced by style (neoclassicism, Art Nouveau, abstraction, minimalism and postmodern art). The results indicate that the highly ranked vases by familiarity and closeness were not experienced as the most beautiful. Subjects experienced as most beautiful vases that were ranked as less familiar and distant. Those findings confirm the thesis that high aesthetic rank is based on a certain level of novelty. They are also in concordance with research that found novelty as an important aspect of aesthetic value and interestingness.*
Keywords: style, aesthetic assessment, familiarity, visual objects

1. INTRODUCTION

Familiarity is an important dimension of aesthetic assessment. Although many findings confirm the strong influence of familiarity with aesthetic assessment, there is no clear agreement between the researchers. A few different hypotheses try to explain this relation.
Usually, the relation between the familiarity and aesthetic value of works of art is described by a reversed U-curve [1,2,3,4,5]. According to those authors, the highest aesthetic values are given to objects that belong to the middle level of novelty, objects that are not completely new or completely familiar.
Another group of authors found a positive linear relation between familiarity and aesthetic value [6,7,8,9,10]. According to them, the beauty of artworks increases with familiarity. The art objects that are seen as the most beautiful are at the same time most familiar to the audience. This relation has been found in the assessment of paintings. It has been noticed that subjects preferred the representational paintings describing them as most familiar to them, while the abstract paintings have been described as less familiar [8]. It has been approved that the aesthetic value of paintings increased by familiarity and at the same time the pleasantness and will to see this painting again, increased too [9].
The third group of authors has found a negative linear correlation between the familiarity and the aesthetic value of art objects. According to them, less familiar works of art have been experienced as more beautiful and reversed, and the more familiar art objects have been experienced as less beautiful. This relation has been confirmed by experiments using simple

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visual stimuli [1], and lately, it has been confirmed by experiments using novel, provocative and ambiguous stimuli [11,12,13,14,15,16].
The diversity between many different findings shows that the influence of familiarity with aesthetic assessment is still an open issue for researchers. There is no simple answer to the question of how familiarity as a dimension influences the response of the audience - does the object that is familiar and is frequently exposed to the audience become more beautiful or not? This problem becomes even more complex when the familiarity is observed in interaction with other factors, such as complexity or symmetry, in the process of forming the aesthetic assessment.
The diversity of research results could be understood by keeping in mind the different research methods used, various samples of stimuli and different levels of experimental control. It has been noticed that, together with factors related to formal aspects of art objects, personal factors such as the level of education in art and art history, experience in art and many others, participate in the process, influence the aesthetic decisions and change the levels of familiarity [17,18,19,20,21,22,23].

2. RESEARCH

In this research, the intention is to test the impact of familiarity on the aesthetic assessment of the design of objects, keeping in mind the diversity of results obtained by different authors. The majority of research has been using fine art paintings as objects, and in this research, well-designed everyday objects have been used as stimuli. They have two-fold functions being at the same time art objects and objects for everyday use. Design is related to the usefulness of objects and it could be assumed that the level of familiarity is higher experiencing such objects compared with experiencing paintings and other fine art objects. Since the design is determined by the function of the object, a certain level of novelty is requested in order to keep the interest of the audience. The design of useful objects is a process which includes constant exploration, innovation and variations of forms, which are visible through different styles and variations within the style. In this research the relationship between the aesthetic assessment and factor of familiarity has been observed, using objects of different styles. The vases have been chosen as objects because they were not commonly used as stimuli in research.
In order to test the relation between familiarity and the aesthetic assessment, two scales have been used – familiarity and closeness, combined with the factor of style.

2.1. Subjects

A total of 40 subjects were included, they were the students of visual arts from the Academy of Arts in Novi Sad. Gender structure: there were 75% of females and 25% of males included. They were students from the groups: painting, sculpturing, graphic arts, new media and design. It was expected that this group was sensitive to formal aspects of an aesthetic experience and was familiar with art history.

2.2. Stimuli

There were 15 black-white photos of vases presented, representing 5 art styles: neoclassicism, Art Nouveau, abstract art, minimalism and postmodernism (Figure 1). Each style has been represented by 3 examples. In order to simplify the procedure and avoid the effect of colours, black-and-white photos have been used. Vases as objects have been chosen because they are at the same time works of art and everyday objects which represent the characteristics of style.

Figure 1. Sample of stimuli of different styles
Sources from left to the right: https://www.karlkemp.com; https://www.pinterest.com; https://www.etsy.com; https://www.pinterest.com; https://www.dezeen.com

Neoclassicism as a style is represented by characteristics such as stable proportion, symmetry, order and clear form, harmony and balance. Art Nouveau style is ornamental, representing natural forms such as a leaf, a flower, human or animal body shapes, unusual colours, curved lines, and strict lows of harmony and contrast. The abstract style uses forms in a non-traditional way, symbols, simplicity, asymmetry, and geometry. Minimalistic vases are simplified, with reduced lines, high symmetry and reduced expressiveness, they are focused on geometric forms. Post-modernistic vases are disproportional, and asymmetric, with oblique forms, focused on details and decoration, they represent the combination of typical styles.

2.3. Instrument

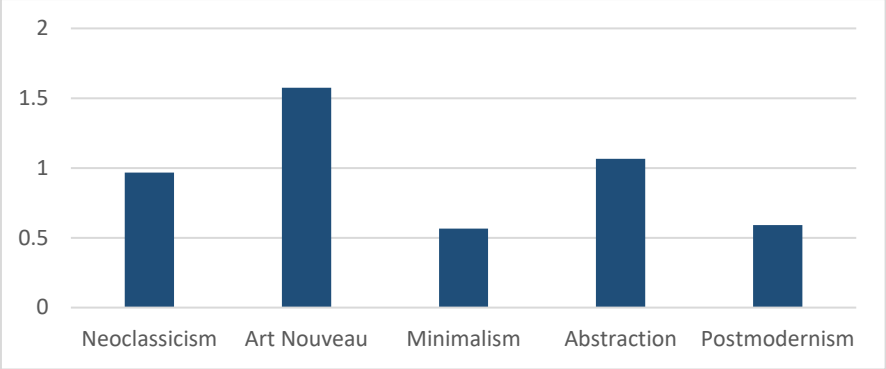
Aesthetic assessment of objects has been measured by the scale of Beauty (beautiful – ugly) and familiarity has been measured by two scales: Familiarity (familiar – unfamiliar) and Closeness (close - distant). Seven-grade, bipolar scales have been used.

2.4. Procedure

The subjects assessed their impressions using the list of scales. Their task was to note one of the numbers representing their impression. Grades on the scales varied from –3 (least present characteristic) to +3 (most present) with 0 in the middle. Stimuli have been presented in a random order using PPT presentation. There was no time limit. The research was organized in groups.

3. RESULTS

The analysis of variance showed statistically significant effects of style on all the scales used. Effects of the style on the factor Beauty show the following results: $F(1)=6{,}53$, $p<.001$; effects of the style on the factor Familiarity show the following results: $F(1)=9{,}87$, $p<.001$; effects of the style on the factor Closeness show the following results: $F(1)=3{,}50$, $p<.01$. The results confirm the effect of style to all the dimensions observed, there are differences between the styles according to impressions of beauty, familiarity and closeness.
Measures of the beauty of objects showed the following rank order: Art Nouveau style has been experienced as the most beautiful, it has been followed by the abstract style and neoclassicism, while the vases of post-modernistic and minimalistic styles have been experienced as less beautiful (Figure 2.)



Picture 2. The Beauty of different styles

The results for the scale Familiarity show high estimations for neoclassicism and minimalistic styles and lower estimations for Art Nouveau, abstract and post-modernistic styles (**Figure 3**).

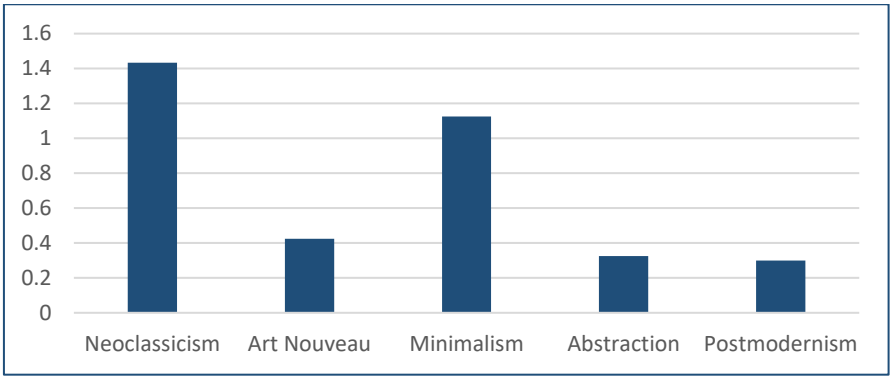


Figure 3. Familiarity with different styles

The results for the scale Closeness are similar to those obtained for the scale Familiarity – the highest measures have been ascribed to neoclassic and minimalistic styles, while the lowest measures have been ascribed to vases belonging to abstract, Art Nouveau and post-modernistic styles (**Figure 4**).

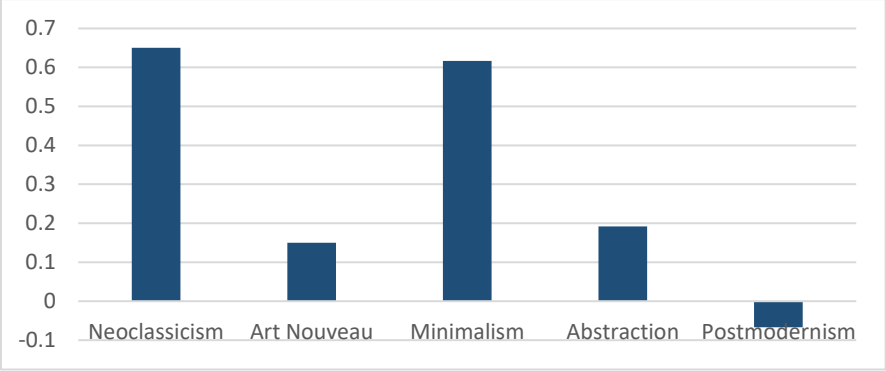


Figure 4. Closeness of different styles

The analysis of the correlation between the scales showed statistically significant correlations between all the scales used. There are certain differences between the levels of correlation. The highest correlation has been found between Closeness and Familiarity ($r=.52$, $p<.01$) which was expected. The correlation between Beauty and Closeness was also high and positive ($r=.39$, $p<.001$). The correlation between Beauty and Familiarity was low and significant ($r=.18$, $p<.01$).

3. DISCUSION AND CONCLUSIONS

The results show that dimensions of familiarity and closeness were not directly related to beauty. The vases that were experienced as the most beautiful were not most familiar at the same time. The highest estimations have been ascribed to Art Nouveau vases which were estimated as modestly familiar and close by the observers. The results are in the concordance with the hypothesis of a reversed U-curve. According to this idea, the most beautiful objects belong to the middle measure between the opposites [1,2,3,4,5].
The vases that are experienced as modestly beautiful belong to abstract and neoclassic styles. The vases that are experienced as less familiar and close by the observers belong to the abstract style. At the same time, neoclassic vases are experienced as familiar and close by the observers. The results show that the intensity of aesthetic assessments and level of familiarity depended on the definition of familiarity as a dimension. It is obvious that considering the design of objects, subjective experience of closeness is a stronger predictor of aesthetic value than familiarity.
It is also obvious that high estimations of beauty are related to a modest level of novelty, the extreme dimensions, such as being too familiar or completely unfamiliar to an observer will decrease the aesthetic value [2]. The novelty of art objects attracts the observers, evoking interest and attention. In order to evoke aesthetic interest, the design of the object should find a fine balance between familiarity and novelty.
The limitation of this research is the small sample of stimuli, future research based on a systematic and fine-balanced set of stimuli is expected to give new insight into this phenomenon.

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ANALOGOUS PRINCIPLE AS AN ADDED VALUE IN GRAPHIC DESIGN IN THE POST-INDUSTRIAL ERA

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Abstract: *This paper delves into the realm of graphic design in the post-industrial era, conducting an analysis of both analog and digital working principles. We aim to uncover their unique characteristics, prevalence, significance, and the implications they hold for graphic design solutions amidst a rapidly evolving technological landscape. Notably, we emphasize the near-total reliance of commercial graphic design on software and vast databases of graphic elements and photographs.Our exploration extends to the promises presented by the continuous advancement of technology and the rise of new media. Additionally, we address the issue of generalizing visual elements that make up the visual content of graphic communication. Within this context, we examine the creation of new digital originals and the replication of analog visual elements following digitization. Moreover, we pose critical questions about overproduction, quality, and the ramifications of societal globalization. The paper also seeks to define the term "post-industrial era" while identifying its defining characteristics. We dedicate attention to visual identity, scrutinizing the processes involved in its creation, alteration, and acceptance, and the critical role it plays in branding, as well as its impact on individual identity stability. Ultimately, our objective is to underscore the significance of implementing the analogous principle in graphic design within the digital age, elucidating why the analogous approach serves as an added value in the realm of digital graphic communication*
Keywords: Analog, Digital, Visual Identity, Added Value, Software

1. INTRODUCTION:

Starting from the twentieth century, one of the primary roles of aesthetics is to serve the society of spectacle[1]. To exist, art should resist this. Perhaps this is one of the main reasons why many theorists today do not see the work of graphic designers as a part of applied arts. Among all artistic disciplines, design is most often abused in the service of mass media, with the aim of acquiring profit and hegemony. For this reason, aesthetics has long ceased to be a question of beauty and now deals with all aspects of life. Although it may seem that such a world is innocent and does not exist in reality, it is actually mirrored in the public and semi-public space through graphic communication solutions.

2. PROPAGANDA AGAINST PROPAGANDA:

Designers who have a desire to oppose this working model and who aim to bring their creativity closer to art can use the same means they use for communication in their work in a subversive way, i.e., propaganda against propaganda. Throughout history, artists such as Jenny Holzer (Figure 1) with her slogans at airports and in public spaces, and Barbara Kruger (Figure 2) through billboards and posters, have shown us the best ways to do this by questioning the commodification of the female body in consumerism. According to the art critics of the Frankfurt School, art must not be in harmony with society in any way. They believed that mass media was destroying it. According to them, art must constantly change, shifting its position. Besides these radical ways of acting, we have the opportunity to bring the aesthetics of graphic visuals closer to art, elevating their artistic quality. In

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spectacle, nothing new is created, but it is only explained differently. Following that logic, and as an additional value, the analog approach can be applied to graphic communication as a consequence of the accelerated work pace and the creation of databases, which will be discussed in more detail later, today's designers mostly use the same elements, symbols, and photographs that are readily available to them. This is the primary reason why visual solutions in the field of digital graphic design lack the artist's unique touch and suffer a loss in quality.

2.1 ANALOGOUS AND DIGITAL WORKING PRINCIPLES:

Software is becoming an increasingly essential, and often the sole, tool for implementing graphic design solutions. On a global scale, only a small number of individuals have control over these software applications. Human potential is often underestimated, with the justification that humans are slow and inefficient. What primarily hampers efficiency in work is the need for expressing desire. In the book Digital Partisans, two principles are mentioned, the analog and digital. The process where order emerges from order, and where a human services while a machine creates, is called digital. When chaos arises from order, and order from chaos, we have an expression of the analog model, characterized by mastery, uniqueness, and originality. From an economic perspective, in the past, the value of unique products crafted by craftsmen or under their supervision represented an analog model. With the replication of labor through various pedagogical models, the digital model emerged. Today, the most significant difference between these two principles is aesthetics. Analog is rapidly disappearing in the field of communication and information technology. In the digital age, every copy becomes an original because it must meet production standards. This is the best example of order from order.

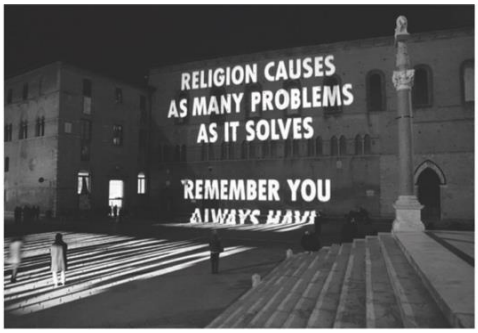

Figure 1. J. Holcer, Projections, Siena, 2009.
Source: jennyholzer.com

Figure 2. B. Kruger, Untitled (We Don't Need Another Hero), 1987
Source: www.whitney.org

2.2 THE ECONOMY OF LUXURY:

The fact that analog has become a luxury economy was first recognized by Marcel Duchamp (Figure 3), who placed everyday objects in a new space and context, thereby changing their function and value. Andy Warhol (Figure 4) followed him, addressing issues of consumerism, reproduction, originality, and machine production. For Warhol, no counterfeit is counterfeit as long as it satisfies the expected similarity. The development of new technologies initiates the development of mass communications. Brands are obliged to follow trends and technical evolution to offer their consumers a range of new possibilities. Today's consumers expect a product to possess both the reliability provided by a digital copy and the uniqueness of the product in an aesthetic sense to nourish their individuality. This distinctiveness is achieved through an analog approach, leaving digital aesthetics on the margins. According to Manovich, as a society, we have not yet fully abandoned analog thinking and creativity. According to him, the new era still encompasses both the analog and digital worlds, marked by the accelerated development of technology and new media, as well as the adaptation of analog media to digital cultural understanding. Communication is both passive and active, and

experiences are both tactile and digital. The computer has become a universal workspace, and the historical significance of the digitization of culture lies in the fact that creatives use the same technology, processes, and software, regardless of whether the final product will be delivered through old or new media.

Figure 3. Marcel Duchamp, Fountain, 1917
Source: thecollector.com

Figure 4. Andy Warhol, Campbell's Soup Cans, 1962
Source: thecollector.com

3. DEPENDENCE ON TECHNOLOGY:

Every day, we are becoming more and more tethered to technology, so it can be concluded that we have entered a state of dependency. Upon examination, we see that humans have embraced cyborgization through medicine and various aids such as prosthetics long before the industrial era. Art has often legitimized different ideologies, serving as a means of verification and giving them an elitist character. Many artists who address the issue of cyborgization, such as Stelios Arcadiou (Figure 5 and 6), connect themselves with computers, embed prosthetics and implants, considering the human body to be outdated. However, from a sociological perspective, this opens up a wide range of questions.

The best example of cyborgization, or the merging of humans and technology in everyday life, is smartphones and smartwatches. This way, we become highly dependent on the rapid availability of information and the transmission of our experiences through social networks, expecting quick responses from our virtual friends.

Figure 5. and 6. Stelios Arcadiou,
Source: theproudmag.com

3.1 PASSIVE DESTRUCTION OF MEDIA AESTHETICS:

From a young age, we have been taught that our work should constantly be evaluated and assessed, which can significantly impact an individual's self-esteem. For this reason, we create the best version

or versions of ourselves virtually to be more accepted, followed, liked, and shared. In this way, one's identity can be greatly compromised. Through social media, we follow people who create aesthetics in their posts on the internet and select information to be appealing to a specific target group. We often adopt their good practices, attempting to buy or imitate their lifestyle, depending on whether we can afford it. This creates digital idols and identities that we aspire to become. The reason for this can be defined through the passive destruction of media aesthetics, which Professor Vladislav Šćepanović discusses in detail in his book "Media Spectacle and Destruction." According to him, by destabilizing and undermining personal identity through constant conformity to fleeting fashion and technological trends, by dismantling the cult of the family through separation, decentralization, and shifting the attention of its members to personalized content from various media, and by diminishing the importance of traditional communities, a terrain is created for the easy manipulation of the individual. People increasingly prefer the sensation of information because the need for belonging and community is precisely what brands promise, and in return, we give them our trust, money, and time. The lonelier people are, the more they turn to work, consumption, and ways to find satisfaction. Strength, authenticity, tradition, image, status, and the size of a brand are perceived based on its visual identity and communication. Visual identity can be defined as the external manifestation of the ideas, company, brand, organization, or location, created based on its internal values. Since information is best conveyed through images, this speaks to the power of the influence of graphic communications. It is presented through symbols, colors, typography, and the way they are composed. These elements should be created and communicated in an original way, with connotations to what is being presented. Significant resources are invested in creating the visual identity of brands. It provides people with security in decision-making, as it creates a representation of something that, in most cases, they do not know.

3.2 TO BE OR TO HAVE:

According to Fromm, we can either "be" or "have." Human consciousness is formed based on what it possesses. Material goods have gained symbolic value. Television has promoted the accumulation of material possessions as the primary imperative for many years. This, in turn, has imposed desires and needs upon us. Today, media still presents aestheticized information. There is a depletion of originality, uniqueness, and irreplaceability, and the aura is lost, replaced by an industrial mode of production. Television belongs to linear media because it follows a narrative. Unlike movies that require our complete presence and attention, with television, we absorb information but can choose the atmosphere in which we watch it. The internet today seems much more democratic as a medium compared to what television was over the last fifty years. However, it hasn't destroyed television, just as television didn't destroy movies, radio, and newspapers. It belongs to metamedia or digital media. These metamedia use old media as their primary material and try to perceive the world in a new way. In the information society we live in, memory is the most important characteristic, and the computer is crucial, unlike in the media society where it was film, with perception taking center stage. Metamedia use data from databases indexed by algorithms. Every process or task is reduced to an algorithm, a series of simple operations that a computer can perform. Software represents the engine of modern society. Databases allow us to create a narrative in a way that suits us, giving us greater possibilities for interaction and easier promotion of our values and connections. In this way, we reveal everything about ourselves without even being aware of it. Technology is presented as neutral. It can pose the greatest danger, given the high potential for abuse. The promises of the digital utopia, as we have the opportunity to read about in the book "Digital Partisans," involve an easier way of working. In return, individuals are expected to be much more productive, as they have help. Technology offers mobility, but it requires the maximum mobilization of the subject. This way, designers are expected to be productive and creative for the brand at all times. Portable technology, software, and communication allow work in any position and place.

4. STOCK PHOTOGRAPHY AND GRAPHIC ELEMENTS:

Aesthetics have become the dominant characteristic of media because images sell products. For this reason, designers use databases of photographs and graphic elements as the simplest solution for gathering materials to create visuals for broadcasting. Advertising photography is the most common type of photography in the society of the spectacle. From the beginning, its function has been to stimulate the desire for consumer purchases. In the diffuse spectacle, it has largely pushed illustration off posters. Products are presented in the best possible light, with models who promote them having a flawless appearance in perfect scenography that suits the product. Given that the spectacle erases the boundary between the true and the false, it creates an impression that we should aspire to such scenes because they seem attainable. Stock photo banks are places where digital collections of images, logos, and vectors are stored for purchase, often for the purpose of creating graphic communications for specific brands and magazines. They only have connotations and perfectly represent a society of the spectacle in its full glory. The backgrounds are extremely simple, models are attractive, and searching such image banks is usually done based on keywords. It can be observed that this is another way in which we disrupt originality and authorship, which should distinguish graphic design solutions.

4.1 ROOTS OF SELLING GRAPHIC ELEMENTS:

By examining the history of posters, we learn that artists from the 19th century, having exhausted social and cultural themes, were not reluctant to create commercial posters. The question arose as to whether painting was interfering with contemporary posters. Many artists, seeing the market potential, produced images and drawings on their own initiative, which they would sell and put in the context of products. This can be considered the beginning of selling graphic elements. With these facts, we can conclude that the existence of such visual banks is not a product of modern times but has been emerging and adapting to the needs of the society of the spectacle.

5. POST-INDUSTRIAL PERIOD:

Although the term post-industrialism is first found in literature in the 1920s, most authors agree that the post-industrial period should be associated with the second half of the 20th century and a time of rapid technological and scientific development. It is a period characterized by an increased importance of knowledge and mass communication, where education and mass media take precedence over the production of goods. Due to the significance of information itself and its dissemination, this period is also called the information era. According to Bell, some of the main characteristics of the post-industrial era or the social world are scientific knowledge and higher education. He believes that cooperation and reciprocity are above coordination and hierarchy. New technologies initiate changes in all aspects of contemporary life and ensure further progress of society. For the analysis of this period, Toffler's theory is interesting. He identifies social acceleration as the basic characteristic of the super-industrial civilization, as he calls the post-industrial period, and points out that science is at the center of technology.

5.1 LIGHT PEN:

Computer technology developed intensively after World War II. There was a tendency to equate computers with humans. In the book "Virtual Art" by Oliver Grau, we learn that Ivan Sutherland made the most significant contribution to the interface, calling it a mediator between humans and machines. He presented all this in his doctoral thesis called "Sketchpad," published in 1963. This created the possibility of drawing on the screen using a light pen. Sketchpad is a precursor to modern illustration programs like Adobe Illustrator. During the 1960s, the first exhibitions on Computer Art

were organized in Europe and America. From 1970, computer art became an integral part of the Venice Biennale.

5.2 ORIGINAL AND REPRODUCTION:

In digital art, the concept of an "original" becomes less significant because there is often no clear distinction between a copy and an original. According to Benjamin, the era of technical reproduction marked the beginning of the mass esthetization, where the aura, uniqueness, and originality were lost. Software and computer hardware are responsible for this transformation. Therefore, the notion of the cult of the original, as proposed by Benjamin, does not apply to visuals that are created digitally. The aura might only be recognizable in cases where the inaccessibility of the work is intentionally provoked. For example, in the case of an expensive installation that is rarely exhibited in a remote part of the world, making it challenging for most people to attend the projection. In digital work, we are always limited by the technical capabilities of the software. The creation process is more like a dialogue, and the final image is the result of computer operations. Numerous tools available in software programs encourage designers to create new visual and graphic solutions directly without the need for analog processes. This approach generates solutions that do not have a material original, and as such, they are ready for further reproduction in both virtual and physical realms. Much of what analog work offers is impossible to fully replicate with digital methods, including the freedom of drawing expressed through the spontaneity of lines resulting from our emotional impulses, the transparency of watercolor hues, the irregular blotches and brush strokes, the imperfections of printed graphic surfaces, the natural variation and diversity of typographic characters in handmade typography, and more.

6. CONCLUSION:

Based on the points mentioned above, it is evident that analog methods are often by passed in contemporary graphic design solutions. The need for speed and the availability of technology have led to a reduction in the quality, originality, and creativity of design solutions created through digital means. Therefore, analog methods, as part of the process, offer an additional value in building identity today.Technological advancements have enabled us to digitize a significant amount of graphic elements from analog works, which are far richer than what we could create digitally from scratch. We can utilize this material for creating graphic communications in countless original ways, either independently or in combination with digital elements and effects offered by software.

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DESIGN AS A FORM OF COMMUNICATION DECONSTRUCTIVE APPROACH TO DESIGN

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Abstract: *In the broader sense, visual communication is the essence of this presentation. Although design is a narrower field of the paper, graphic design is its focal point. Most of the statements are based on research in the arena of graphic design. This paper will explore how to identify good design and what is a concept that defines it. It is also important to underline that this paper is based on notes on graphic design in the Western world, allowing that assumptions and definitions may vary across geographies. Visual information is initially perceived intuitively. It is based on liking, loving and attractiveness. Those descriptions alone, mean nothing. A question here is why do we like or love the design? Design is also often recognized as good or bad; beautiful or ugly, right or wrong, etc. What do these concepts really stand for? What are the true meanings of those classifications and based on what are we making such statements?*
Keywords: Design, Visual communication, Communication, Elements of design, Principles of design

1. INTRODUCTION: What is Visual Communication?

Communication is a word of significance, here. Communicative design is what makes a good design. Still, it is not enough that message is being delivered. How it is being delivered becomes crucial. An analogy with words could be made now; there is a difference if a message is just plainly said or whether it is delivered through poetry. A line between *a message is sent* and *a message is communicated* here is drawn. A message communicated stands for good design!
One can define visual communication as the practice of visually representing information in a way that can be effectively understood. It is everything that is crafted and perceived visually, such as: painting, drawing, sculpture, industrial design objects or graphic design objects.
It will be exhibited how visual impulses (liking and loving) are deconstructed into basic principles and elements of design and thus transformed into reason. It will also be argued how the reason converts into knowledge before it becomes innate. From this point on, visual information is perceived intuitively again. In the end, it becomes clear when the design is communicative and when it is plainly bad.

2. GRAPHIC DESIGN What is it?

Graphic design may be defined as “the art and practice of planning and projecting ideas and experiences with visual and textual content”. [1] In other terms, graphic design communicates certain ideas or messages in a visual way. Technically, graphic design is the communication of an idea using visual means. It is art or skill of combining text and pictures in print or digital media.
Yet, what is graphic art? What Graphic means? Is drawing graphic art? Is calligraphy graphic art? Is photography graphic art? Some people might identify black and white two-dimensional works by name of graphic. This would be wrong as graphic does not have to be black and white. It, however, may be presented in a plethora of colors. How do we know if something is graphic art vs. simply a drawing, for example? Where is the catch?

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Everything we call by name of Graphic has a matrix. It can be digital or physical matrix, but it has to have one. Graphic is never an original piece; it always has 2 or 200002 copies of the same matrix. It involves reproductive methods such as: engraving, etching, lithography, photography, serigraphy, and woodcut. In contemporary world, graphics assume digital files (that can be multiplied numerous times). Graphic also means that one visual solution has 2 or 20002 exactly the same prints (from the same matrix printed with the same parameters). What we identify as graphic today is everything from photography (negative film or digital file as matrix), packaging design (layout as a file), billboards (digital files), posters, etc. Calligraphy and typography were mentioned before. In this context calligraphy is not graphic art, while typography is. Calligraphy is hand written; so even though one may utilize a certain letter style while writing, the letter would turn out having multiple differences to one another (no matrix; hand is not a machine).Typography, assumed by its name, is graphic art; every time one presses a letter in a certain font, the letter turns out exactly the same.

3. ELEMENTS OF GRAPHIC DESIGN

Elements of graphic design are the basic units of which visual composition is constructed. They are the features that help the designer convey messages and help the viewer read the design adequately. Elements of design are fundamental pieces of any visual composition. As number and preference of the elements may vary among the designers, the most ubiquitous are as follows: line, shape, color, value, typography, texture, size, space [2].

Line
Often the starting point for all artistic expression, the line is one of the most essential elements of design. It can be unbroken, broken, or implied. A line can be vertical, diagonal, horizontal or curved. Implied line moves our eyes through the composition and gives a sense of dynamics.

Shapes and Form
Objects are two-dimensional. All objects are composed of shapes, and all elements of design are shapes in some way. Forms are three - dimensional, and there are two types: geometric (man-made) and natural (organic).

Color
Hue typically references to a wavelength of light in the color spectrum, which is blended from the primary colors of red, green, and blue (commonly referred to as RGB).

Value
Value refers to the lightness or darkness of a color. It defines a color in terms of how close it is to white or black.

Typography
Typography is the art of arranging type. This one is critically important as it can greatly affect the design’s messaging. Different weights (bold, regular, or light), combined with varied sizing, colors, and spacing, add power to the concept a designer is trying to communicate. Typography ultimately defines good or bad design.

Texture
Texture in design refers to how things look like they would feel if they were to be touched. For example, texture can be rough, smooth, glossy, soft, hard, etc. It gives warmth to the design.

Size
Size is simply how small or large something is. In design, size is used as an indication of importance and it can also create visual interest in a design by using contrasting sizes.

Space
Space refers to the areas of design that are left blank. These areas include any distance or areas between, around the other design elements. Designers intentionally place spaces in the design to add emphasis to areas they want to be in focus.

4. PRINCIPLES OF GRAPHIC DESIGN

There is no real consensus in the design community about what the main principles of design actually are. That said, the following six principles are those mentioned most often in articles and books on the subject: balance, emphasis, alignment, variety, unity and contrast [3].

Balance
Balance is the concept of visual equilibrium of similar, opposing, or contrasting elements that together create a unified whole. It refers to the appropriate arrangement of the objects in a design to create the impression of equality in weight or importance. It comes in 2 forms: Symmetrical (when the weight of a composition is evenly distributed around a central vertical or horizontal axis) and Asymmetrical (when the weight of a composition is not evenly distributed around a central axis).

Emphasis
It marks the location in a composition which draws the viewer's attention. It is also referred to as the focal point. It is the most important area or object when compared to the other objects or areas in a composition.

Alignment
Alignment is about keeping the design organized. All aspects of the design should be aligned with the top, bottom, center, or sides to create a visual connection between the elements.

Variety
It refers to the combination of different elements. Those elements are put together based on intricate similarities, such as values, lines, textures, shapes, hues, etc. As the opposite of unity, variety should provoke changes and awareness in the art piece.

Unity
In art, unity conveys a sense of completeness, pleasure when viewing the art, and cohesiveness to the art. Unity is used to describe the relationship between the individual elements and the whole of a composition. Colors can provide unity when they are in the same color groups, and a splash of red can provide variety.

Contrast
Most compositions include a variety of different and opposing elements. This can include a range of lighting, an assortment of colors, or even an array of textures. A designer can increase the contrast between two objects to highlight, for example, one being in the foreground and the other in the background.

White Space
White space, also referred to as negative space, is the area of a design that do not include any design elements. The space is, effectively, empty. Many beginning designers feel the need to pack every pixel with some design elements and overlook the value of white space. But that white space serves many important purposes in a design, especially as it gives the elements of the design room to *breathe*. Negative space can also help highlight specific content or specific parts of a design. If you are a design maker (as opposed to only a viewer) you might think: "What could I add to the composition; it lacks something." Usually, the answer is that something needs to be removed from the composition

and not add to it, as white space is usually overlooked, yet one of the most important principles of design. What space is to interior design, white space is to graphic design.

5. CONCLUSION: A voyage from intuitive understanding to a design connoisseur

In contemporary world, when there is a need for visual communication, it will be, most likely, communicated via graphic design. This decision would be made on a mere fact that through graphic design the same message could be delivered to as many people as needed. We may now imagine that instead of graphic design a message is presented through painting (which is also a legitimate way to communicate visually). There is only one painting of the kind and there are only a few people to see it. Graphic design, thus, in all its scope, is the way to go today. Graphic design is a democratic medium.

Clearly presented above is how the complexity of visual communication can be deconstructed onto basic principles and elements of design and how this deconstructive approach serves us to better use and read visual vocabulary. It is the same principles and elements of design that we all use; creativity here is the major factor that combines all these together, yet different from other visual solutions. For example: If the same message is delivered through not wisely chosen principles and elements of design, the message would, most likely, be misunderstood. Principles and elements of design could be associated to words. Creativity of a designer is a potential that may transform words into poetry.

This presentation illustrate how we are to distinguish good from bad design; it is never a question whether the design is pretty or not. It has always to do with whether it communicates the message effectively or not. We need to understand that displaying a message blatantly, is not a design; it is message only. What architecture is to building, design is to communication.

Design is never pretty. It can be ugly because it does not communicate. If we perceive it positively, it is then beautiful, as it communicates to a spectator effectively. It is beautiful because it transforms messages to visual poetry with wits, craftsmanship and ease. A viewer must feel a sense of joy or content [4], when looking at good design. Good design adds value to the meaning. Good design goes beyond communication. It speaks to the higher senses and it is thus, being ingrained in our mind. A sole message is rarely remembered; feelings are remembered. Good design is lovable design and that is the one that is truthful, direct, concise and the one that sparks joy [4,5].

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GRAPHIC DESIGN BY MIODRAG VARTABEDIJAN VARTA VARTA'S GRAPHIC MARK IN YUGOSLAVIAN AND WORLD DESIGN

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Abstract: *In the era of cultural renewal after the Second World War, the first generation of graduates of the Academy of Applied Arts, Belgrade, pioneers of graphic design in Yugoslavia, created contemporary works that defined the field of modern graphic design related to everyday life and social needs in the region. The artistry and aesthetics of applied graphics and graphic design, as a new concept in the phase of affirmation, were implemented wherever there was a need for public and mass communications in the spheres of culture, politics and economy – propaganda or agitation, and thus influenced the formation of citizens' tastes. Graphic design appears as a product of the ideological and existing economic context, and in accordance with the development of graphic technology and the great changes that took place in the printing process in the sixties.*
One of those pioneers, who from the end of the 1950s until the end of the first decade of the 21st century actively participated in the development and changes of both graphic design and the improvement of printing, was Miodrag Vartabedijan Varta, a Serbian artist of Armenian origin, painter, graphic artist and designer, who received the greatest international recognition in the field of artistic book design.
Keywords: Book, design, vartagraphy, illustration, calligraphy

1. INTRODUCTION

At the graphic workshop of the *Open Graphic Studio* at the National Museum of Serbia in 1990, he formalised his technique of *vartagraphy*. This technique created images on paper or canvas using the frottage method which involved taking rubbings of stone reliefs with hard metallic chalks and oil pastels. This process created an authentic pictorial representation of a texture, inscription or picture, which he then transposed into modern art and graphic design.
The creativity of Miodrag Vartabedijan Varta sublimates his origin, climate and social conditions in which he lived. In Varta's creative works, you can feel the fusion of the influences of all the cultures that left their mark on the soil of the former Yugoslavia, as well as the grounding in Armenian roots and culture. He proudly emphasised his individuality, right to personal attitude and freedom of artistic expression. In his work, he achieved aesthetic harmony according to intrinsic artistic laws. The link that binds his creative endeavours in the field of graphic design and artistic creativity into one whole is the rich cultural history of both nations to which he belonged, as well as the human and artistic need to honour that heritage through contemporary art (fig. 1). Transition from civilisation to civilisation, fusion of traditional and modern, quoting mythology is a typical tendency at the end of the 20th century, positioned as the art of postmodernism.
Miodrag Vartabedijan Varta was born on 23/05/1933 in Mladenovac. He graduated in 1958 from the Academy of Applied Arts, Belgrade (graphics department), and in 1961 he completed postgraduate studies. After graduating in 1958, he worked as an art editor in many newspapers and publishing houses: Jugoslovenska Revija, Pregled, Potrošački Informator, Građevinarstvo, Žurnal, Zvezdina

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Revija, Nota, JAT-ova Revija, Ateks catalogue, Sokoj newsletter, etc. In 1963, he left Potrošački Informator to become the art director of the magazine Jugoslovenska Revija. In 1983, he became the art director of the *Motovun* Publishing House in Istria, Croatia. On June 15, 1992, his employment status ceased to be valid due to the political s ituation between Croatia and Serbia.
He illustrated approximately 20 books for children and adults. He designed over 60 posters in the fields of tourism, medicine and the food industry, as well as dozens of newsletters, prospectuses, catalogues, diplomas, memorandums, and logos.
He was the art director and designer of over 300 photo-monographs of countries and cities, as well as books in the field of art and cultural heritage which were printed in five or more world languages, including titles such as: *Chilandar*, 1977; *China*, 1980; *Studenica monastery*, 1981; *Arts and Crafts of Yugoslavia*, 1984; *World Encyclopedia of Naive Art*, 1984; *Gypsies of the World*, 1988; *America*, 1988; *Russia*, 1989; *Patriarchate of Peć*, 1990; while *Tibet*, 1981, by Jugoslovenska Revija, was printed in 14 languages with a circulation of 240,000 copies.

Figure 1. Illustration and design, Belgrade Audio Anthology, LP, 1981

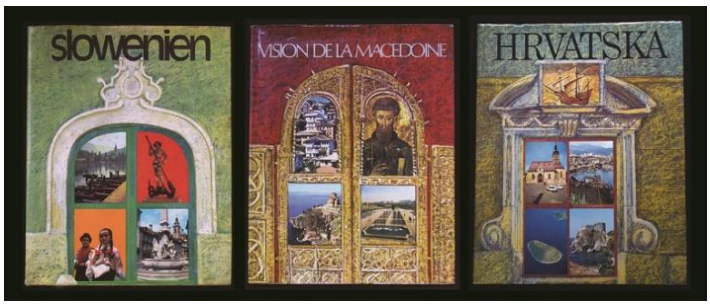

Figure 2. Book design of photo-monographs, Slovenia, Macedonia, Croatia, seventies

He cooperated with publishing houses from 70 countries around the world, worked on book projects in China, England, Switzerland, France, Slovenia, Croatia, Bosnia and Herzegovina, and Italy – where he also supervised the printing of books. He was a long-term collaborator and designer for cultural institutions: Serbian Academy of Sciences and Arts, National Tourism Organisation of Serbia, Belgrade Philharmonic Orchestra, Open Air Museum *Old village* Sirogojno, Belgrade City Institute for the Protection of Cultural Monuments.
In 1992, he became the art director of the *Interprint* graphic publishing company and a full professor at the Belgrade Polytechnic College for the courses Graphic Design and Calligraphy. He retired in 2000. He was a member of ULUPUDS (The Applied Artists and Designers Association of Serbia), ULUS (Association of Fine Artists of Serbia) and the Journalists' Association of Serbia.
He had more than thirty-five solo exhibitions in the country and abroad, and participated in group exhibitions more than 250 times. He was the recipient of 85 awards and recognitions in the field of graphic design and fine arts, among the most significant of which are: The Acquire Award of the Ministry of Culture of the Republic of Serbia at the October Salon, Belgrade in 1980; Award of the English Booksellers in London for the photo-monograph *Russia* which was among 5000 books printed in English in 1990; Grand Prix in Leipzig in 1993 for the photo-monograph *Bohinj*; ULUPUDS Lifetime Achievement Award in 2000; Coat of arms of the municipality of Mladenovac for his life's work in 2003. He died on September 8th, 2009 in Belgrade. He was buried in the Alley of Distinguished Citizens at the New Cemetery in Belgrade.

2. THE FIRST ILLUSTRATED MAGAZINES AND PRINTING DEVELOPMENT

As the art director of *Review – Yugoslav Monthly Magazine* (Jugoslovenska revija), a newly opened illustrated and exclusive magazine, printed in five foreign languages and distributed all over the world, he gave his artistic mark to the pages from the very first issue in 1963. He created a magazine, advertisements and designed the first greeting cards in Yugoslavia. Formed with a dynamic change of large images and text, always recognisable cover pages with superb photos and a modernly designed header, the *Review* was an important propaganda tool of Yugoslavia abroad. Presenting

important names in culture and art, cultural heritage and the beauty of the country, the content in the editions of the *Review* influenced the construction of the multinational identity of Yugoslavia, showing the strength and importance of the country on an international level. In 1965, he received the Annual Award of ULUPUDS for the artistic design of the *Review* magazine, and in 1966 and 1968, he received the first prize in Milan for advertisements created for Yugoslav Air Transport – JAT (Premio Europeo Rizzoli Torchio d'Argento). The magazine was printed in Italy from 1967, where Varta supervised the printing and the complete realisation of the magazine. Apart from improving the quality of printing in the Serbian and Slovenian printing houses with which he cooperated, these experiences brought him new knowledge and opened up the possibilities that he was looking for in his graphic solutions. It was a pioneering time for the introduction of colour into printing and experiments with three, and later with four colour printing processes [1].

3. TRADITIONAL SYMBOLS IN VARTA'S ARTWORK AND GRAPHIC DESIGN

Traditional symbolism appears to be the essential source and subject matter of a considerable part of Miodrag Vartabedijan Varta's artwork. By combining the technique of frottage – rubbing, painting and collage he transposes the inscriptions and figures from stone monuments into modern authentic works of art, which thus becomes the guardian of art heritage.

His artistic exploration is based on stone inscriptions, the oldest and most enduring documents of writing, ornamentation, and symbols, which are the most significant achievements of civilisation. Symbols, as a visual interpretation of human understanding of the world, are collective means of communication and comprehension, and became integral elements of Varta's artistic work. Working as an art director on numerous photo-monographs that presented the culture and heritage of Yugoslavia and the world, he had the opportunity to engage in artistic work on-site. Accumulating records, visual materials, impressions, and artifacts, the influence of the collective unconscious sedimented and emerged as a palimpsest through the chosen artistic expression, whether it be graphics, paintings or books. [2] As a painter and graphic artist, he reached the pinnacle of creative possibilities in book design as well as illustration and graphics. The book, as a portable guardian of heritage, knowledge, and ideas, communicating through space and time, occupied a central place in Varta's creative interests.

In his design of photo-monograph covers in the mid-1970s, pastel and collage were often used. Book covers such as *Croatia*, 1972, *Macedonian Vision*, 1972, and *Slovenia*, 1974 (fig. 2) are collages featuring a pastel technique, a stone texture and a characteristic arched window with ornaments, combined with attractive photographs visible through window frames. All the monographs and photo-monographs designed by Varta are originally and richly formed, presenting a stylistically unified whole, which is the fundamental and most significant component of the book's visual design. From the unique and attractive book cover, thoughtfully designed endpapers, to creatively typographically designed chapter headings, vignettes and decorations, with pages dynamically presenting accompanying photographs alongside the main text, such designs bring forth a diverse interplay of colour, shape, and typography. Examples of Varta's graphic design thinking can be seen in *Chilandar*, 1977 (fig. 3) or *Arts and Crafts of Yugoslavia*, 1984 (fig. 4). Varta directly interprets and conveys the theme through book pages that are clear, well-structured, legible, and accessible, yet visually lavish. Text and image harmoniously alternate on these pages. On one hand, Varta always prioritises the function of the book in the treatment of text and theme, while on the other hand, allows the image and visual design to claim space, creating aesthetically harmonious relationships. [3, 4] By combining these two logical tendencies, the application of typographic purity and clear design, and the insistence on visually rich and elegant book design, Varta creates their own artistic expression in graphic book design, which remains exemplary even today.

Figure 3. Book design of photo-monograph Chilandar, 1977

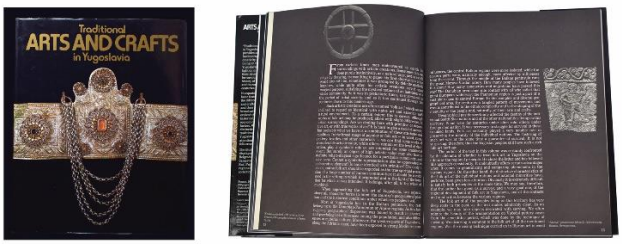

Figure 4. Photo-monograph - Arts and Crafts in Yugoslavia, 1984

The education textbook for the 7th grade of primary school, *Zelengora Lake* (Jezero na Zelengori), 1968, by Petar Gudelj, with an illumination fragment from the Miroslav Gospel on the hardcover, does not resemble a textbook and was then, as a complete creative endeavour, something entirely new (fig. 5). It changed the previous understanding of school books and became a model for future textbooks, considering the design and illustrations created with the utmost taste and balance, to the last text and verse. [5]

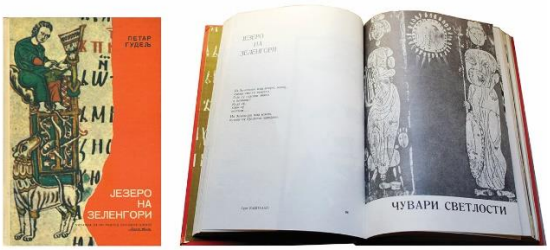

Figure 5. Illustration and design for the textbook Zelengora Lake, 1968

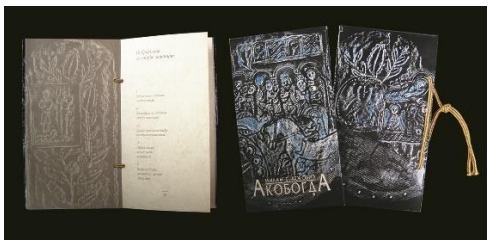

Figure 6. Illustration and design, Poems - Akobogda, 1995

From the early 1990s, Varta shaped the covers of many books with fragments of Armenian or Serbian stone monuments. The book *God Willing* (Akobogda) by Milan S. Kosović is richly and thoughtfully illustrated with composed motifs from temporally and geographically different sources (fig. 6). Impressions from reliefs intertwine: the Assumption of the Virgin Mary, architectural arches, ornaments and symbols – birds, horses, and warriors, as well as floral motifs with distaff. The inner pages, printed on imitation parchment paper, are enriched with initial letters and vignettes, as well as illustrations that occupy whole pages [2].

Among the multitude of posters, newsletters, prospectuses, catalogues, charters, memorandums and logos that he designed, there is also a logo, as well as the annual programme of the Belgrade Philharmonic Orchestra (fig. 7), with a stylised depiction of a lahuta player from a stone relief from the 15th century (bifora of the Kalenić Monastery); a poster for the 40th Yugoslav Documentary and Short Film Festival (Festival jugoslovenskog dokumentarnog i kratkometražnog filma) from 1993 (fig. 8), dedicated to ethnological film (multiple imprints of Serbian anthropoid crosses, arranged in a diagonal sequence as if dancing a reel, and the figure of a young man rubbed from a tombstone holding the festival's logo in his hand).

Figure 7. Logo and annual programme of the Belgrade Philharmonic Orchestra, 1992

Figure 8. Vartagraphy and poster design for the Yugoslav Film Festival, 1993

4. TEXT LAYOUT

When it comes to the layout of text, Varta carefully selects fonts and their variations in the chosen size for each project. The primary focus is always on ensuring that the text is clear, structured and readable, designed in a modern way with thoughtfulness and creativity. In accordance with the formats of designed graphic products, the width of text columns is determined. Initial letters are used in positive space and in outline versions, often in large dimensions with significant indentation. Various width and appearance typographic lines (dotted, dashed) are applied in its design. In the case of photo-monographs, the entire page is placed within a rectangular frame with margins, designed with text and photographs. Headings are underlined to highlight them and make them visually rich. They are also expressed in pagination, often placed in the margin. In Varta's books, from the cover and its jacket, through to the endpapers, introduction page, half and full title page, book block, preface, table of contents, bibliography, bookmark, it is all designed as a unified entity with text, photographs and visual illustrations. The same applies to catalogues, brochures, magazines, posters, business papers, greeting cards and even to small business cards. The unity of ideas, function, aesthetics, and production itself is at the highest level and in line with the printing standards of that time and beyond. Sometimes, impressive results in text layout are achieved even with seemingly limited resources.

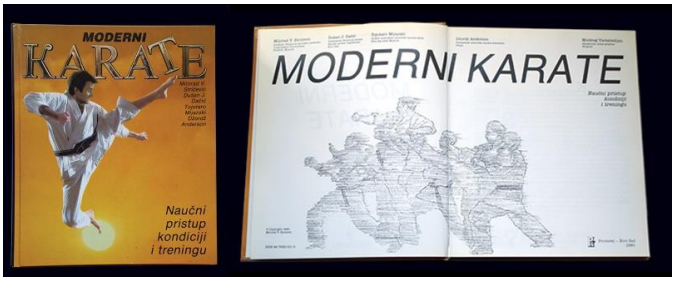

Figure 9. Illustration and book design – Modern Karate, 1990

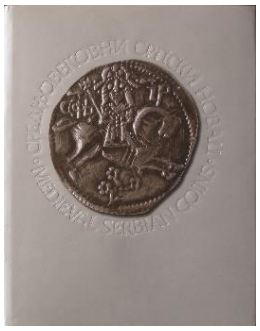

Figure 10. Monograph design with blind embossing technique, 1997

In photo-monographs, the use of a large title is composed across facing pages of the book, featuring large photographs or details related to the theme. These titles are carefully selected and skilfully used to create a harmonious aesthetic balance between large and small, calm and restless elements. In the book *Modern Karate* (fig. 9), the full title page is in cursive combined with a linear illustration and text, forming an aesthetic whole. On the cover there is a photograph of a karateka with one leg positioned on a heated point (sun), symbolising Japan and the Land of the Rising Sun, while the other leg performs a kick that lifts the letter "T" in the title. The cover of the book *Medieval Serbian Coins* (fig. 10) features a title in both Serbian Cyrillic and English language, arranged in a circular shape around a coin and designed using a blind embossing technique on a silver background, creating a three-dimensional appearance resembling a medieval coin impression. For the cover of the book *Szentendre* (Sentandreja) (fig. 11), a photograph featuring a cross is chosen and used as the letter "T" in the title, creating a unique composition with the typography of the title.

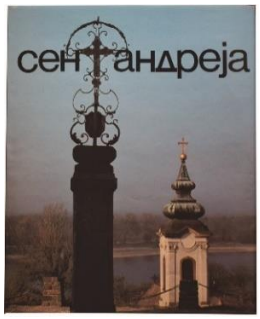

Figure 11. Book design of photo-monograph Szentendre, 1982

Figure 12. Catalogue design with die-cut form, 2004

The unconventional appearance of the catalogue for the exhibition *Animalistic Sculptures (Animalistička Plastika*) by Mira and Sava Sandić (fig. 12) is achieved by using a die-cut form that shapes the catalogue into the contour of an owl sculpture.

5. CALLIGRAPHY

As a tireless explorer of new forms of artistic expression, Varta also tried his hand at calligraphy. For his design works such as book covers, exhibition catalogues, certificates, diplomas and invitations, he creates calligraphic inscriptions for titles as well as entire alphabets including Cyrillic and Latin scripts that he used in his work.
He utilised wooden sticks for writing, which he cut and shaped in various ways. Sometimes a straight-edged tip, which leave a uniform trace when writing, while at other times he would cut the wooden stick tips with two or three incisions, allowing the trace to be composed of two or three lines when writing.
Varta's typographic script *Varta Script* (fig. 13), a cursive character of uppercase letters, is derived with emphasised serifs that give liveliness to the handwriting, along with jagged edges that give it a pictorial quality.

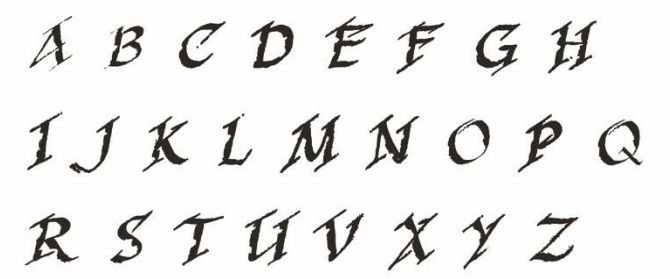

Figure 13. Varta-script, 1999

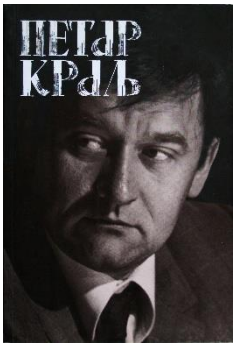

Figure 14. Calligraphy in cover design, monograph - Petar Kralj 1999

6. CONCLUSION

Varta's rich opus of interests and in-depth explorations in artistic design, which can be seen in his creations, provides a picture of an authorial signature that remains recognisable, unique, and enduring in these regions, like an inscription in stone. Varta's retrospective at the Museum of Applied Arts in 1983 was called *Book and Painting* and the exhibition *From Stone to Book* at the Art Gallery *Stara Kapetanija* in 1990, indicating that stone, picture, and book are inseparable parts of the structure of his creativity. Following his own path, leaving traces of cultural heritage, he developed his distinctive modern artistic expression which he transposed into assigned graphic forms. Layers of influences from various cultures expressed through modern means have made his work accepted and published worldwide. In this way, symbols from forgotten cultural records have become contemporary codes of Varta's unique language of graphic communication. Varta's work will remain a source of inspiration for young emerging artists for years to come.

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UTILIZING PARAMETRIC COMPUTER-AIDED DESIGN AND MODAL ANALYSIS FOR THE REDESIGN OF ANGLO-SAXON MEDIEVAL LYRES

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Abstract: *This study presents a novel approach to redesigning two famous Anglo-Saxon medieval Lyres, namely Trossingen and Sutton Hoo, using parametric Computer-Aided Design (CAD). The redesign process was based on early chronological publications, with the initial objective of creating lightly modified replicas of the two medieval instruments while minimizing assumptions and enhancing their sound. The redesigned instruments consisted of various components, such as soundboards, bodies, and yokes. To analyze the impact of different configurations of the soundboards on the structure and sound quality of the instruments, two configurations were designed and compared using spruce and maple materials. Concerning the soundboard's thickness and materials, modal analysis was employed to identify the resonant frequencies of the instruments. The insights obtained from this analysis were utilized to optimize the design of the lyres, aiming to enhance their sound quality and overall performance. Using modal analysis, this research contributes to the preservation and documentation of the musical heritage linked to the lyres and offers in-depth insights into their construction and acoustics.*
Keywords: CAD, FEA, Modal Analysis, Parametric Design, Medieval Lyres

1. INTRODUCTION

The Anglo-Saxon lyre (also known as the Germanic and Viking lyre) is a historically rich and culturally significant musical instrument that appeared in the 1st millennium CE warrior graves. It is part of a strand of lyre development distinctly separated by the Greek-Roman lyres (such as the Lyre of Classical Greece), with findings dated as early as the Iron Age discovered in numerous places in Austria, England, Brittany (France), Poland, and Scotland (where the bridge of a lyre dating to 2300 BCE was discovered in the Isle of Skye) [1,2].
Even if this stringed musical instrument, inspired by lyres played by Germanic tribes, has left a mark on various historical records and artifacts, our understanding of its original design and construction is somewhat restricted due to limited well-preserved remains.
Today, the Anglo-Saxon medieval lyre carries profound significance in its historical context, representing cultural identity and artistic expression. Its relevance extends to historical revival, academic research, cultural heritage, artistic inspiration, and experimental music, making it a valuable instrument that continues to bridge the gap between the past and the present.

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Following this direction, the Sutton Hoo lyre is of immense significance due to its representation of Anglo-Saxon artistry and its role as a musical instrument from the early medieval period. Accordingly, the Trossingen lyre represents medieval Germanic artistry and its role as a musical instrument from the Iron Age. Together, they contribute to understanding cultural and social aspects of those times [3]. Figure (1) illustrates the two well-known replicas of the lyres from Michael J. King since 2012.

Figure 1. Sutton Hoo and Trossingen Lyres replicas by Michael J. King in 2012 [4][5]

Numerous studies have already been carried out on lyre reconstruction; however, the available documentation remains inadequate, often lacking minor specifics [6]. This research aims to restore the Anglo-Saxon lyre using parametric design approaches. Our variations will undergo modal analysis by employing various design methods, resulting in different lyre configurations. Modal analysis helps to preserve and document the musical heritage associated with the lyre by providing detailed information about its construction and acoustics. The models developed in this study serve as invaluable tools for instrument makers, allowing them to experiment with different geometric characteristics and material properties to estimate and enhance the acoustical characteristics of the instrument before its physical construction.

2. Methodology.

The present study introduces the redesign concept using parametric three-dimensional Computer Aided Design (CAD). The process involves Solidworks (Dassault Systemes, Yvelines, France) as the 3D CAD software to create parametric designs for the individual components and generate the final assemblies of the lyres. As a widely used CAD and CAE program, SolidWorks is recognized for its exceptional flexibility for a wide range of applications in many sectors and for its automation, user-friendly interface, logic, and simple learning process. It makes use of a parametric approach and contains a process tree to track the history of the components' alterations.

As Figure (2) illustrates, the Anglo-Saxon lyre comprised a total of 9 components: the main body or soundbox, the soundboard, arms, yoke, bridge, tail, tailpiece, tuning pegs, and strings. Typically, wood was employed for crafting all parts except the strings, which could be made of gut. The main body was predominantly shaped by carving a solid wood piece, aiming for its distinctive teardrop or pear-like contour. The interior was hollowed to enhance resonance and sound projection. The soundboard, fixed at the top of the main body, was securely attached to prevent vibration damping, featuring small soundholes, drilled or carved, to enhance acoustic qualities. The arms were symmetrically attached to the body. Tuning pegs were positioned on a separate component known as the yoke. An essential element, the bridge, was situated perpendicular to the strings near the soundbox's vertical centre, facilitating the strings' proper positioning and effective transmission of vibrations. Lastly, historical accuracy was maintained through adornments such as engravings, paintings, or patterns that embellished the lyre's appearance [7].

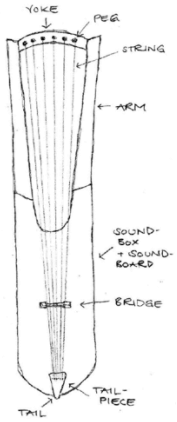

Figure 2. A lyre with all its components [8].

3. Design and Configurations

3.1 Sutton Hoo Lyre

The initial lyre under examination, the Sutton Hoo, was designed according to the data provided by Myrtle and Rupert Bruce-Mitford in chapter IX of their 1983 book "The Sutton Hoo Ship Burial – Vol. 3". [9] The design of all major components, encompassing the body, soundboard, and yoke, was carefully guided by the insights provided in this book. However, minor assumptions in specific areas were introduced to complete the design due to certain gaps in the available information. The complete assembly includes a total of seventy-one components, which are derived from eight individual parts. The structure's core comprises three primary components: the body, soundboard, and yoke. The body is thoroughly hollowed to create a vibrating chamber, enhancing the amplification of sound. Towards the upper section, two arms extend from the main body, connecting to the yoke through tapered joints referred to as escutcheons. Positioned atop the body, the soundboard also vibrates to produce sound waves. It was designed in two variations: the first exhibits variable thickness, ranging from 3 to 7 mm at its centre, while the second maintains a fixed thickness of 3 mm, as illustrated in Figure (3). The bridge, located in the middle, serves as the medium that transfers the vibration from the six strings to the soundboard. These strings are fastened at the bottom with an endpin, referred to as "tailpiece", and secured at the yoke through six pegs. Finally, there are 53 nails positioned around the periphery of the soundboard to firmly attach it to the body. Figure (3) also reveals the final assembly, as well as its exploded view.

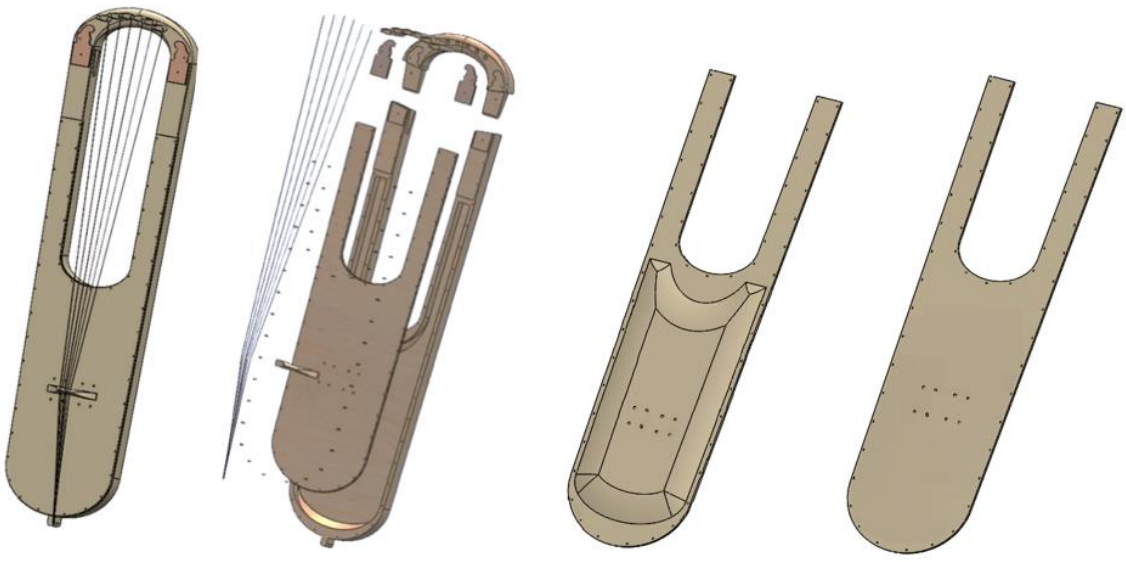

Figure 3. The Sutton Hoo Lyre assembly (left) with two soundboard configurations (right)

3.2 Trossingen Lyre

The Trossingen lyre followed the same design principles. Reference materials, including publications and images by Barbara Theune-Großkopf, served as the foundational basis for the design process. Many design challenges mirrored those encountered with the previous lyre and were resolved efficiently. In this instance, the escutcheons were omitted due to the integrated yoke into the solid lyre's body, resulting in a total assembly consisting of 20 components derived from seven individual parts, as clearly depicted in the exploded view in Figure (4). The main body was hollowed to facilitate vibrations, and four small pegs were strategically added to connect the soundboard to the body. The tuning pegs and strings design were influenced by the information provided in Großkopf's publications, while, as mentioned earlier, the tailpiece and bridge were shared components between both lyres. In terms of soundboard thickness, two configurations were developed. The initial approach, based on previous research, featured an adaptive thickness, from 3 mm at the edges to 7 mm at the center of the model. The second configuration maintained a consistent 3 mm thickness throughout its entire extent, as indicated in Figure (4).

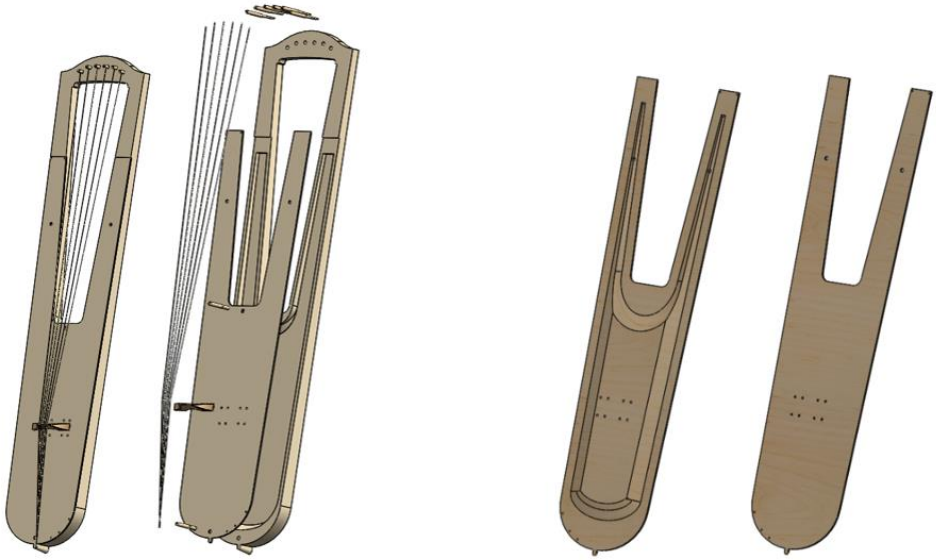

Figure 4. The Trossingen Lyre assembly (left) with two soundboard's configurations (right)

4. Modal Analysis

Modal analysis was also accomplished, which is a specific type of vibration analysis that focuses on identifying a system's natural frequencies and modes of vibration in the current work to determine the resonant frequencies of the instrument and vibrational patterns of its various components. This information was used to optimize the design and construction of the lyre, as well as to improve its sound quality and performance. Modal analysis helps to preserve and document the musical heritage associated with the lyre by providing detailed information about its construction and acoustics. The two configurations of each lyre, Sutton Hoo and Trossingen, were analysed using ANSYS (Canonsburg, USA, PA) software. The first three resonant frequencies of the four configurations are illustrated in Figures (5-6), while Table (1) indicates the first ten resonant frequencies of each analysis. The modal analysis of the ancient lyres, Sutton Hoo and Trossingen Lyre, showed significant shifts in resonant frequencies between their initial and improved designs. For the Sutton Hoo Lyre, there was an average reduction of approximately 9.9% (ranging from 7.6% to 17.1%) in resonant frequencies, with the most substantial decrease occurring in the first mode, which decreased by 6.019 Hz. Similarly, the Trossingen Lyre exhibited an average decrease of about 8.1% (ranging from 4.7% to 12.5%) in resonant frequencies, with the most notable change observed in the sixth mode, which decreased by 27.96 Hz. These changes suggest substantial improvements in the acoustic characteristics of both lyres with their improved designs.

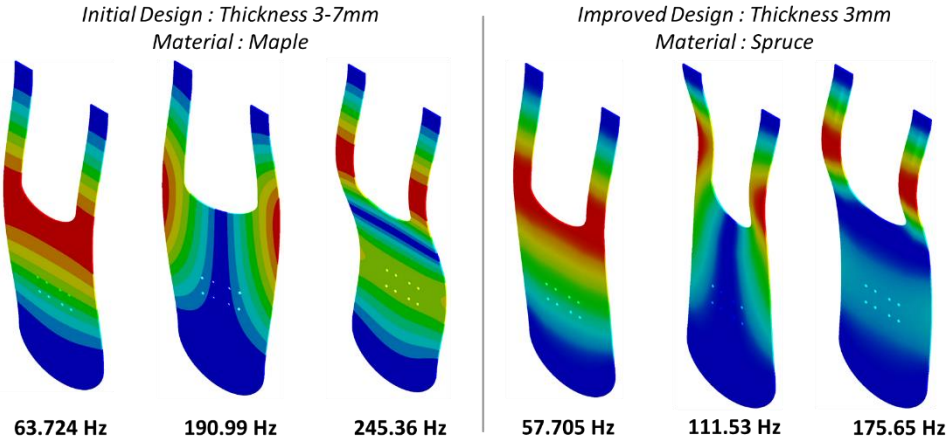

Figure 5. The first three resonant frequencies of the Sutton Hoo soundboard's configuration.

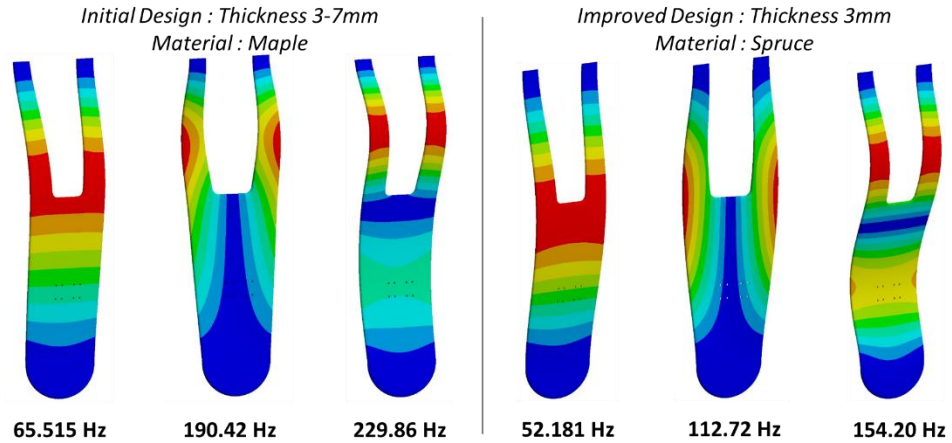

Figure (6) The first three resonant frequencies of the Trossingen soundboard's configuration.

Table 1. The ten resonant frequencies of each soundboard

Lyre	**Sutton Hoo Lyre**		**Trossingen Lyre**	
Resonant Frequencies	**Initial Design (3-7 mm)**	**Improved Design (3 mm)**	**Initial Design (3-7 mm)**	**Improved Design (3 mm)**
1st	**63.724**	**57.705**	**65.515**	**52.181**
2nd	**190.99**	**111.53**	**190.42**	**112.72**
3rd	**245.36**	**175.65**	**229.86**	**154.20**
4th	306.78	246.66	315.63	231.23
5th	397.62	329.10	398.06	302.94
6th	613.06	432.34	637.08	410.12
7th	704.35	482.09	710.57	503.72
8th	882.27	545.77	801.29	580.47
8th	993.96	683.70	902.84	640.09
10th	1037.6	763.76	988.82	752.28

5. CONCLUSION

The created models serve as valuable resources for instrument craftsmen, having the convenience of easily tweaking geometric attributes and material properties. These models also serve as instruments for fine-tuning the acoustic properties of an instrument on an individual basis before embarking on the construction process. Moreover, modal analysis serves an additional purpose by contributing to the preservation and documentation of the lyre's musical heritage. This is achieved by furnishing

comprehensive details regarding the instrument's construction and acoustic properties. Acoustic analysis, in general, entails the utilization of signal processing techniques, encompassing factors like wave propagation, amplitude, wavelength, and spectral content. A profound understanding of wave interactions and the influence of environmental and boundary conditions, which culminate in normal mode oscillations, is vital.

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EVALUATING THE INFLUENCE OF INFILL PATTERN AND DENSITY IN FUSED FILAMENT FABRICATION 3D PRINTING TECHNOLOGY THROUGH MULTIMEDIA DATA ANALYSIS

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Abstract: *The Fused Filament Fabrication (FFF) technology involves various printing parameters that can be investigated and analysed to understand their impact on the final printed model. The infill of the model, consisting of both the pattern and density, holds a crucial role in the slicing software of the 3D printing process. The selection of infill pattern, such as grid, lines, or gyroid, can greatly affect the strength, weight, and stability of the printed model. Moreover, the infill density, which determines the amount of material inside the model, directly affects its overall mass and volume. Hence, these parameters also have an influence on the mechanical behaviour of the printed object. This research aims to examine the different infill patterns available in commonly used slicing software. All patterns were tested at a specific density using cylindrical block pieces. The research methodology involved employing two distinct image processing techniques. The 2D image processing of the slicing phase was carried out using programming language, while the 3D image processing was conducted using micro-computed tomography (μCT) on the printed models. The analysis and comparison between the pixel data obtained from the 2D image processing and the voxel data derived from the 3D computed tomography, provide valuable insights into the relationship between imaging data and the final mass of each printed model. These insights contribute to a deeper understanding of the impact of infill patterns and densities in 3D-printed objects.*
Keywords: Additive Manufacturing, Multimedia Data, Computed Tomography, 3D Printing, Image Processing

1. INTRODUCTION

Fused Filament Fabrication (FFF) additive manufacturing technology has revolutionized both the manufacturing industry and the researchers by enabling the creation of complex and intricate models, layer by layer. There are more than 500 different settings [1] to examine in the FFF technology. Infill, one of the most crucial parameters in FFF 3D Printing technology, plays a significant role in determining structural integrity, mechanical properties, and overall performance of printed parts. It refers to the internal structure or lattice pattern printed inside the solid shell of an object.
The infill pattern is critical because it affects the strength-to-weight ratio, stiffness, and durability of the printed object [2]. By strategically altering the infill pattern, designers and engineers can optimize the mechanical properties of 3D-printed parts to meet specific requirements. Research studies [3,4] have extensively explored the influence of infill parameters, such as pattern type, infill density, and infill percentage, on the performance of printed parts. The choice of infill pattern, including

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honeycomb, rectilinear, gyroid, and others, directly impacts the mechanical behavior and functionality of the printed object. Furthermore, infill density, or the amount of material used for filling the internal structure, can be adjusted to balance strength and material consumption. A higher infill density enhances the structural integrity and strength of the object but consumes more material and prolongs printing time. Conversely, a lower infill density reduces material usage and printing time but may compromise the strength and stiffness of the printed part. The influence of infill in FFF 3D printing technology is not limited to mechanical properties alone. It also affects other factors such as weight, cost, heat transfer, and aesthetic appeal [5,6]. The ability to optimize these factors by adjusting infill parameters makes FFF 3D printing a versatile and adaptable manufacturing method.
On the other hand, multimedia data analysis has emerged as a vital research area due to the explosive growth of multimedia content in various domains, including education, healthcare, and production lines. With the increasing availability and diversity of multimedia data, there is a growing need to develop robust techniques and algorithms to extract valuable information and gain insights from these complex and heterogeneous datasets [10]. Multimedia data refers to data that encompasses different forms of media, such as images, videos, audio, text, and sensor data, often combined [11]. These diverse types of data present unique challenges in terms of their volume, variety, velocity, and veracity, commonly known as the four V's of big data. Analyzing such data requires advanced computational techniques to handle the complexity, heterogeneity, and large-scale nature of multimedia datasets [12].
The aim of this study is to analyse the impact of the infill pattern in the 3D printing process, by analysing multimedia data from various sources. The thirteen different infill patterns available in the slicing software, were investigated through 2D image processing, and 3D μCT. The analysis and comparison between the pixel data obtained from the 2D image processing and the voxel data derived from the 3D computed tomography, provide valuable insights into the relationship between imaging data and the final mass of each printed model. The image processing phase is conducted before the 3D printing process, while the computed tomography and the mass measurement are conducted subsequently after the 3D printing process.

2. METHODOLOGY

The approach encompassed a series of three consecutive stages. The initial step involved replicating the printing process, specifically the slicing method. A cylindrical sample, appropriate for compression testing [7], was created and imported into the slicing software (Cura™ Ultimaker software). The software has thirteen distinct options for configuring the infill pattern, including variations like Grid, Lines, and three-dimensional designs such as Gyroid or Cubic. These patterns are depicted in Figure (1). Polylactic Acid (PLA) was the chosen material for this investigation. The remaining printing variables were kept consistent to ensure a uniform G-code file across all printing instances. The unchanging parameters of the G-code are outlined in Table (1).

Table 1. The constant printing parameters

Printing Parameters	**Value**
3D Printer	*Creality Ender 3-S1*
Layer Thickness	0.2mm
Infill Density	*25%*
Walls	0
Speed	60mm/sec
Print & Bed Temp.	210°C / 60°C
Support & Brim	No / No
Cooling System	100%
Flow	100%

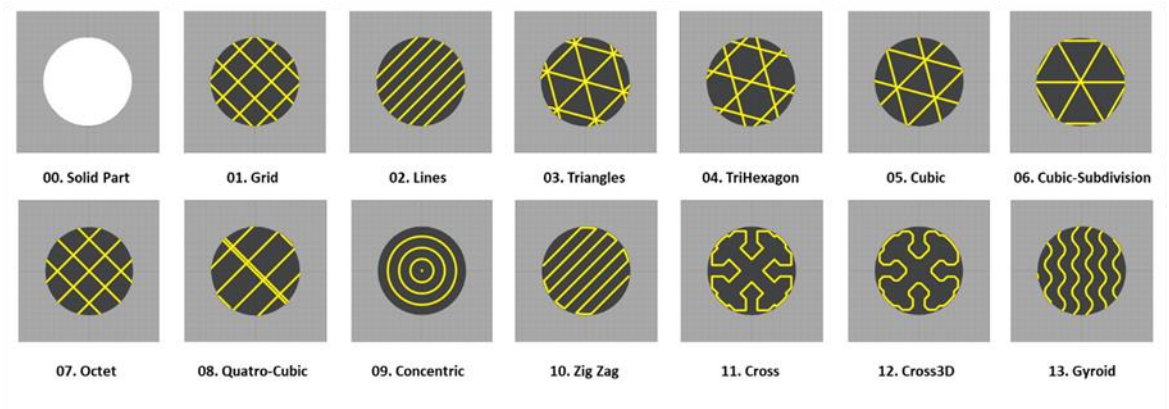

Figure 1. The thirteen available patterns investigated.

The initial approach involved determining the mass. Given the dimensions of the cylindrical section in the experiment (D 12.5mm x H 25mm), the computed surface area, equated to 1.226 cm^2. The complete volume of the object was calculated to be 3.066 cm^3. Concludingly, the density of the PLA material (Spectrum, Parkowa, PL) is manufacturer-stated as 1.24 g/cm^3 and the solid cylindrical segment had a mass of 3.80 grams. Following the 3D printing procedure, each pattern was subject to measurement using a digital balancing scale.

3. ANALYSIS AND RESULTS

3.1 Computed Tomography

Following the mass measurement, internal images of the samples were examined through the application of μCT. A micro-CT apparatus (Tomoscope HV Compact 225kV, Werth Messtechnik GmbH, Germany) was employed to acquire the CT-data and VGStudio MAX 2.2 software (Volume Graphics GmbH, Germany) to compute the total count of voxels present within each printed cylindrical specimen. Since all cylindrical specimens displayed symmetry across all axes, the analysis was restricted to the intermediate layers spanning from layer 25 to layer 100, which corresponds to a height of 15mm out of the total height. A solid segment measuring 15mm in height contains an estimated 440.224 million voxels, encompassing a circumscribed volume of 1780.23mm^3. Table (3) outlines the measurements obtained from μCT for the 13 distinct patterns, while Figure (2) illustrates an example of the 3D reconstruction derived from the μCT in various infill patterns.

Table 3. Voxel Measurement from Computed Tomography

No.	Infill Pattern	Voxels Amount (gr)	Voxels Ratio (%)
00	Solid Part	440.224	100
01	Grid	67.794	15.40
02	Lines	67.926	15.43
03	Triangles	88.705	20.15
04	Tri-Hexagon	86.107	19.56
05	Cubic	76.334	17.34
06	Cubic-Subdivision	65.241	14.82
07	Octet	84.214	19.13
08	Quatro-Cubic	88.088	20.01
09	Concentric	61.851	14.05
10	Zig Zag	63.436	14.41
11	Cross	70.788	16.08
12	Cross3D	59.738	13.57
13	Gyroid	73.121	16.61

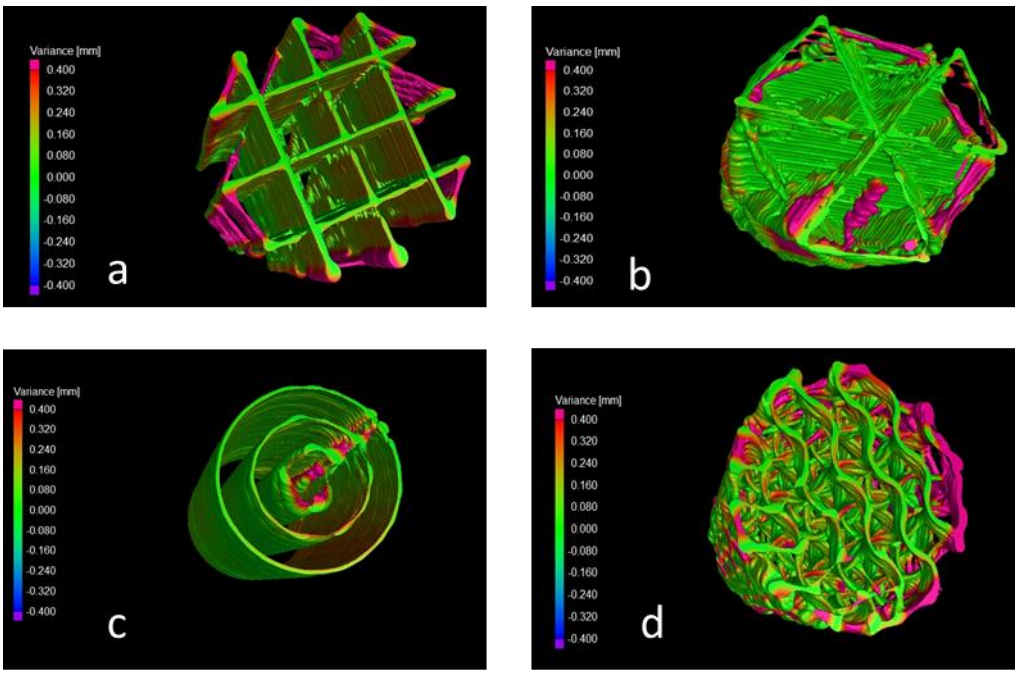

Figure 2. 3D reconstruction of the Computed Tomography in Grid (a), Cubic (b) Concentric (c) and Gyroid (d) infill Patterns

3.2 Image Processing

The outcomes from the two subsequent evaluations – measuring the mass of the printed samples and determining the voxel count through computed tomography – generated information for each distinct infill pattern. The image processing analysis is a pre-processing technique that furnished valuable insights into the 3D printing outcome. Employing the Cura slicing software numerous screenshots for each infill pattern were extracted in JPEG format. During the image processing stage, a highly significant factor is maintaining consistent image dimensions, and consequently, an identical pixel count throughout the entire experimental process. If there's a variance in the image aspect ratio compared to the other images, it would lead to inaccurate area calculations [9]

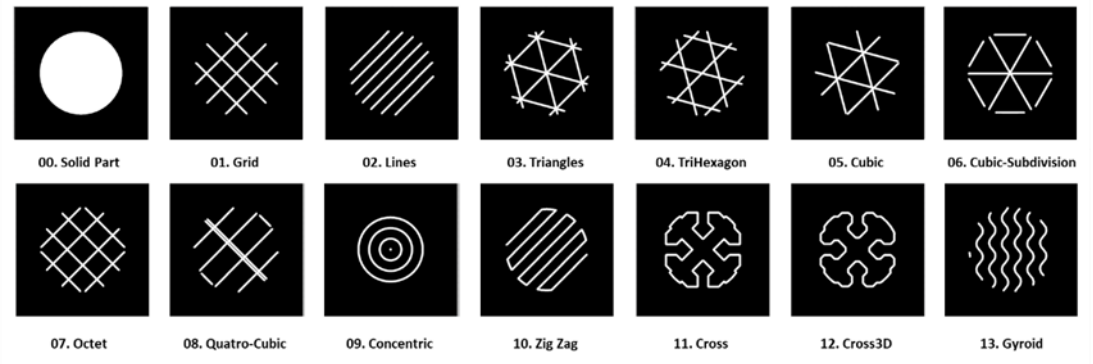

Figure 3. The binary format conversion of the solid model and the infill patterns

The image processing algorithms were executed using the MATLAB computing platform. The images were first transformed into grayscale and subsequently into binary format, where the white pixels indicated the printed volume, as depicted in Figure (3). The identified white pixels within the solid component were 129,825. The overall average count of white pixels across all instances was 21,631 with a corresponding average ratio of 16.66%, as detailed in the results in Table 4.

Table (4) White Pixels detection and the corresponding ratio

No.	Infill Pattern	Pixel Amount (gr)	Pixel Ratio (%)
00	Solid Part	129,825	100
01	Grid	19,728	15.24
02	Lines	22,747	17.52
03	Triangles	24,729	19.05
04	Tri-Hexagon	22,856	17.61
05	Cubic	20,208	15.57
06	Cubic-Subdivision	19,477	15.00
07	Octet	23,618	18.19
08	Quatro-Cubic	20,892	16.09
09	Concentric	18,342	14.13
10	Zig Zag	24,731	19.05
11	Cross	21,561	16.61
12	Cross3D	19,886	15.32
13	Gyroid	22,374	17.23

The results of the three evaluation techniques were equivalent. The pre-process approach of the image analysis verified the subsequent post-process techniques of mass measurement and computed tomography. Measured ratios for all infill patterns, encompassing the comprehensive average from each approach, are outlined in Table (5). Notably, the Triangles, Tri-Hexagon, and Octet infill patterns demonstrated the most favorable average outcome, hovering around 19%, whereas the Cubic-Subdivision, Concentric, and Cross3D patterns yielded the lowest ratios, averaging less than 15%

Table 5. The ratios from every infill pattern in the three methodologies

No.	Infill Pattern	Ratios (%)			
		Mass	Voxels	Pixels	Average
01	Grid	16.05	15.40	15.24	**15.56**
02	Lines	16.84	15.43	17.52	**16.60**
03	Triangles	18.42	20.15	19.05	**19.21**
04	Tri-Hexagon	17.89	19.56	17.61	**18.35**
05	Cubic	16.05	17.34	15.57	**16.32**
06	Cubic-Subdivision	14.21	14.82	15.00	**14.68**
07	Octet	17.89	19.13	18.19	**18.41**
08	Quatro-Cubic	18.68	20.01	16.09	**18.26**
09	Concentric	13.42	14.05	14.13	**13.87**
10	Zig Zag	16.05	14.41	19.05	**16.50**
11	Cross	14.74	16.08	16.61	**15.81**
12	Cross3D	13.42	13.57	15.32	**14.10**
13	Gyroid	18.42	16.61	17.23	**17.42**
Average		**16.32**	**16.65**	**16.66**	**16.55**

The techniques introduced for visualizing and analysing multimedia data from μCT and image processing assist in comprehending the amount of the extruded material, hence the total mass of the printed model. Nonetheless, there are certain factors to consider when assessing the information required through this approach. For the μCT analysis, the precise alignment of the printing trajectory is crucial for obtaining quantitative results [8]. For instance, in the case of a 100μm layer height and a voxel resolution of 10μm, each layer is captured with exactly ten voxels. To ensure the accurate assignment of each print path layer to the corresponding voxel size, the registration error in this dimension should be less than five voxels.

4. CONCLUSION

This research investigates the various infill patterns offered by commonly used slicing software. All patterns were subjected to testing at a specific density using cylindrical block pieces. The research methodology involved the utilization of two distinct image-processing techniques. The slicing phase's 2D image processing was accomplished through programming, while the 3D image processing was conducted via micro-computed tomography (μCT) on the printed models. The utilization of image processing to evaluate infill patterns has yielded a preliminary analysis method for FFF 3D printing technology. This image-based process method could be used for further analysis of various 3D printing parameters, enabling the anticipation of printing outcomes without the necessity of executing the actual process. Across all 13 infill patterns, the image processing method yielded relatively consistent results, all of which fell notably below the desired percentage (ranging from 6% to 10%). The capacity to assess and forecast the behaviour of a 3D printed object before its physical construction serves to significantly diminish the experimental time required for subsequent analyses involving varied printing parameters and distinct CAD designs. Moreover, a machine learning approach can be implemented to analyse even further the G-code file and replicate a more accurate extruder path.

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ENVIRONMENT AND SUSTAINABLE DEVELOPMENT. MECHATRONICS. OCCUPATIONAL SAFETY AND HEALTH AND FIRE SAFETY. SMART MANAGEMENT SYSTEMS. GRAPHIC ENGINEERING. DESIGN. TRAFFIC ENGINEERING. BIOTECHNOLOGY AND HEALTHCARE. MECHANICAL ENGINEERING. ECOTOURISM AND RURAL DEVELOPMENT.

LEATHER RECYCLING IN THE CONTEXT OF HAUTE COUTURE

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Abstract: *In this paper we will show both theoretical written work and original artwork created as a result of research in a number of different areas. As well as exploring traditional craft jewelry-making techniques as an important part of intangible cultural heritage and their importance in preserving and maintaining the continuity of the country's cultural tradition, the theoretical research focuses on ecological and environmental issues and the possibilities for sustainable design and art. The aesthetic expression of jewelry, which through its richness and diversity suggests a visual link with a traditionally recognizable appearance of jewelry, is the main idea of this thesis. However, through the use of completely different materials and jewelry making techniques, jewelry is placed in the context of contemporary design. The focus is therefore on the process of the creation of the object itself, in a modern way, through the use of traditional forms. It is precisely this approach of creating and confronting diversity: traditional - modern, old - contemporary, handmade - machine-made, etc., that makes it possible to fully explore the possibilities of old craftsmanship, harmoniously combined with the new values of the modern age, pointing to the paramount importance of the presence of artistic engagement.*
Key words: Recycling, Ornament, Leather, Couture, Jewelry.

1. INTRODUCTION

The environmental impact of technological progress, the amount of waste produced, climate change, etc., are everyday issues in today's social systems. Production processes generate substantial amounts of waste, and achieving efficient waste usage calls for significant changes in the way of production and consumption. This leads us to consider the role recycling plays in the 21st century. Currently, industrial production is shifting toward industrial ecology, which relies on the level of corporate awareness and logistics in the business system - and is based on the connection between industry and natural systems. The fundamental principle of industrial ecology is the eco-efficiency of a complicated industrial system with the goal of lowering resource and energy usage, consequently minimizing the overall waste of the industrial sector. This project is the result of the author's involvement in the design and creation of fashion accessories for more than two decades. The idea of reusing waste materials to create high quality garments, ornaments, jewelry and other fashion accessories was inspired by professional experience and knowledge of the significant amount of waste and the problems of its processing and disposal. The focus was on how to use waste to create innovative new products through art and design.

2. INDUSTRIAL ECOLOGY AND SUSTAINABLE DESIGN

The concept of *sustainable development* seeks to assure that society advances by utilizing available resources to fulfill its needs without harming natural resources and the environment. Consequently, environmental protection necessitates an array of diverse system solutions. The term *eco-efficiency of industrial systems*, known as *industrial ecology* [1], refers to the objective analysis of the

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industrial production process. This includes the generation, treatment, and disposal of waste within the system. Industrial ecology explores the relationship between industrial systems and natural systems. One fundamental concept of industrial ecology is that of the eco-industrial network, which involves the eco-efficiency of a complex industrial system with multiple factors that result in the exchange of materials and energy between different organizational units. The primary goal is to minimize the consumption of resources and energy, thereby reducing the amount of waste generated by the industrial sector. This industrial symbiosis results in enhanced resource productivity during the production process, waste reduction and generation, and utilization of waste materials as valuable raw materials in other production sectors. The industry generates 360 million tons of waste annually. A significant amount of waste in the leather goods industry is post-industrial rather than post-consumer. Recycling is a feasible solution for approximately half of the leather materials that become waste. Both the economy and the environment reap the benefits of proper disposal methods. Recycling, as a global imperative that modern society deals with in different areas and through many forms of action, has also intrigued numerous artists to join the fight for better utilization of natural resources. This type of artistic activity is increasingly present in many spheres of artistic creativity. Many established world designers accept the concept of sustainable design - 3R concept: *reduce, reuse and recycle* [2].

3. COMBINING TRADITION AND NEW TECHNIQUES

From a historical perspective, jewelry is a distinct aspect of a nation's spiritual and material culture as it has utilitarian, religious, and aesthetic properties. Over time, jewelry has undergone significant changes in function, characteristics and aesthetics. Essentially, it functions as a type of clothing, with a practical purpose, manifesting the owner's status in their class, family or religious group. The symbolic and aesthetic value of jewelry and its ubiquitous use make it a compelling subject. Traditional jewelry making is an important part of a nation's intangible cultural heritage. To preserve this heritage, it is essential to maintain the historical techniques through ongoing research in current jewelry-making procedures. In the creation of jewelry, various techniques are used, such as forging [3], pressing, engraving [4], filigree [5], granulating [6], enamelling [7], etching etc, each with its own unique characteristics. In this project, each of these techniques was chosen for its crucial role in the practical application or experimental development of a new process. Recent technological advancements have enabled the enhancement of old techniques and the introduction of new processes for producing jewelry. The use of sophisticated materials, combined with improved technical processes and emerging technology, has resulted in a rise in both the quantity and diversity of forms, designs and embellishments. The concepts of intangible heritage and traditional craft are in a constant state of flux, which reminds us of the ageless nature of art. Thus, it is possible to establish a correlation between art, culture, intangible heritage and the nature of their existence, as their survival depends on constant and repeated revival.

4. THE PROCESS OF CREATING LEATHER JEWELLERY BY HAND

The research process was aimed at exploring the possibilities of working with leather under modern technical and technological conditions. The results obtained brought together different practices that could be used to create a new and innovative leather treatment process. The aim of this part of the research was to create new tools and technological processes for the assembly of leather elements that would imitate the appearance of metal jewelry.

4.1 Leather selection and preparation

The practical part of the project was preceded by a long study of the technology of leather processing and preparation in industrial conditions. This was essential to ensure that the material reached the required thickness (0.10-0.40 mm) and fine quality equivalent to that of the historical

jewelry pieces that served as the inspiration for this project. Since this material has not previously been used in the production of this kind of decoration, selecting a type of leather that complements its aesthetic and technical properties requires knowledge of all types of leather and their characteristics in order to make a good choice. When selecting the material, the initial step was based on the purely visual appearance of the leather itself, the richness of its colors and the variety of its textures, which in their visual characteristics resemble certain types of precious metals, precious and semi-precious stones or other materials used in the manufacture of jewelry. The final selection included a range of leathers, from calfskin and lacquered leather to *spazzolato*[2], as well as textured leather. Prior to this, each type underwent a technical analysis to assess its hardness, elasticity, and requisite strength for further processing. Only the leather that met the above technical requirements was used in the final selection. Over 40 distinct types of leather were used in the production of ornaments and completed pieces of jewelry. The initial phase of preparing the leather for processing involved *thinning* the leather through *splitting*. Based on extensive research and thorough analysis of the techniques and tools traditionally used in jewelry making, through a series of conducted experiments was discovered that the use of only two basic and simple tools - the hammer and the *holepunch tool*[3]- could produce excellent results and facilitate further steps in the process. It started with the base of the circle, specifically circles of different sizes, i.e. diameters (from 1 mm, 2.5 mm, 3 mm, up to 30 mm). Then, hole punching tools were made of different diameters (f).

4.2 Variability of circular patterns as a fundamental artistic motif

The following section focuses on the creation of circular designs using a range of experimental techniques. The ultimate goal is to produce a unique ornament by combining multiple circles of varying sizes within a single larger circle. All this supports the claim made by Slavik Jablan that *the potential of the modular design principle is limitless. The variety and richness of motifs are produced by variations of geometric sets of fundamental elements* [8]. Another important principle that I adhered to in this project is the concept of *modular design*. This involves utilizing variations of geometric sets of fundamental elements to produce limitless and intricate patterns. By applying this technique, an extensive array of modular designs can be obtained, each one featuring a unique, aesthetically pleasing appearance. A structure is generated using a modular approach based on symmetry theory to calculate the number of distinct structures obtained by certain *algorithms* [9] that ensure completeness, according to Slavik Jablan's combinatorial formulas. In doing so, this methodology has the potential to generate novel and contemporary ornamental forms, thereby redefining the aesthetic relationship of ornament and symbolism through the circular prism. The development process of the circle as a fundamental component, leading to the ultimately accepted visual solution, was challenging. It involved numerous alterations, adaptations to the given production conditions, and unsuccessful attempts. However, exploring potential solutions resulted in successful outcomes via mutual union, multiplication, and combinatorics with varying forms and numbers. This study, conducted during the early stages of research, analyzes the technical process that determines the feasibility of the project, and defines the direction for the aesthetic development of ornaments. It is the point when the circle, as a fundamental element and one of the earliest and most straightforward graphic symbols, exhibited its universal nature, owing to its distinct visual appeal and the possibility of creating many derived forms and ornamental compositions.

[2] The term *spazzolato*, derived from the Italian word for *polished*, refers to a type of full-grain leather used in the leather goods industry. This leather has a higher shine than average but is typically less lustrous than traditional lacquered leather.

[3] *Hole punch tools* are made from specifically designed materials to withstand hammer impacts. They are produced by specialized companies that manufacture both manual and machine tools and equipment for the production of leather and footwear.

4.3 Achieving Visual Dynamics

In Figure 1, the process begins with a circular element containing smaller circle copies arranged at equal intervals, forming the foundation for the following phase. Once the initial phase has been completed, the elements within the same circle of the ornamental motif are multiplied by repeating the whole process, with the difference that the separated circles return to the same position and change direction, i.e. rotate 90 degrees. To create intricate designs, strings of ornamental structures are used within the same grid, grouped in a circle to create a final ornament.
Visual dynamism is introduced by the ornaments created as a result of the symmetrical reflection of the isolated element in the first phase and the new division of the color fields within a circle - the change in their position creates a new visual interaction within the same ornament. Therefore, the structural alterations and discrepancies that emerge at each production stage can be traced throughout the ornament's development, and each instance of the same element's variation yields a distinctive ornament while maintaining the circular motif's use. Next is the classification of colored ornaments, which broadens the range of motifs. I followed the path of the development of the circle motif through the variability of the changes in the shape of the ornaments, while preserving symmetry as the basic visual language of their building and structural elements. At the same time the regularity and decorativeness of the rosette elements was preserved through the complexity and integrity of the individual form of the ornament and as a part of the building element in the structural composition being created. The decorative archetypes designed in this project are presented through the richness of color combinations (Fig. 2).

Figure 1. Creation of the individual elements in the ornament. Procedure for creating ornaments (a–f)
Source: Desnica,I,d.um. projekat *Recikliranje kože u funkciji visoke mode,* Univerzitet Umetnosti u Beogradu, 2022.

Figure 2. Completed fashion accessories
Source: Desnica,I,d.um. projekat *Recikliranje kože u funkciji visoke mode,* Univerzitet Umetnosti u Beogradu, 2022.

5. CONCLUSION

This project demonstrates that the modern resource management model can establish a connection between eco-industrial networks and the cleaner production system. The focus has been on traditional jewelry-making techniques, some of which have been used in their original form, while others have led to the creation of new innovative processes and workflows, always with a view to preserving the processes. Traditional jewelry-making techniques, which have been included in the UNESCO list of intangible heritage protection since 2003 as part of the techniques of old crafts, concentrate on the process of making and transferring knowledge about skills and crafts, rather than on the product as the end result of the making process [11]. We see modernity as an interpretation of new ideas, which helps to clarify today's perception and understanding of ornament. It is interesting to consider the interplay between heritage and modernity, as well as the contrast between artisanal and industrial approaches. This dialogue can both inspire and challenge our understanding as it shapes the aesthetic consciousness of contemporary society. The process also has wider implications. These include recognizing the continuity of jewelry making and expanding the meaning of ornament. The selection of fundamental decorative shapes and their subsequent amalgamation were influenced by manufacturing techniques and technical procedures when forming compositional pieces.

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ENVIRONMENT AND SUSTAINABLE DEVELOPMENT. MECHATRONICS. OCCUPATIONAL SAFETY AND HEALTH AND FIRE SAFETY. SMART MANAGEMENT SYSTEMS. GRAPHIC ENGINEERING. DESIGN. TRAFFIC ENGINEERING. BIOTECHNOLOGY AND HEALTHCARE. MECHANICAL ENGINEERING. ECOTOURISM AND RURAL DEVELOPMENT.

DESIGN AND EDUCATION: TRADITIONAL AND ONLINE ENVIROMENT

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Maida Gruden[2], The Student's City Cultural Center

Abstract: The theme of this paper represents a cross-section of Annual School Exhibitions of works by Academy of Technical Vocational Studies – Belgrade design students, from 2004 to 2023 in cooperation with Dom Kulture Studentski grad, and explanations the educational process and cooperation with our school. In addition to the presentation and written work, posters and catalogs from 2004 to 2023 will be displayed in a special showcase. The connection between traditional and digital approaches in the educational process become even more prominent during the Covid pandemic. Online exhibitions have become a new reality. Development of digital media and their implementation in the educational system led to a different expression and communication in art and design.
Keywords: *design, education, online environment, digital art, communication*

1. INTRODUCTON: Relationship Between Traditional and Digital Approach

Relationship between traditional and digital approach in the field of education and design is an intertwined process and permeates each other. The idea is the basic starting point in art and design. The title theme of the exhibition „Distance that unites us" held in 2021. was inspired by the situation caused by the COVID-19 virus pandemic in which we lived and how it affects creative processes in the sphere of design and art. The situation led to a change in the presentation of artistic content and design and their communication with the public in the form of online exhibitions, but it denied the possibility for a more direct, physical and spiritual experience of artistic and design work and interaction in real, tactile, spiritual and physical communication.

Figure 1. *Poster for student's exhibitions in DKSG, 2021.*

Figure 2. *Poster for student exhibition in DKSG, 2022.*

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Contemporary aspirations in the field of design, emergence and use of new technologies and materials, increasingly massive use of digital technologies in design and market demands, encourage us to modernize and raise the quality of teaching. It also obliges us to prepare students for today's market in accordance with their creativity. The exhibition is also an opportunity to evaluate our pedagogical abilities in nurturing young talents, through their work in classical art techniques and digital technologies. The exhibitions included all segments of sociological aspects - topics such as education, ecology, health, culture, anti-war movements and other current topics of modern society.

The development of digital art and the use of digital technologies in design flow together with the development of computers. The set of digital technologies has transformed traditional techniques such as drawing, painting, sculpture, graphics into new forms such as internet art (network art), pixel art, data art, computer games, digital installations and they are becoming generally accepted artistic practices. One example of the acceptance of digital art is the artist Andy Warhol[3], who created digital art using the software „amiga paint", which he publicly introduced at Lincoln Center, and whose art has influenced all areas of contemporary design from graphic to fashion. I would also like to mention the artists Barbara Kruger[4], known for conceptual art and graphic design, and the artist Josh Begley[5], digital artist known for data visualizations, and his work *Every NYT Front Page since 1852*.

2. NEW TECHNOLOGIES AND DIGITALIZATION IN ART

Famous for her incisive photomontages, Barbara Kruger has focused increasingly over the past two decades on creating environments that immerse the viewer in language. At the Hirshhorn, Kruger recently completed *Belief+Doubt*, a site-specific installation that fills the museum's lower-level lobby and bookstore. Using a bold color scheme and towering text, *Belief+Doubt* explores themes of money, power, and belief. The phrases in her works often include pronouns such as "you", "your", "I", "we", and "they", addressing cultural constructions of power, identity, consumerism, and sexuality. Kruger's artistic mediums include photography, sculpture, graphic design, architecture, as well as video and audio installations.

Figure 3. *Barbara Kruger Installation, Hirshhor Museum and Sculpture Garden, 2012.*

[3] Andy Warhol, (1928-1987), American artist, painter, film director, writer and star. He is the founder of „Interview"magazine.

[4] Barbara Kruger, (born January 26, 1945), American conceptual artist and collagist associated with Pictures Generations, Professor at the UCLA School of the Arts and Architectures.

[5] Josh Begley, (born 1984), American digital artist, creator of Metadata+, an iPhone application

Known as *word art*, her method includes developing her ideas on a computer, later transferring the results (often billboard-sized) into printed images. Most of her work deals with provocative topics like feminism, consumerism, and individual autonomy and desire, frequently appropriating images from mainstream magazines and using her bold phrases to frame them in a new context.
At the beginning of the eighties of the twentieth century, Andy Warhol used *Amiga* computers to generate digital art, including *You Are the One*, which he helped design and build with Amiga, Inc. Andy Warhol was a pioneer in digital art. The world of digital art has exploded with online galleries and auctions, cryptocurrency trading, and a plethora of artists, both old and new, creating and selling digital artworks as NFTs (non-fungible tokens). This new era of art has quickly become a global sensation; it has proved itself to be unimaginably lucrative, and a powerful cultural force in the democratization (and general transformation) of art itself.

Figure 2. *Warhol and the Amiga – The Andy Warhol Museum*

The world of digital art has exploded with online galleries and auctions, cryptocurrency trading, and a plethora of artists, both old and new, creating and selling digital artworks as NFTs (non- fungible tokens). This new era of art has quickly become a global sensation; it has proved itself to be unimaginably lucrative, and a powerful cultural force in the democratization (and general transformation) of art itself.
The young American digital artist Joch Begley known for his data visualizations. He is the creator of Metadata+, an iPhone app that tracked every reported United States drone strike. In July 2012, Begley developed an iPhone application that would send a push notification every time there was a US drone strike in Pakistan, Yemen, or Somalia. In 2014, after five rejections, Apple accepted Begley's iPhone app. It was then approved as Metadata+. Josh Begley has compiled every front page of The New York Times since 1852 and created a fascinating visual timeline that documents the history of the image. taking the form of a video, the piece feeds through thousands of pages collected from the late 19th century up to the present day, capturing the chronology of text and picture-based layouts. while early examples are clearly devoid of any imagery, later covers begin to feature some hand-drawn illustrations, before the introduction of the camera completely changes the face of the publishing industry. The 55-second-long video rapidly streams through the most major international events in history, yet its mesmerizing quality is truly triggered by the introduction of photography. Begley’s film demonstrates the paper’s increasing use of black and white images, before color photography changes the game; today, a multitude of pictures feature liberally across front pages. more than 60,000 covers are included in the short film, packing history into a single, hypnotizing minute.

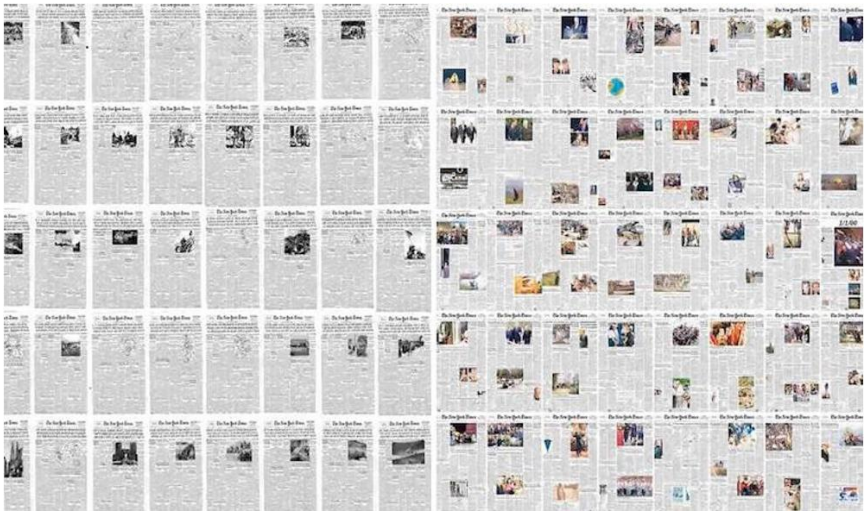

Figure 3. Joch Begley, Every NYT Font Page since 1852 in 60 Seconds, video, 2017.

3. SIGNIFICANCE AND COOPERATION BETWEEN ATSSB AND DKSG

Dom kulture Studentski grad[64] is one of the places in Belgrade with the longest tradition that provides space and support for students and young artists to present their creativity to colleagues, peers, and the more professional, as well as the general public. Through its activities, DKSG enables students to actively participate in the process of conceptual preparation and technical realization of the exhibition that is accompanied by the catalog. For decades, since the opening of this institution in 1974, the art program of DKSG has profiled itself as successful in the act of early recognition and discovery of young talents, which is of exceptional importance as an incentive to young authors in their further creative path and career.

Figure 4. *Dom kulture Studentski grad, Belgrade*

The implementation of all segments of the Art Program of the Student City Cultural Center is aimed at encouraging the development of creativity and critical thinking in the visual arts, bringing contemporary art closer to students, developing awareness of art as an important educational tool that can be used to reflect on modern life and encourage one's own creativity. From year to year, exhibitions are held where students, young artists, art historians and curators have the opportunity to present to the public the latest artistic production realized in the most diverse media from drawings, through graphics, photography, design, new media art (digital art, art installations, video arts, artistic research) to a unique art form that develops at the intersection of different disciplines, which is an art book. By affirming innovative ways of art presentation, media representation and communication, the aim is to promote the reception and popularization

[6] Dom kulture Studentski grad, (The Student City cultural center), (was faunded in 1971.), The House of Culture is an educational institution within the Ministry of Education, Science and Technological Development of the Republic of Serbia

of fine art in the wider public. Permanent education in the field of artistic practices and theories takes place through workshops, lectures, conversations with artists and other relevant actors of the Serbian art scene.

A significant part of the art program's work is cooperation with art academies from the country and abroad. It is also an opportunity for art faculty students from other cities to be directly present in Belgrade and to meet their colleagues and the audience in direct communication.

In this sense, DKSG nurtures two biennial events that network students of Art and applied academies from the country and abroad and multi-year cooperation with the Design Department of the Belgrade Polytechnic, Academy of Technical Vocational Studies Belgrade:

1. DKSG has been organizing biennial exhibitions of student drawings and graphics continuously and alternately since 1981. The basic idea of these exhibitions of student works is to gather and display the works of future academic fine and applied artists in one place, and thus provide an insight into the unique manuscripts of different fine arts schools. Every year, more than 100 authors have the opportunity to exhibit at the Biennale of Student Drawings and Student Graphics. The prize of the Biennale consists in organizing a solo exhibition for the awarded author in the Gallery of the "Student City" Cultural Center. The fact that many, especially the awarded participants of the Biennial of Student Drawing and Student Graphics, have prominent positions on the contemporary art scene, both here and abroad, confirms the quality and representativeness of this manifestation.

2. The 2nd International Student Biennial of Book Art, a form that develops at the intersection of various disciplines (graphic design, illustration, literature, photography...) is a unique student event in Serbia that was initiated by the editor of the DKSG art program Maida Gruden and Prof. Olivera Batajić (FPU) in in the House of Culture, Student City, in cooperation with the Faculty of Applied Arts from Belgrade. The Biennale has developed further and the Cultural Center from Belgrade has joined us as a partner.

3. Cooperation with the Department of Design of the Belgrade Polytechnic, the Academy of Technical Vocational Studies Belgrade through the annual exhibition of undergraduate students' works, five accredited study programs: Graphic Design, Interior Design, Industrial Product Design, Fashion Design and Concept and Character Design opens opportunities for the students of the Belgrade Polytechnic to professionally present their work related to the culture of everyday life and to introduce themselves to the wider market and enable them to establish contact with future employers. In the last few years, the works of Master's students in graphic design, as well as special thematic projects dealing with current topics of contemporary society, have been presented as a separate unit. Exhibitions are often accompanied by a fashion show and lecture programs. DKSG is aware of the great importance of this exhibition as an opportunity to include the experience of exhibition activity for students in the teaching process. Students have the opportunity to familiarize themselves with the organization of exhibition settings and public presentations of their work. For many, it is the first professional presentation and viewing of work in a new dimension before the public and the media. Cooperation with the Belgrade Polytechnic department was not interrupted even during the Corona virus pandemic, since the practice of online presentation of student works through virtual exhibitions on the website of the Belgrade Academy of Technical Vocational Studies was established.

During the covid pandemic, DKSG also strove to develop new activities that did not necessarily require a physical presence. The online series "Where are they and what are they doing today" was launched with the idea of presenting, in the form of short video clips, artists who had their first independent exhibitions at DKSG, as well as the winners of the Biennale of Student Graphics and Student Drawing awards, and who are still active participants on the contemporary art scene, and some of them are very notable authors on the international scene as well, such as Professor Jelena Jocić from the Department of Belgrade Polytechnic. In each episode of the series, many artists talk about their artistic journey, role models, creative inspiration, as well as their current work, future plans and other interesting topics. Video contributions are broadcast on the DKSG YouTube channel and shown on DKSG social networks.

In addition to working with students of art academies, DKSG is also dedicated to working with students as an audience, given that this cultural center is located in the surroundings of one of the largest student dormitories in the Balkans - Student City. Namely, since 2020, DKSG has been implementing the international project "They: Live - student lives revealed through context- based art practices", which deals with student life from the end of the Second World War to today in four countries: Serbia, Croatia, Montenegro and Spain in the context of daily life in student dormitories, cultural habits and free time of students, interpersonal and gender relations, as well as social and political involvement of students. The goal of the project is to encourage the student population to participate in the understanding and joint creation of contemporary art, using archival materials and participating in practical artistic activities during artist residencies in student dormitories.

Figure 5. Annual exhibition of works by ATSSB design students, Belgrade, 2023.

The project is implemented within the European Union's "Creative Europe" program for culture and media. During the year 2022, 5 art residencies were realized in student dormitories lasting one month in Belgrade, Novi Sad, Rijeka, Madrid and Podgorica, in which pairs of artists and curators developed participatory artworks with students who today live in student campuses using the collected archive about student life published on the international digital platform Topoteka.

4. CONCLUSION

The New technologies and their implementation in the educational process are an integral part of the future and modernization of teaching processes, as well as the digitization process. Cooperation between DKSG and ATSSB is of great importance for our students, through this exhibition activity students get to know the organization of the exhibition itself and the public presentation of their work. For many, it is the first professional presentation and review of their work in front of the public and the media. With this cooperation, we encourage students to engage even more in their creative work, pointing out to the public young talents and introducing future students to the design study programs of the Academy of Technical Vocational Studies Belgrade and the Department of Belgrade Polytechnic.

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ENVIRONMENT AND SUSTAINABLE DEVELOPMENT. MECHATRONICS. OCCUPATIONAL SAFETY AND HEALTH AND FIRE SAFETY. SMART MANAGEMENT SYSTEMS. GRAPHIC ENGINEERING. DESIGN. TRAFFIC ENGINEERING. BIOTECHNOLOGY AND HEALTHCARE. MECHANICAL ENGINEERING. ECOTOURISM AND RURAL DEVELOPMENT.

DESIGN, FASHION AND THE INDUSTRY: THE CONTEXT OF THE EMERGENCE OF FASHION DESIGN AND READY-TO-WEAR CLOTHING PRODUCTION

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Abstract: *This paper aims at providing some insight into the context in which the fashion system was first established through haute couture and the accompanying ready-to-wear clothing production during the second half of the 19th and the start of the 20th centuries. The main focus is on the technological aspects and the research into the prerequisites which facilitated the industrial production of garments. Since the moment when the first garment was made with the use of machines represents a moment in history when the requirements for the laying of foundations for the fashion design were met, this paper also gives an account of the inventions (first and foremost machines used for pattern-making and sewing) which had contributed to the emergence of textile and fashion industry.*

Keywords: fashion design, fashion industry, ready-to-wear clothing, *haute couture*, *prêt-à-porter*

1. INTRODUCTION

The new social and cultural circumstances during the 19th and at the beginning of the 20th centuries, technological development and the industrialization brought about the establishment of the new paradigms in art as well as in the field of clothing. During the 18th century a distinction was made between the fine art and crafts whereas the garment production remained affiliated with the crafts during this "aristocratic moment" for clothing as Gilles Lipovetsky put it [1, pp. 22-30]. In the 19th century and during the first decades of the 20th century, through numerous movements, associations and schools (from Arts and Crafts movement to Bauhaus), an approach to the design of utilitarian objects emerged which took into consideration esthetics and functionality, ergonomic and economic components, included the use of crafts, knowledge about fabrics and application of the new technologies. Fashion made a grand entrance onto the scene of visual arts with the opening of the first *haute couture* fashion house (*maison de couture*) in Paris in 1857 when Charles Frederick Worth (1825-1895), a dressmaker, became a fashion designer, i.e. became an undisputable author who can impose dictates of fashion [1, p.67]. The first term for fashion was *couture* which is French for sewing or needlework, [2] which encapsulated the very essence of the trade, only to be substituted by the term *haute couture* which suggested originality and high level of execution of tailor-made garments [1, 3]. With a view to supervising the organization, management, improvement and protection of haute couture creations [4, p. 298 – footnote 29] a Chamber of Paris Designers *(Chambre Syndicale de la Confection et de la Couture pour Dames et Fillettes)* was formed in 1868 and in 1910 *La Chambre Syndicale de la Couture Parisienne* was constituted [2]. Worth marks the start of the reign of "a hundred years' fashion" as Gilles Lipovetsky [1, p. 65] refers to the period which started at the end of the 1850s and lasted till the 1960s dominated by the *Paris haute couture* and when dictates of fashion spread to other European cities and the rest of the world from France. *Haute couture* was accompanied by the development of serial, industrial

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production of standardized clothing reaching a larger number of customers – ready-to-wear garments (in French – *confection*). According to Gillo Dorfles, an aesthetician and art critic, one of the first conditions a utilitarian object should meet in order to be considered in the field of design is the manner of its production which includes mechanical production [5]. The possibility of recreating the produced object, i.e. the serial production, as well as designing objects with an aesthetic component built in, are the prerequisites mentioned by Dorfles, [5] which can be applied to fashion design as well. *Haute couture* and ready-to-wear clothes are the two intertwined sides of fashion, which have continued to develop alongside the visual arts on the one hand and in accordance with the technological development on the other.

2. FASHION AND THE INDUSTRY

Since the story of fashion does not rely solely on exceptional talented individuals who worked in this area of applied arts, but also on, among other things, technological development which facilitated the growth of fashion design and mass production of garments, innovations which made a significant impact on the textile and fashion industries should be mentioned here. The changes in textile industry started in the 18th century with the implementation of innovations such as the flying shuttle (1733), the spinning jenny (1764), power loom (1786), Jaquard loom which enabled the production of fabrics with complex patterns (1801) [4, p. 305]. However, the industrial production of garments started somewhat later in the 19th century with the use of the sewing machine. It took a long time to perfect the sewing machine from 1829 [4: p. 430 – footnote 11; 6: p. 56] so that it could be used in industrial production. The production of clothes also evolved over time finally being organized in factories according to the division of labour as opposed to having one worker in charge of an entire garment (the complete garment method) [7, p. 74]. In the early days of mass production of clothes cut denim workman's trousers for Levy Strauss in 1850 had been sent out to machinists' homes in individual bundles to be sewn [6, p. 56]. Factory-made clothes in England, France and the US in the beginning ranges from clothing for armed forces, rough sailors' clothing, i.e. work clothes during the American "gold rush" in the mid-19th century to ordinary urban daywear for men which appeared as early as in the 1830s and 1840s in London [7, p. 73]. English tailors situated on the celebrated Savile Row brought to perfection the construction of men's suit by using a tape measure, which had been in use since the end of the 18th century, thus enabling the taken measurements to be exact [8, p. 155]. In addition, tailors of men's suits further developed the system of pattern cutting by relying on mathematical calculations and by taking into consideration the proportion between the height of the body, width of the back and other parts of the body while their pattern-cutting systems were published so that others could use them [4, p. 376]. Significant contribution to setting up a system of the pattern cutting was made by a German mathematician Henry Wampen in his publications: *The Mathematical Art of Cutting Garments According to Different Formation of Men's Bodies* (1834) and *Mathematical Instructions in Constructing Models of Draping the Human Figure* (1863) [4, p. 376 – footnote 2]. In the segment of tailored suit made for women, by borrowing strict male shapes menswear tailors replaced dressmakers who created dresses by draping fabrics directly onto the body or, more often, based the pattern on unstitched old dresses [4, p.386, 388]. Men's suit at the start of the 19th century through its shape and appearance had already been designed in modernist style whereas following the "Empire" style women's fashion became more complex, intricate and the shape gained more in volume, which was why it had been difficult to adapt the shape and the production of dresses to the requirements for factory-made clothing.

An American inventor, Isaac Singer, filed a patent for an improved sewing machine in 1851 and continued afterwards to develop variations of a foot-treadle machine until 1859 and by the 1860s started their mass production in his company [6, 9]. Since then, sewing machines have played an important role both in making clothes at home and in industrial production [6, p. 56]. An increasing number of women's magazines published patterns, many in life sizes, which could be used for making clothes at home [4, p. 386-387]. However, in order to make complex shapes in mechanical

serial production precision is required, both in pattern cutting and in the sewing process, in addition to having to standardize sizes. As a consequence, the first dresses made according to standardized measurements appeared in 1870 [1, p. 98]. Less demanding items were made in factories on a larger scale, clothes with simple outlines, as well as fashion accessories – underwear, scarves, lace shawls, coats and small capes [1, p. 98]. Nevertheless, in time the use of the sewing machine in serial production included all of the articles of clothing (coats, rain coats and everyday clothes for a "new woman" to go out in or to wear to work, dresses, skirts and blouses tailored after men's shirts) [7, pp. 77-78] reducing the time needed to make a dress to 1/7 of the time necessary for making it by hand [4, p. 305 – footnote 33].

On the other hand, the use of synthetic fibres allowed cheap imitations of more expensive fabrics to be made such as artificial silk, available since 1892 in France [4, p. 306; 7, p. 71]. This fabric has been known as viscose rayon since 1924 [2, pp. 213, 270]. During the 19th century the centre of silk production was in Lion, France, which was connected with the fashion houses in Paris, the centre of fashion [7, p. 70]. In order to allow the ladies to follow the *Art Nouveau* style in fashion at affordable prices, in addition to the artificial silk, hand-made embroidery and lace were replaced by mechanical versions [4, p. 306]. Textile innovations and the search for new materials continued into the first half of the 20th century when synthetic fibres were produced, [2, 7] namely, *nylon* in 1940 and *polyester* in 1941, *acrylic* substitutes for wool in 1947 and finally *lastex* in 1930 [10, p. 80] and *lycra* in 1958.

As Suzanna Shonfield states, Worth ran his fashion house up to the late 1870s practically according to the rules of industrial production considering the number of copies he had been turning out [11, p. 29]. The House of Worth had 1200 employees at the start of 1870s, which included tailors, seamstresses, embroidery workers and models [8, p. 173]. Owing to the use of sewing machines and the division of labour which allowed only pattern cutting, embroidered interventions and hemming to be done by hand, *haute couture* designs could be reproduced faster while cheaper versions were made from other, less exclusive fabrics [11]. During the period between 1890 and 1910 mass production of clothing exploded in the UK and the USA [7, 12]. In France *haute couture* designers fought to control the production and distribution of products and conquer new markets through licensing, thus preventing unauthorized copying and ensuring the protection of their rights as authors of the designs. This is why the philosopher Gilles Lipovetsky saw *haute couture* as a commercial enterprise and a part of the luxury industry, which borrowed the idea from ready-to-wear clothing to group together once separated actions of buying directly from the factory, selling fabrics and making finished garments, for the purpose of making a profit [1, p. 97].

The beginnings of the textile industry and industrial clothing manufacture in Serbia were recorded in the text "Herald of Culture" (*Vesnik kulture*) published in the magazine *Tekstilna industrija*, no. 12 in 1927 [13]. According to this source, a company founded in 1907, *Kosta Ilic and Sons*, functioned as a "concern of textile products" which included, *inter alia*, "a baize factory (since 1907), a department for cotton and canvas industry (since 1910), a spinning mill for worsted wool, department for haberdashery (since 1923)" and these factories supplied with fabrics the First Serbian Clothing Factory (*Prva srpska fabrika konfekcije a.d.*) in Kanak, which was founded after the World War I as a part of this concern [13, pp. 232-233]. This factory produced ready-to-wear garments for children and men, undergarments and military uniforms [13, Ibid.]. Between the two world wars Belgrade had a number of fashion houses which followed Paris fashion and on occasion offered quite original designs, as was the case with Katarina Mladenovic who patented "The Procedure and Mixture for Plastic Coating of Fabrics" in 1923 [13, p. 133].

3. HAUTE COUTURE VS. MASS-PRODUCED FASHION

Lipovetsky mentions that, following the example of Worth, twenty *haute couture* fashion houses appeared at the exhibition in 1900 and this number increased to 72 in 1925 when the exhibition of decorative arts was held. However, after the World War II the number started to fall and in 1959 about 50 fashion houses were registered [1, p. 68]. *La Chambre Syndicale de la Couture Parisienne*

prescribed rules that fashion houses were to observe in order to secure their status as a couture house and these included the number of employees in workshops, which was not to be under 20, and a presentation of at least 50 original designs as a part of collections in each season shown to the Press in Paris [2, p. 130]. Organized fashion shows (Fr. *la revue*) offered an overview of new designs through a variation of stage shows. They appeared between 1908 and 1910 when fashion became "hypercentralized" and a highly regulated system had been established [1, p. 68]. After the World War I summer and winter collections were shown in Paris at a pre-defined time and, primarily for the sake of foreign buyers, mid-season collections were introduced for spring and autumn [1, p. 69]. Couture houses showed collections to respectable foreign clients or authorized buyers, predominantly from America and Europe, who could purchase creations made-to-measure or obtain licensing rights for serial production of the selected designs which provided them with the paper or linen patterns [2, p. 130]. Since ready-to-wear clothing developed side by side with *haute couture*, soon after the spectacular fashion shows of Paris couture houses, simplified versions of the shown designs were available at affordable prices [1, p. 69]. Fashion thus acquired a democratic and international air.

Technological advancement and production growth continued after the World War I and as Lipovetsky asserts "industrial clothing manufacture was profoundly transformed" mainly due to the division of labour in industrial production, innovations in the chemical paint industry and textile industry, as well as newly improved machines [1, p. 67]. Electrical sewing machine appeared on the market in 1921 [6, p. 56] and in the 1930s circular blade rotary cutter was introduced, [7, p. 80] allowing the expansion of production capacity and the rise of mass-produced fashion. By quickly adopting new technological inventions and offering ready-to-wear lines of clothing to clients the US was at the forefront of this trend. The concept of ready-to-wear clothing (also known as ready-made and off-the-rack) included mass-produced garments for women, men and children, of different styles and made from various fabrics, available in all sizes, sold in shops and department stores [14]. Mass-produced fashion as a "ready-made garment" also keeps the designer's name – the brand name that brings a certain cultural capital to the product. In response to the American version of mass-produced fashion, France introduced *prêt-à-porter* lines in 1949 in an attempt to "merge the industry and fashion", to industrially manufacture clothes according to fashion trends [1, p. 106]. Most designers of haute couture, including Pacquin, Worth and Poiret, were aware of the importance of the American market [11, p. 29]. However, in addition to those who obtained licenses to reproduce French designs, there were too many unauthorized copies flooding the market. This issue was addressed by the designers' associations, nevertheless, the licensing practices and the possibility of buying the rights for mass production brought into question the "exclusivity of haute couture designs" [11, p. 35].

Gabrielle Coco Chanel (1883-1971) was not concerned about this as she had always wanted to participate in the creation of accessible, functional and even mass-produced fashion. In an interview for *Vogue* in February of 1953, in the second half of her career, she sums up her goals in fashion: "I am no longer interested in dressing a few hundred women, private clients; I shall dress thousands of women" [11, p. 37]. Chanel announced something similar with her first collection for women in 1917 when she used jersey, a fabric that had not been used for women's costumes before except for sportswear and outer garments. Staying true to her fashion philosophy, Chanel sectioned off a small part of her couture house (registered with the Paris Haute Couture Chamber in 1919, right after the First World War) for making "ready-made clothes" [11, p. 37]. Patou and Lelong presented the same year as Chanel their first collections inspired by "ready-made clothes" [11, p. 35]. This moment heralded the rise of *prêt-à-porter* and the gradual decline of *haute couture* in the following years. Lucien Lelong (1889-1958), famous for his *haute couture* collections in Paris, was the first designer of *haute couture* who added a ready-to-wear department within his couture house, opened in 1918, in 1934 [15, p. 22]. Pierre Cardin (1922-2020) and Yves Saint Laurent (1936-2008) [16] continued to develop accessible fashion through *prêt-à-porter* collections following in the footsteps of Chanel. Pierre Cardin was the first *haute couture* designer to allocate a store for the *prêt-à-porter* collection in 1959 (a *prêt-à-porter boutique)* which caused him to be expelled from the Paris

Designers' Chamber [17, p. 101]. Yves Saint Laurent, on the other hand, in 1960s successfully expanded the offer with *prêt-à-porter* collections, which he designed with the same care as *haute couture* collections under the brand name *Rive Gauche* (in 1966 he launched a *prêt-à-porter* collection for women and for the first time in 1969 for men) [16, 17]. The number of buyers of haute couture and clothes made-to-measure was much lower in 1960s [1, p.104], which caused Cristobal Balenciaga (1895-1972) to close his Paris fashion house in 1968 as he refused to comply with the market demand to start a mass-produced line of clothes and signalled that haute couture had reached its end [10, p.194]. On the other hand, YSL fashion house remained in the field of *haute couture* until 2002 when it turned completely to *prêt-à-porter* collections [11, p. 143]. At that time only 11 registered couture houses remained [11]. In the meantime, Paris introduced a practice of showing *prêt-à-porter* collections the way *haute couture* collections had been shown once and the event was trade marked as *Prêt-à-porter Paris* [6, p. 39].

4. CONCLUSION

Fashion was considered in this paper from the perspective of technological and industrial revolution which facilitated the "merger of fashion and industry". In other words, the artistic elements in fashion had to be adapted to technical requirements for mass-production of clothing. It has been established that ready-to-wear clothing even precedes *haute couture* and that *haute couture* was set up according to the rules of ready-to-wear clothes production – designing, producing, presenting and selling were conducted in the same space and there was a licensing option for luxury products. Bearing in mind the position of the fashion industry today and contemporary mass-produced clothing, the paper sheds some light on the context which surrounded the emerging fashion industry and the birth of ready-to-wear clothing for mass markets. Haute couture started losing its relevance in the 1960s and when there is talk today of the end of fashion, it is actually "the death of haute couture" that is being referred to. The retreat of couture houses before the ready-to-wear designer lines and closure of many of them marked the new era in fashion which has introduced new rules. Once hypercentralized fashion has become plural and global. This inaugurated *prêt-à-porter* collections whereas the surviving couture houses have joined the market for mass-produced clothing. Fashion for the masses and the global market in the 1990s, according to numerous fashion theorists, heralded the definite end of fashion. If we look solely at the market share of *haute couture*, it is pointless to comment it as a significant part of contemporary fashion, however, it is still relevant in the context of fashion advertizing of the now dominant *prêt-à-porter* fashion collections.

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DESIGN, IDEOLOGY AND PROPAGANDA

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Abstract: *In this paper, we investigate how the design of everyday objects and ideology are connected. In different cultures ideology is present as a design component, both in a spatial, geographical, and in a temporal, historical sense. In this way, culture and ideology become part of the story or biography of a certain object or visual solution. Numerous examples show that there is no object that, through either form, use, production or market, does not reflect the ideology with which it is inevitably connected. Even an ornament that we believe has a purely decorative function reveals the ideological background from which it arose. In cases where the ideological plan is emphasized to the point of explicit expression, the design becomes an instrument of propaganda. Every day, utilitarian objects become a platform for ideological messages with clear content. In this paper, we will present some examples of clear and unambiguous propaganda messages as a means of introduction into a certain ideology.*
Keywords: Ideology, Propaganda, Design, Visual Culture, Material Culture

1. INTRODUCTION – IDEOLOGICAL COMPONENT OF DESIGN

Van Dijk defines ideology as a basis for the social representation of members of a certain group, and Fairclough defines it as a construction of reality that contributes to the production, reproduction or transformation of relations [1]. Berger and Lukman talk about this mutual relationship in "The Social Construction of Reality": "Society is the product of man. Society is objective reality. Man is the product of society" [2]. In this dialectic, the only thing left out is the variability that is immanent in the reconstruction and development of ideologies, and therefore in everyday life and the experiences that man acquires and creates at the same time.
Every functional society has a "main" reality that is sometimes ideologically imposed and represents a dominant structuring force in the formation of people's perception and judgment [2]. Observing everyday life as an experience that is intertwined with the use of various tools, objects, constructed and designed spaces, it is clear that they also represent a reflection and part of the ideological structure. Companies and designers involved in the production and design of new products today focus on the communication, semantic and ideological components of everyday objects. The awareness that objects represent an integral part of culture and that as such they can shape new experiences, initiate new concepts and significantly influence the economy and politics, has been present from the very beginning of thinking about products as an outcome of the industrial revolution. In 1978, Horst Oehke especially emphasized that design is not limited only to the sensory perceptual plan of the object. The designer should deal with the needs of social and individual life. In 1979, the D**esi**gn Zentrum Berlin set a complex definition of design in the context of the exhibition, in which

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the obviousness of the object's function, the visibility of modern technological achievements, the prominent uniqueness of the object, the ecological, energy and ergonomic component, and especially the relationship between people and objects [3] were repeatedly emphasized. In his definition from 1987, Michael Erlhoff particularly emphasized the social component in design: "Design, which, unlike art, requires practical reasoning, finds application in four spheres – social, functional, meaningful and concrete" [4].

On the example of the construction and manufacture of canoes in the Solomon Islands, it is possible to see how culture and ideology are incorporated into the design process itself and how a realized canoe becomes a specific utility object that will never be marred by something as mundane as market value. The people of the Solomon Islands build a special type of canoe for tuna hunting, which is a sacred task, dedicated to the deities. As this type of canoe is considered an expression of superior skill and artistry, supervisors are brought in to oversee their construction. Each boat produced in this way is dedicated to a deceased person and once dedicated and launched it cannot be sold or exchanged [5]. Therefore, the ideological basis of the subject is not a peculiarity related only to industrial design or to Western culture. Each newly created object is incorporated into the culture in which it will be used and gets its place in the connotative network of meanings. These meanings are not fixed to the object itself, but exist only in the context of its use. The same canoe, rug or vessel has one meaning and significance in the culture in which they were created and a completely different meaning when they are used or traded in a different cultural and ideological framework.

The ideological basis of industrially produced objects was instrumentalized at the beginning of the 20th century and culminated in a sharp division during the Cold War, although at that time function and aesthetics were still in focus as the two main components along with rationality, i.e. economic profitability when it comes to socialist social systems.

2. ORNAMENT AND IDEOLOGY

During the period of modernism, ornament was stigmatized as a superficial and unnecessary component. Decorativeness, which has no other function, was undesirable, it was considered kitsch and an instrument for seducing uneducated buyers. It acquired this status through its separation from function and its physical connection with the exterior of the object. In the 1950s in East Germany, at a congress of the Association of Architects, Kurt Liebknecht, the president of the association, attacked the principles of "formalism" – a style in art and design reminiscent of the Bauhaus and modernism. He claimed that formalism is "foreign to people" and even hostile, and that the Bauhaus is an international weapon of imperialism. It was emphasized that "formalism" is actually "form without ornament" and that design in East Germany should turn to the old German styles known to workers and farmers. Their slogan illustrates the ideological basis of the design they proclaim: "socialist content, national form". Even the very term "industrial design" was undesirable, prompting a discussion on whether to change the name of the school from "Institute of Industrial Design" to "Institute of Applied Arts". Ornament is recognized as a part of tradition and an expression of traditional style [6]. Soon, the lack of resources – natural raw materials as well as money – led to a different approach in architecture. East Germany accepted the necessity of building typical houses with a reduced appearance, and baroque and rococo furniture did not fit into such an architectural form, so soon the production of furniture without complex details, sporting a geometric shape increasingly reminiscent of the modernist style, begins. This style will be called economic rationalism. In his dissertation, "The Significance of Industrial Product Design in a Developed Socialist Social System", Martin Kelm, president of the East German Industrial Design Association (Amt für industrielle Formgestaltung, AIF) points out that "consumption in socialism is not only a matter of satisfying needs through the purchase of things, but a process through which a socialist personality is created". Successor to the Bauhaus, the Ulm School of Design further deepens the separation from ornament through a sharp break with the historical ballast of class and culture, rejecting the aura of expensive artefacts (tables and bulky furniture).

3. DESIGN AND PROPAGANDA

Propaganda is a powerful tool often used by political ideologies to increase the number of supporters and impose value systems and opinions. Technological progress, natural raw materials and superior design of industrial products are also related to political and social progress, i.e. they represent its manifestation and thus hold a significant potential for use in propaganda purposes.
The politicization of modern art and design was also one of the "weapons" of the Cold War. Superiority, a better standard of living, as well as economic and scientific progress [7] were shown through the design and shaping of everyday life. Product design during the 20th century was marked by the ideological struggle between East and West, between two ideologies – socialist and capitalist. The State Department funded exhibitions that traveled around Europe in the 1950s promoting American design as proof of American dominance and the superiority of capitalism over communism.

3.1 Psychological and emotional component of design as a platform for propaganda

Boudrillard gives a kind of semiotic interpretation of the "Traditional environment" or the interior of a house by interpreting the shapes of the furniture, the organization of the space and the positioning of the objects: "The arrangement of furniture offers a faithful image of the familial and social structures of a period. The typical bourgeois interior is patriarchal; its foundation is in dining-room/bedroom combination. Although it is diversified with respect to function, the furniture is highly integrated, centering around sideboard or the bed in the middle of the room. There is tendency to accumulate, to fill and close off the space. The emphasis is on unifuctionality, immovability, imposing presence and hierarchical labelling" [8].
The basic function of objects in such an interior is the personification of interpersonal relationships. In this relationship, Boudrillard sees that objects transcend their physical space and utility function and achieve a psychological and emotional connection with people during their interaction. A certain combination of furniture and interior decoration becomes a representation, a picture, of what we call home. Furniture becomes the "spatial incarnation" of emotional ties and family permanence, but also a mirror or extension of wider social structures. Like clothes, furniture and interior decoration are a reflection of the ideology that shaped them. He sees the ideological function of the system of objects in the need for personal achievements, which is satisfied through the acquisition (purchase) of objects. As David Raisman says: "The product now in demand is neither a staple nor a machine, it is a personality" [9]. The customer, through the acquisition of objects and the desire to be a subject, becomes an object themselves by fulfilling the sociologically imposed need for achievement through possession. Since the differences in the items are determined at the industrial, production level and the consumer's choice is only seemingly free, it renders authenticity through acquisition – an illusion. The system that Baudrillard describes is based on democratic ideology and is affirmed as one of the aspects of social progress by giving everyone the opportunity to climb the social ladder characterized by greater material luxury and special personalization of objects [8].

3.2 Propaganda in textile design

War rugs are traditionally associated with the area of Iran and Afghanistan. The practice of crossing the feminine craft of carpet weaving and war scenes is linked to the period of the first attack of the Soviet Union on Afghanistan in 1979. Carpets are usually associated with private life, domesticity, apoliticality, decorativeness, comfort and warmth of the home, so the juxtaposition with acts of war, politics, aggression and destruction seems surprising and shocking, assigning a completely new function to an everyday, traditional object – subversive communication. While the war carpets from the period of the Soviet attack retain the artistic elements of traditional carpets, shaping the motifs in a manner characteristic of the traditional transposition of forms, the war carpets from the period of the beginning of the 21st century are more reminiscent of posters. The forms are stylized as in the

graphic design of politically engaged posters, and only the border has been retained from the traditional elements.

From 1894 to 1942, a large part of Japanese traditional kimonos and textiles in general were decorated with explicit images of modern wars, violent attacks on enemies, tanks, fighter planes and warships. Such Japanese "war patterns" are often called "propaganda kimono", but this term does not quite reflect the complex interweaving of meanings that the creators, producers and users associate with this textile.

The propaganda kimono predates the contemporary use of textiles and clothing for propaganda purposes. Even at the beginning of the 20th century, the Japanese kimono was a tool for explicit propaganda, and for centuries it has been a powerful communication tool at the heart of numerous rituals and ceremonies. They were created as a response by kimono manufacturers to society's desire for modernity. Brightly colored designs are associated with social realism, Art Deco, Dadaist and Cubist collages, cartoons. Propaganda kimonos were mostly worn at home and at private gatherings. Since these designs were mostly on the inner layers of clothing, only a small number of family members and friends would see them.

A typical kimono from the 1920s depicts the Western idea of a consumerist future – cities, steam locomotives, cars and airplanes. Historians note the year 1931 and Japan's advance towards Manchuria with the establishment of a puppet regime as Japan's turn to militaristic nationalism and increased isolation from the West. This is why propaganda kimonos combined nationalist themes with iconography from popular culture. For example, a child's kimono from 1933 shows a boy in a sailor suit, surrounded by a battleship, a biplane, a modern American car and small soldiers in uniform.

As Japan's isolation intensified, motifs associated with Japan's rare friendships, such as Italy and Germany, appeared more and more on kimonos. Images from Italian colonies – Somalia and Ethiopia – appear on kimonos. One kimono shows a strange contrast between Mussolini's haughty pose and an innocent Ethiopian boy in a military convoy pushing a wagonload of weapons. There are also pictures supporting Nazi Germany, but they are not even close to the German propaganda of the time. Stylistically and conceptually, they are completely different. Japanese designs include locomotives that merge with fighter planes, but also a mixture of gentle and brutal. One kimono features a small boy with a puppy, shown packing aid for soldiers at the front. There are no racist symbols or any implication of racial superiority in these depictions unlike German Nazi propaganda.

A kimono from the 1940s celebrates the signing of the Tripartite Pact between Italy, Germany and Japan and features three flags in a foam of smoke and fighter jets, reminiscent of the chrysanthemum – a traditional Japanese symbol.

After the war, these patterns became a source of shame and were suppressed and forgotten [10]. The secrecy of the collectors of propaganda war kimonos is understandable from the contemporary context. Although the Japanese war kimono is not the only example of a war textile, it is conceptually and aesthetically different in approach compared to the others. The combination of tenderness and brutality, absence of hatred and focus only on images of victory and success, an unusual combination of traditional and modern, Western perception in relation to self-perception, makes them authentic. From the aspect of communication through design, this is an interesting expression within a common function.

4. CONCLUSION

These examples of propaganda through textile materials and implying ideological motives represent one form of specific communication through design. It appears on the very surface of an object that has primarily a decorative and protective function and that is not explicitly perceived like a poster or an illustration or a print on a t-shirt. However, no design product is ever truly ideologically neutral, whether the message is explicit or not. The ideological plan appears from the very beginning of the development of industrial design and mass production of objects. The continuation of the Bauhaus school in East Germany had a strong Stalinist ideological component, just as the original Bauhaus

rested on leftist ideals of prosperity, social justice and the availability of quality products to the masses [6]. Design in East Germany was oriented towards a departure from Western or American aesthetics in order to create a utilitarian and authentic look associated with mechanization and industrial progress. Designing objects in the spirit of modernism and the illusion of freedom of choice and socio-economic progress, abundance and achievement was part of the American dream and an instrument of seduction and promotion of liberal capitalism. By studying the semantic and communication component in design and semiotic analysis, it is possible to analyze the ideological component in the industrial design of everyday objects as well as the everyday life of people in a certain period. Given that design deals with the future, the shaping of the ideological component of new objects shapes the future relations of users and the world of objects, as well as material and immaterial culture.

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THE SOCIAL SIGNIFICANCE OF VIDEO GAMES

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Abstract: *The aim of the paper is to point out the social significance of video games. Video games are used today in the development of artificial intelligence, as an educational tool for students, soldiers and pilots. They are also used to maintain the mental condition of young and old. Video games apply technologies of virtual and augmented reality; they became a place of protest against entertainment industry and started the fight for their own artistic status, e-sport was created, they are the scene of conflicts of gender and racial politics, they became a new virtual space for socialization of young people, around them specific cultures of fans are formed creating a gaming subculture. Secondly, it will be explained how, via mobile gaming industry, video games reached the widest social strata and generations and thus became a mainstream industry from a subcultural one, and video games became mass media in the full sense of that term. Today gaming industry earns more than film and music industry combined and every year its social significance becomes greater.*
Keywords: *Video games, society, gaming industry, gamer*.

1. ECONOMIC PROSPERITY OF THE INDUSTRY AND INCREASE IN THE NUMBER OF VIDEO GAME PLAYERS

A paper on the importance of video games could start in different ways, but we will start by citing data on the explosion of earnings within this industry and the huge growth in the number of (consumers) players. The video game industry is a very lucrative and rapidly growing sphere of popular culture and entertainment. According to the results of the website STATISTA, the video game industry is a billion-dollar business and has been for many years. During the year 2022, the revenue from the global gaming market is estimated to be almost US$347 billion, with the mobile gaming market generating an estimated US$248 billion of the total [1]. Furthermore, the video game market revenue is projected to reach US$385 billion in 2023 and US$522 billion by 2027 [1]. The largest market is mobile games with a market volume of 286 billion US dollars in 2023 [1]. In a global comparison, the largest revenue will be generated in China (US$109.2 billion in 2023) [1]. The average revenue per user (ARPU) in the video game market is projected to reach US$142.50 in 2023 [1]. The importance of this industry from the perspective of economic potential and profit earning is therefore enormous because it is more than the music and film industries, combined together, have earned in years. Many national economies of the world, among them the Serbian one, are starting to see the export and sale of video games as an important part of their economy. Also, there is data on the constant growth of employees within the industry, which brings with it above-average incomes [2].

However, the growth of earnings in the industry would not be possible if there was not a constant increase in the number of players, while the entire industry depends on the number

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of players and on their willingness to spend money while playing the game. The explosion in the number of players and the transition of video games from the world of subcultures to the mainstream is primarily due to mobile gaming. Ever since, in the 2010s, the transition to smart mobile phones with high processing capacities in everyday life, an increasing number of people have started to consume video games. Smartphones today, like computers, are open systems with strong processing capabilities for which a wide variety of video games are developed, and some of them are extremely audiovisually complex. According to a report by DFC Intelligence, there are nearly 3.1 billion video gamers in the world as of mid-2020. This means that about 40% of the world's population plays video games in some form. The report also shows that the largest market for video games is Asia, with 1.42 billion pay-to-play game users, followed by Europe with 668 million [3]. The fastest growing segment of video gamers are those who play games only on their smartphones, accounting for nearly half of all video game users. Mobile gaming makes up the majority of this market and is responsible for the high prevalence of video games. For example, data from DFC Intelligence shows that out of nearly 3.1 billion gamers, only about 8% of them consume video games using consoles, although this small group is significant to the industry, as it has the highest consumption per user [3]. In the past, only IT enthusiasts, mostly men, sat for hours in front of the screen passionately playing video games. Today, the demographics have changed with the advent of mobile devices and now both men and women alike, as well as young and old, play video games. The advent of smartphones with their touch screen interfaces has made games easier to play, which has led to the fact that today children as young as three, with underdeveloped motor skills, start consuming video games. During the 20th century, young children could not play video games because there were no devices that they could use without mastering the motor skills of controlling a joystick or a computer mouse and keyboard.

In the paper "Why and how video games are important", the author Alidini states that according to the research available to him, children aged 2 to 5 years represent the fastest growing group of players [4]. Alidini states that, according to projections, children will play games every day until they turn 18, and the time they will spend consuming video games will equal or exceed the time they spent in classes in elementary and high school [4]. Furthermore, data from 2014 show that 91 percent of Americans under the age of 17 have played or are playing computer games [4]. Many of them will continue to practice video game consumption in some form even in the later stages of life. Since the video game industry is worth about 347 billion US dollars in 2022, it aims to attract loyal players from an early age, which in practice means adapting them to the consumer discourse or indoctrinating it with it so that they continue playing as long as possible in life [4]. Due to the frequent availability of mobile devices, today's children are falling prey to this industry, which is why in many countries of the world, in the past decade, the public has come forward and intensified debates about perspectives, possible regulation and the place of video games in society.

2. SOCIAL IMPACT OF VIDEO GAMES

During the 1970s, video games were a negligible part of the world of the games played by humans. The world of games for children and adults in a short period of time was filled with video games and, as stated, today they are a mass type of entertainment [5]. In human civilization, play was an element which every human being grows up with and it represents an essential feature of life [5]. However, unlike the games that children have been playing for decades on the streets, in the yards of their houses or in front of their buildings, video games are created by the video game industry, and the question immediately arises whether video games are a matter of spontaneous and disinterested playing or promotes an ideological view

of the world and, as mentioned, encourages consumerism (many video games cost from scratch, while in the later gameplay something can always be bought with money from virtual tools or weapons and the like or for some add-on the user is offered to watch commercials in order to pay). In his book *The PlayStation Dreamworld*, Alfie Bown writes that smartphones and video games, from fulfilling our desires to play, gradually begin to influence what we want and control us [6]. Although video game users think they are doing what they want, there still seems to be nothing spontaneous and natural about someone's desire to buy something (a weapon, a new life, shorten the waiting time for a reward) from a video game in order to improve the situation of their virtual character during the gameplay. The video game industry has the power to create desires for players (especially children) and organize their fulfillment. Of course, users, especially young people, tend to view externally imposed desires as their own. Summarizing his arguments, Bown says that video games do not fulfill the user's wishes, but transform the way we want them [6]. Second, video games demonstrate the existence of corporate hegemonic control of cyberspace [6]. Third, the desire for a certain physical object does not exist before the electronic media and technology through the process of mediation created the desire for it.

Contrary to this, it could be said that there are independent video games that are not the fruit of corporate capital and do not represent an attempt to manipulate and indoctrinate their users. However, as Maravić writes in his book *The Total History of Video Games*, the idea of most independent video game developers was not to distance themselves from the industry, but quite the opposite, for their game to find its way to large corporations and become a commercial hit that will bring them wealth. [7]. Therefore, a great number of video games was created as a capitalist product intended for certain target groups of users. The last decade has seen the creation of extremely complex games in terms of gameplay and high-quality audiovisual experience. The production costs of such video games are so high today that they often exceed the budgets for making Hollywood films, and any error in judgment and failure in the market can be fatal for the studio that markets the video game and lead to its shutdown. Therefore, creating video games is a very risky business. Potter states that only 3% of all games make a profit [8]. Experimentation with gameplay, aesthetics, and game mechanics is left to independent developers, while the industry follows established practices using tried and tested formulas, genres, and clichés. Therefore, profit and directing the user's desires to spend more, within the game itself, is a key factor for the video game industry. Industrially produced video games follow established rules in order to achieve commercial success with a large audience. Some of those rules are that the game must reward good players, be relatively easy to learn (even if they are complex it is not evident at the very beginning), be available on all platforms (from consoles and computers to smartphones), furthermore, the game must be predictable for the consumer and it must present a challenge (that after the start of the game, new levels of the game with an increasing challenge follow). If these rules are not respected in the production of a video game, it can easily become simple and players will quickly lose interest in it. However, it should be noted that the movement of indie developers represents an important experimental field of the industry because when a novelty in the world of independent games becomes popular, the industry appropriates it without exposing itself to risk [7].

Although it has been established that video games are created as a product of industry and have a manipulative side, they still satisfy man's need for play. The vast usage of video games among the human population has led to the fact that they are nowadays used for a wide variety of purposes, including as a means of training pupils or students. The frequent use of video games created a virtual space for the socialization of youth, formed groups of fans and specific subcultures. According to Maravić, video games today are much more than just a game [7]. They are real media and have the property of a technological device that

serves as a means of communication, they can convey meanings and be the environment within which communication takes place [7]. One specific area of human behavior has been heavily influenced by video games, and that is traditional sports to which esports has joined. Esports is the competitive playing of video games at a professional level. In other words, it is an organized type of sport where video games are played, in which players compete against each other, often for significant amounts of money and prizes [9]. Video games, as part of esports, are mostly played on computers, but also on consoles and mobile devices, and can be individual or team-based and usually involve professional players or teams, organized tournaments and large audiences. "Esports competitions are often held in large arenas and stadiums, with fans filling the seats to root for their favorite players and teams. Esports events have become increasingly popular in recent years, with many of the biggest tournaments and competitions taking place in large arenas and stadiums" [9]. These events can attract thousands of fans from all over the world, who gather to watch their favorite players and teams compete. Esports is a growing industry today that has attracted many players, fans and sponsors. Some of the most popular esports games are *League of Legends, Dota 2, Counter-Strike: Global Offensive, Fortnite and Overwatch*. Esports first became popular in East Asia, especially in China and South Korea, where professional games were licensed as early as the 2000s. However, esports has spread to other regions, such as Europe and America, where many gaming events are held and leagues have been established.

It should be said that there has been professionalization in this field of video games (as in traditional sports during the 20th century) and that esports is not only a form of entertainment, but also a potential career path for many players who aspire to become professionals. Esports players can earn funds from various sources, such as rewards, salaries, sponsorships, referrals and YouTube streaming. In addition to players, coaches, analysts, commentators, YouTubers and other professionals working in the industry can also make money from esports. Today, cable operators, in addition to traditional sports channels, also have specialized channels for the transmission of esports with an accompanying team of expert commentators. Esports can be a lifestyle choice and a professional orientation, including players, coaches, analysts, commentators and others working in the industry [9]. Today, there are dedicated esports leagues and organizations around the world, and many universities even offer esports scholarships to talented players [9].

The growing social importance of video games was recorded by the academic community, so in addition to media studies or film studies, special video game studies were formed. According to theoretician Mitrović, within the academic community "... video games are studied as a media phenomenon, a technical-technological phenomenon, a (pop) cultural artifact, and a narrative and dramaturgical practice that includes interactivity in the canonical models of creation, presentation and reception of story worlds. At the same time, other artistic practices involved in games (music, graphic design, performance) are studied, as well as anthropological, linguistic, psychological and sociological (from identity and gender studies to the recognition of addiction) and economic research and approaches" [10]. According to Mitrović, in the academic circles themselves, 2001 is considered the starting year of video game studies, because the first scientific international scientific conference on video games was held in Copenhagen in that year. Many believe that the development of criticism and theoretical reflection is the reason for the inclusion of film in universities and its classification as art, so that the same is necessary for video games. More and more higher education institutions are opening majors needed by the video game industry such as: concept character design, visual effects, programming, animation, video game design and game art. Additionally, outside of college, private schools are booming with courses that offer quick and cheap training for jobs in the growing gaming industry. Staff from these courses are

usually able to perform a fraction of the work in the industry or to work in one program standardized and templated work.

3. CONCLUSION – TENDENCIES IN THE GAMING INDUSTRY

Some of the latest trends in the industry include new cloud gaming technologies, the inclusion of augmented reality (AR) and virtual reality (VR) technologies, and the use of artificial intelligence (AI). Experts from the video game industry hope that in 2023 it will be possible to play video games in the cloud, because the technologies and services have reached the necessary level. Cloud gaming refers to video game streaming that allows players to play games on their devices over an online connection without the need to purchase new gaming hardware or install games locally, and can provide access to video games to players who are unwilling or unable to afford appropriate devices for the latest industry products. With this progress, the video game industry expects a significant increase in the number of players, as expensive hardware will no longer be an obstacle to entry into the world of video games. Also, VR and AR technologies have shown great potential because consumers are highly interested in them and the gaming industry will move in the direction of implementing these technologies in their products. The key difference between VR and AR games is the level of virtual world immersion and social interaction. VR gaming offers a more visually immersive experience that can transport us to different worlds, but at the same time isolates us from our surroundings. AR video gaming offers a broader social gaming experience that can enhance or alter reality, but also leads to limitations in the perception of reality. AI is widely used in the video game industry, however, over time, as it develops, more and more opportunities for its implementation arise. The application of AI in games is not only reflected in the creation of very realistic supporting characters in video games, but also in improving the user experience during gameplay. Finally, AI already participates significantly in the design and programming of entire video games, and over time its use and importance will increase.

Concluding the paper on the social impact of video games, we can state that all the mentioned trends suggest that video games have become one of the dominant forms of entertainment and earnings. The data indicate that both the number of players and the number of employees in the video game industry is growing, and that the forecast is that this growth will increase from year to year. At the beginning of the 21st century, the academic community began to give credibility to video games as a medium, a cultural phenomenon and an art form. Today, video games still do not have the same status as film or music, but things are changing in that field as well, so more and more art faculties are opening majors related to character design or some other aspect of video games. All of this development of video game influence takes place under the veil of capitalist production, and critical studies of video games never lose sight of the fact that gaming often functions as a supplement to capital. Critical academic studies must also deal with the negative aspects of video games such as the process of gamification in which game design principles are used to stimulate workers who in fact become the objects of the game. Although the gaming industry is a type of creative industry, it is nevertheless characterized by the characteristics of neoliberal capitalism, such as user control and direction, consumer values, cheap labor (outsourcing) and profit.

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ENVIRONMENT AND SUSTAINABLE DEVELOPMENT. MECHATRONICS.
OCCUPATIONAL SAFETY AND HEALTH AND FIRE SAFETY.
SMART MANAGEMENT SYSTEMS. GRAPHIC ENGINEERING. DESIGN.
TRAFFIC ENGINEERING. BIOTECHNOLOGY AND HEALTHCARE.
MECHANICAL ENGINEERING. ECOTOURISM AND RURAL DEVELOPMENT.

INTERDISCIPLINARYNESS OF SUSTAINABLE DESIGN

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Abstract: *Sustainable design in the fashion industry, with a focus on the footwear industry, implies new approaches in planning, design, engineering and production of the final product. It is no logner enough today, that a designer is exclusively occupied with the creative process. The designer is now expected to know special software packages that speed up the process of working out his conceptual solutions, construction models, networking into a complete production system. The designer must know new technologies of the production process itself, and all so that the design he creates is of a sustainable type. Those new technologies include additive manufacturing, which is already applied by well-known global fashion companies. By implementation of the disciplines of science and design, with specialized software to ensure the saving of time and materials, with the application of additive manufacturing technology, there are chances that the design we create today will protect our living environment, but also ensure its profitability.*
Keywords: Interdisciplinarity, CAD/CAM, Additive manufacturing, Sustainable design, Eco materials

1. INTRODUCTION

Interdisciplinarity in design should connect different aspects of the product, so that all its parameters are functional, profitable and harmless to our environment. In order to achieve such design solutions, it is necessary to move our thinking from just "beautiful creation" and to include in product design research based on consumer experiences (UX-user experience). Also, scientific experiences and new technologies, taking into account ergonomics, if necessary for that area of design, experiences from an economic point of view, in order to check the profitability of the production concept, but also experiences of environmental protection, based on analyzes of the biggest polluters. Introduction of the additive manufacturing process (known as 3D printing) in the footwear production, may be one of the solutions to improve the sustainability in this industry. This paper aims to indicate possible procedures that can be used to improve the approach to footwear design, in order to highlight aspects of sustainability and present examples of how additive manufacturing is used to footwear manufacturing, with a special emphasis on FDM (Fused Deposition Modeling) technology. The additive manufacturing, which is being developed every day, show great potential for future progress in the various branches of industry. The Aeronautics and Space industry, as well as the automotive and medical industries are the application of 3D printers for manufacturing products [1]. The concept of applying additive manufacturing also implies the use of materials that can be processed, recycled, reused with redesign or in a completely new design solution and used in subsequent production the so-called 6R concept - which implies (Reuse, Recycle, Redesign, Remanufacture, Reduce, Recover). Based on this approach for the product development, we are talking about the "circular production" model (CM-Circular Model), which has proven to be one of the good engineering solutions that should be considered for sustainable production. In such circular model, the design of the product, the used materials and production process, plays an essential role [2].

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2. DESIGNING THE PROTOTYPE

The development of footwear products begins with the creation of conceptual solutions, which can be prepared in one of the software programs specialized for designing and modeling footwear, but also in some other software with the possibility of exporting an STL file, which is further used to prepare the digital model for additive manufacturing [3]. The Shoemaster project is proved to be the most complete software package, in the footware production. The main advantages of using this program are increasing the efficiency of the designer's work, because softvare provides a possibility for easy change of conceptual solutions, providing the best solution, changing the design lines with the simulation of the materials that would be used. Through Shoemaster Patterns, the basic pattern is quickly and accurately created, which is necessary in classic production, while the production of the footwear with additive production, is guided only by a 3D model. Software programs ensure efficiency and infallibility in certain tasks related to engineering design, such as reducing the complexity of the design process in production, reducing the time spent on project preparation, reducing project work costs, as well as reducing costs related to all production operations.
When creating conceptual solutions for classical footwear production, it is impossible to perform complicated design solutions, while the creation of conceptual solutions with software is limited only by the designer's imagination [4]. German designer and architect Stefan Henrich designed and produced the "Cryptide" footwear model inspired by the feet of mythical creatures. The model was produced using selective laser sintering-SLS technology on a Sintratec S2 printer. (fig. 1)

Figure 1. Stephan Henrich, *Cryptide* (shoe), SLS technology
Source: https://urlis.net/edu3ee33

Existing shoe styles are completely different and the question is when the market will be ready for some radically different solutions. [5]. With the help of such software, it is possible to scan the foot, and record 3D data about the feet, from technologically advanced 3D foot scanners and achieved data can be imported into Shoemaster CAD systems, in order to make orthopedic footwear. Advanced CAD/CAM system for shoe development engineers, enables integrated control and optimization of all stages of the development process. Networking is also reflected in the fact that new design solutions can be easily obtained. Clearly, Shoemaster is a flexible 3D CAD system that allows creative designers to quickly develop new ideas and concepts.
It provides such design tools for building different solutions, experimenting with multiple ideas. What is also important is that this reduces the number of physical samples. Creating virtual prototypes, data for rapid prototyping and accurate transfer of design ideas to production, are essential for more efficient production. (fig. 2)

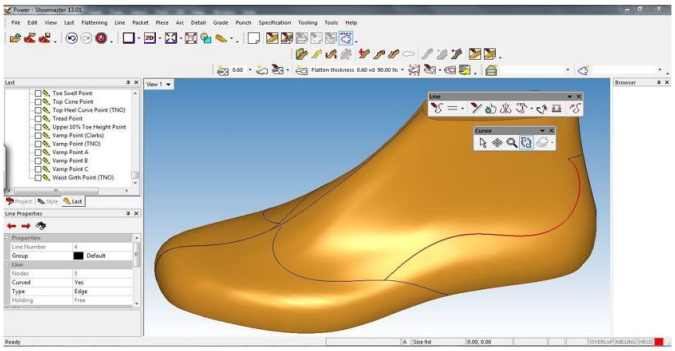

Figure 2. Designing footwear models, CAD/CAM, Shoemaster software
Source: original

Ensuring the improvement of the quality of the project infrastructure through the reduction of modeling costs, as well as faster production testing, is the goal of every small and large manufacturer. Acceleration of the production of duplicate models, designed in a fast and efficient way can be achieved today only by using software that is adapted to a specific production. In the footwear industry, it is necessary to classify every piece of leather into I, II, III class, and what is shocking in today's possibilities of technological progress, is that in many factories this is still entrusted to the experience of a worker. Certain companies have improved their production by using the Shoemaster software in this segment to avoid the error of the human factor, so that the scanner classifies the leather and the classification is entered into the database from which the information is further retrieved, so that a certain part of the upper assembly can be cut with a Cater machine from the required skin class. This reduces costs related to the production of knives used to cut parts. It is also possible to calculate the consumption of leather and synthetic materials, with different methodologies, to make the estimation of material procurement and production costs fast and efficient. It manages databases of materials and suppliers, and that database is simple and can be connected to the company's warehouse system. With this program, we can develop our own technical specifications, integrated with template engineering modules, to share technical information that is always updated. Shoemaster makes it possible to significantly reduce the time required for pattern output and input, as well as grading, which results in faster flow and increased production capacity. A flexible and fast 3D CAD data customization system allows shoes designed for the mass market to be quickly adapted to individual requirements. This system of production process has already been improved compared to classic production, because the software speeds up and specifies all the mentioned work operations, but thinking about the progress of this branch of industry, additive production would bring an even simpler and more precise way of production. Camper is a Spanish company that successfully makes footwear using additive manufacturing, especially Fused deposition modeling-FDM technology. The company uses printers with two extruders, in the production. (fig.3)

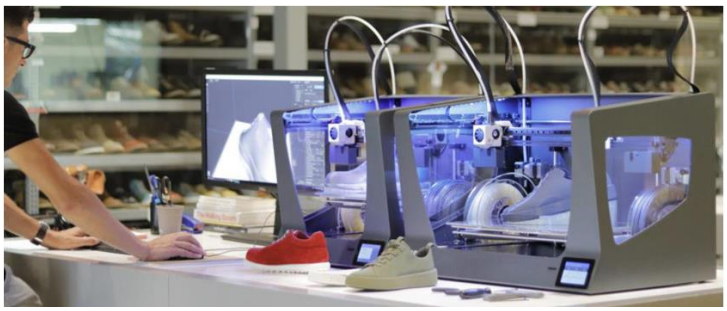

Figure 3. Additive manufacturing of footwear, Camper, Model from the 2019 collection
Source: Additive manufacturing of footwear, Camper, Model from the 2019 collection

Design for easy assembly and disassembly; Design for efficient joining and fastening; reduction of the number of shoe parts, increased flexibility of the model and connection between the parts of the model. Within footwear, parts and materials are standardized. Design solutions are mainly guided by modularity [6].

3. ADVANTAGES OF ADDITIVE PRODUCTION-CIRCULAR PRODUCTION

If we consider the concept of production from the point of view of circular production, additive technologies are the future. As already existing studies have shown, the circular design approach involves rethinking the design of the product, not only for its use, but also for the user environment [7]. All segments of the product manufacturing process are considered, where at the end of that journey there is the end of its life, and in this sense the reuse of the product is highlighted, facilitating its new insertion into a closed production loop and finally disassembly for improved recycling possibilities. An interdisciplinary approach to this problem can bring better and safer

solutions. According to data from 2019, a record year for the volume of footwear produced, 24.3 billion pairs or more than 65 million pairs of footwear were produced and sold per day [8]. The footwear industry is an important branch of industry, and the production of footwear itself is a demanding and complex process. As already mentioned in certain types of footwear, such as sports footwear, protective footwear or those produced for the needs of the military, they can consist of up to 60 or more individual parts including very demanding manual work that can have around 360 production steps. The traditional production approach is still very complex, machine-intensive for the production of footwear parts and assembly of the final product. In addition to certain software packages that can improve and speed up production, it is still a very financially demanding process overall. Consequently, footwear manufacturers are looking for new ways to optimize their production process [9]. Additive production is an alternative to classic production, which allows shoe manufacturers to simplify the production process of individual shoe components or the entire shoe assembly, all depending on the designer's idea [10]. Unfortunately, these approaches are still in their infancy and it is difficult to say whether the footwear industry is aware that additive manufacturing is a sure advance in this branch of the industry.

The advantages of additive manufacturing compared to the classic process can be seen in the following benefits:

- Less time and costs for developing a conceptual design solution
- Lower cost of setting up and improving prototypes and lower costs of tools used in industry
- Environmentally acceptable method of production because it emits less CO2 emissions
- Economically more affordable production of small batches
- Feasibility of complex design forms, without limitations of the designer's imagination
- Shorter product delivery time
- Complex products relatively easy to manufacture
- Flexibility of the production process - production at the request of special customer requirements
- Quick and efficient design change and production launch of a new model
- Less waste generated after production
- Rapid prototyping

The main steps to produce custom 3D printed footwear include: data collection, which can be done with the help of 3D foot scanning, anthropometric measurement based on anthropological data, creating a 3D model of the foot using 3D software such as a CAD program, further in the process involves 3D data analysis to ensure accuracy and precision of data, shoe design, calculation of projected material consumption, prototyping, simulation and testing and production. In this way, it is possible to produce shoes that are designed and optimized for orthopedic problems, but also high comfort shoes that provide absolute support properties for the individual consumer [11].

4. ADDITIVE PRODUCTION AS A SYSTEM FOR PRODUCTION OF SUSTAINABLE DESIGN

If the production system is considered as a circular process, and if we consider the possibility that material should be recycled in the footwear industry, it is sure that the additive production has numerous advantages compared to classic production. Within 3D printing, two production segments are separated. These are the assembly segment and the disassembly segment. These segments aim to reduce costs and improve reliability without changing product function, and are based on specific design principles. The system viewed in this way has significant potential for circular production, which reduces waste, energy consumption and production costs in small production scales [3]. It also facilitates reuse by creating parts in a modular design that facilitates their reuse and repair [12]. In addition, additive manufacturing enables the development of sustainable products, taking into account the principles of sustainable and circular development from the beginning of the design process. This can result in products that are more sustainable and can be easily recycled or reused at the end of their life [13]. Referring to research from 2020, it is estimated that 3D technologies can use up to 97% of the used material [14].

Additive production compared to traditional production has the following advantages:

- Efficiency of the material used: unlike traditional manufacturing, in additive manufacturing it is created only what is needed for the product with a minimal support structure. In the Aeronautics and Automotive industries, for example, additive manufacturing enables the production of lightweight products that provide weight savings and thus lower fuel consumption. Repairs to certain parts can be completed using 3D technology, which essentially extends the life cycle of the original part. Waste is reduced because fewer product replacements are required. Biodegradable materials are another way that additive manufacturing contributes to reducing environmental pollution.

Effectiveness of existing resources: refers to how streamlined 3D machines are in general. Because these machines have less need for auxiliary equipment than traditional machines, additive manufacturing requires fewer resources and has less energy needs. Also, because these auxiliary tools and equipment are not required for production, smaller manufacturers can make parts closer to customers, reducing transportation costs.

- Manufacturing flexibility: the ability to quickly switch between different products without expensive or time-consuming setup enables a more streamlined supply chain and cost-effective production runs that meet customer needs. [11].
- Inventory reduction: The ability to make products on demand reduces inventory. With additive manufacturing, it is possible to respond quickly to customer orders, it is not necessary to have large stocks of manufactured goods, and in this way, production has an effective effect.
- Waste reduction: Additive manufacturing contributes to material utilization almost entirely. In addition to the fact that materials can be recycled, no waste remains after additive manufacturing, which is not a situation in traditional manufacturing.

To date, 3D printing has primarily been used only for the production of specific parts of footwear, such as the sole, which is the layer of the underlying sole. The mechanical performance of the materials used varies from one to another and has very different applications. The area that can be further improved, is the area of the material wich can be used for the production of the shoes in additive manufacturing. Also, a good understanding of key process parameters is very important in the complete process, such as manufacturing orientation, printing speed and layer thickness, all of which affect the mechanical properties of the finished product [15], so research in this area is just emerging.

5. CONCLUSION

Today, interdisciplinarity is a prerequisite for economical, sustainable and environmentally friendly production in all branches of industry. Footwear production is also an area that has room for improvement, and the approach to include research and conclusions from different disciplines in the complete design of production leads to the complete progress of this area of the industry. Additive manufacturing can still be seen as a way of making products that is not used enough, justified or unjustified, but it is certain that 3D technologies allow designers to reach different solutions than traditional ones. Not only that, but that by using these technologies, both, designers and everyone else, in the chain of the production process has an awareness and responsibility towards the ecology, but also the sustainability of production in the footwear industry.

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ENVIRONMENT AND SUSTAINABLE DEVELOPMENT. MECHATRONICS. OCCUPATIONAL SAFETY AND HEALTH AND FIRE SAFETY. SMART MANAGEMENT SYSTEMS. GRAPHIC ENGINEERING. DESIGN. TRAFFIC ENGINEERING. BIOTECHNOLOGY AND HEALTHCARE. MECHANICAL ENGINEERING. ECOTOURISM AND RURAL DEVELOPMENT.

MOTIVATION FOR ENGLISH LANGUAGE LEARNING AMONG THE STUDENTS OF THE DESIGN STUDY PROGRAMS AT THE ACADEMY OF APPLIED TECHNICAL STUDIES BELGRADE

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***Abstract**: The need for knowledge of languages in the modern world is very noticeable today. Linguists who have studied the process of foreign language learning have come to the conclusion that motivation is one of the key factors in the process of learning, especially in the acquisition of a foreign language. The topic of this paper is the research of factors that influence the motivation for English language learning among students of the Design study programs at the Academy of Applied Technical Studies Belgrade, Belgrade Polytechnics, with the aim of improving the process of English language teaching within the Academy. Special attention is paid to the analysis of students' opinions on the reasons that motivate them to learn a foreign language, as well as on the factors that can influence the improvement of their motivation.*
Keywords: Motivation for Learning, Students, Design Study Programs, English Language

1. INTRODUCTION

Motivation is defined as a desire or need that moves a person to a certain activity. Anyone involved in education must think about the motivation of their students as one of the key aspects of its successful implementation. What is very important is that motivation cannot in any case be viewed as a unitary phenomenon whose level is simply high or low. Motivation is a complex psychological phenomenon that consists of different levels. If we want to improve the level of student motivation, we have to observe it from several different angles and act accordingly. The research of motivation itself is very complicated, like all psychological processes in general, because we must first understand it and take into account all the factors that influence it. One of the important factors that we must take into account is the fact that motivation is an individual matter, which largely depends on the personal level of development of students, whether it is the sociological aspect, the existence of obstacles, the proximity of the goal, the needs of students, their work habits, their routine, organization of time and other factors that greatly influence the formation of motivation to learn foreign languages [1], as well as its persistence over time.

2. TYPES OF MOTIVATION

The study of motivation as a psychological phenomenon can be very interesting and undoubtedly very useful. It is very important to find out the origin of motivation, because that way we can influence it. Also, we must monitor how it develops, whether it grows or weakens over time, whether it changes or is constant. If we have an insight into these aspects of motivation, we can use this knowledge to motivate students to learn a foreign language better and more efficiently. If we study the level of students' motivation, we must take into account their activities and observe the psychological processes that activate them, and the motives that drive them to those activities. Are

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these their inner desires, emotions, thoughts or needs to acquire new knowledge, or is their ambition driven by external factors? There is a constant tendency to view motivation as a concept that is unique and a constant effort of teachers and employers to simply raise the level, quantity and intensity of motivation among their employees or students. On the other hand, there are theorists who believe that there are different types of motivation, viewed from the aspect of its origin and outcomes. For example, there is a classification into intrinsic and extrinsic motivation [2], then the difference between motivation that is driven by the desire for knowledge and motivation that is aimed at the best possible academic result [3]. Also, there is motivation that is stimulated by achievement, as well as the one whose goal is to avoid failure [4]. For this reason, it is important to analyse the motives that drive students and approach the problem from the point of view that we see is most present among them and apply those methods that could give the best results.

In this paper, the authors will mostly deal with the difference between intrinsic and extrinsic motivation among the students of the design study programs at the Academy of Applied Technical Studies Belgrade and the strategies that can be used to improve the process of English language teaching within the Academy. The term intrinsic motivation refers to that aspect that includes psychological processes such as personal, internal needs, desires, attitudes, the need for advancement, curiosity, etc. Students who are motivated by this type of motivation learn a language because of their desire to improve and their need to learn is fueled by a sense of satisfaction from personal progress, regardless of the reactions of the environment. On the other hand, students who are motivated by extrinsic motivation are motivated by external factors. This type of motivation is separate from the actual activity that the student carries out and its goal in this case is to get a passing grade on the exam, a higher grade or avoid a certain type of punishment if the exam is not passed. Recent research has shown that extrinsic motivation that is stimulated by reward and not punishment to a certain extent enhances the level of intrinsic motivation [5]. However, if that reward is tangible, it can affect the reduction of the level of intrinsic motivation [6], so, in any case, intrinsic motivation, the kind of motivation that promotes the internal development and progress of students, should be nurtured.

3. RESEARCH

The research was conducted among the students of the design study programs at the Academy of Applied Technical Studies Belgrade. The survey was conducted in June 2021, online, anonymously, using the https://www.surveymonkey.com/ [7] tool. The survey consisted of ten questions and due to the restriction of the survey tool, forty students were able to participate in the research.

It was important for us to check whether the students are aware of the necessity of knowing the English language. All of the surveyed students answered positively to the question: *Do you think that knowledge of the English language is necessary for functioning in the modern world?* This implies that it is absolutely clear to them that functioning in contemporary world is virtually impossible without the English language. However, the response ratio was slightly different with question number two: *If you could choose, would English be your first choice as a foreign language that you would like to learn?* Even though majority of students chose English (72.50%), some for them opted for other languages (Table1). The reason for this might be the omnipresence of the English language or the growing market in non English speaking countries.

Table 1. Question Nº 2

Source: https://www.surveymonkey.com/

ANSWER CHOICES–	RESPONSES–	
Yes	72.50%	29
No	12.50%	5
Maybe	15.00%	6
TOTAL	40	

It was important for us to determine how many students had had the chance to learn the English language independently, in courses they took out of school context. Surprisingly, only 22.50% answered positively, while 77.50% said no. There are several possible reasons that could be the cause of this, apart from the lack of motivation. The lack of time needs to be taken into consideration, as well the financial aspect, since most of these courses aren't free.
The goal of question number 4 was to determine the level of motivation for independent language learning that includes various techniques and methods. *What is the most efficient method for effective English language learning?* Here we can see that the majority of students prefer learning the language independently but spontaneously, by watching movies or travelling, rather than taking classes (Table 2).

Table 2. Question Nº 4
Source: https://www.surveymonkey.com/

ANSWER CHOICES	RESPONSESSS	
Reading books in English language	7.50%	3
Taking English language classes	5.00%	2
Watching movies, TV shows, series etc. in English language	42.50%	17
Listening to music in English language	5.00%	2
Online communication in English language	12.50%	5
Travelling to English speaking countries	22.50%	9
Constant self improvement (writing down and learning new vocabulary, phrases etc.)	5.00%	2
TOTAL		**40**

When asked about the regularity of their attendance in courses English language 1 and English language 2, 37.50% students replied that they were regular in attending lectures, 37.50% attended the lectures, but not regularly, 15.00% attended lectures sometimes, and 10.00% didn't attend them at all. Question number 6 was: *Do you think that attending the lectures is beneficial for you*? It provided us with the following answers: 40.00% said yes, 10.00% said no, while 50.00% replied: up to a certain point. In the comment section they mostly appreciated the chance to communicate in English, but they also said that for those who are advanced learners it was beneficial up to a certain point. The next question was: *Do you think that the syllabus is compatible with the students' needs?* The students answered as follows: 32.50% said yes, 15.00% no, while 52.50% replied: up to a certain point. The reason for this can be found in the fact that students from several study programs attended the same course. When asked how they would describe their motivation in the period of learning the language in courses English language 1 and English language 2, the students provided us with the following answers (Table 3):

Table 3. Question Nº 8
Source: https://www.surveymonkey.com/

ANSWER CHOICES	RESPONSES	
I am motivated by the desire to learn as much as possible because that knowledge will be beneficial to me in the future	38.46%	15
I am motivated by the desire to learn as much as possible because I want to get the best possible grade on the exam	12.82%	5
I am motivated by the desire to pass the exam	48.72%	19
TOTAL		**39**

Unexpectedly, more than a half of students were driven by exam- related motivation, showing that a large proportion of students are extrinsically motivated.
The teacher, as a central figure in the process of English language teaching was also the subject of the survey. Questions 9 and 10 provided us with the following information (Tables 4 and 5):
Question 9: *Do you think that the teacher has motivated the students to attend lectures?*

Table 4. Question Nº 9
Source: https://www.surveymonkey.com/

ANSWER CHOICES	RESPONSES	
Yes	37.50%	15
No	17.50%	7
Up to a certain point	45.00%	18
TOTAL		**40**

And question 10: *Which of these strategies should the teacher employ in order to improve students' motivation?*

Table 5. Question Nº 10
Source: https://www.surveymonkey.com/

ANSWER CHOICES–	RESPONSES–	
The teacher should explain to the students the importance of knowing English language in the modern world	23.08%	9
The teacher should reward attendance by giving points	23.08%	9
The teacher should adapt the syllabus to the needs of the students	46.15%	18
The teacher should offer students the material for reading and additional practice	7.69%	3
TOTAL		**39**

4. CONCLUSION

Based on the information that the authors have gathered, it can be concluded that among the students of design study programs at the Academy of Applied Technical Studies Belgrade, a large proportion of students are aware of the necessity of knowing English language. However, the lack motivation for learning the language independently and the extrinsic motivation are present among more than a half of the total number of students. Their main goal is to pass the exam instead of gaining knowledge that they might find useful in future. Some of the strategies that could raise the level of motivation among the students might include some modifications in the teaching material and the introduction of certain teaching techniques that could develop a deep approach towards learning among students. All things considered, motivation is the key aspect of successful language learning and as such, it is necessary to implement all the available strategies to raise its level.

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ENVIRONMENT AND SUSTAINABLE DEVELOPMENT. MECHATRONICS. OCCUPATIONAL SAFETY AND HEALTH AND FIRE SAFETY. SMART MANAGEMENT SYSTEMS. GRAPHIC ENGINEERING. DESIGN. TRAFFIC ENGINEERING. BIOTECHNOLOGY AND HEALTHCARE. MECHANICAL ENGINEERING. ECOTOURISM AND RURAL DEVELOPMENT.

DOES FRANK LLOYD WRIGHT'S FALLINGWATER HOUSE REPRESENT A PRECURSOR TO SUSTAINABLE DESIGN?

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Abstract: *In this work, we analyze sustainable design on the example of Frank Lloyd Wright's Waterfall House project from the perspective of three critics. We use basic methods of structural-functional analysis and deduction, as well as the comparative method in the comparative research of the opinions of critics. The purpose of the research is to establish whether or not Frank Lloyd Wright's Fallingwater House is a forerunner of sustainable design and to explore to what extent critics' opinions on the subject overlap. In this work, the concepts of sustainable design and organic architecture are briefly presented, the character of Frank Lloyd Wright and his style of organic architecture are explored, the Fallingwater House project is analyzed, the opinions of three critics are analyzed and compared on the topic of sustainable design on the example of the Fallingwater House and it is established whether this project falls into the field of sustainable design.*
Keywords: Fallingwater, Frank Lloyd Wright, Organic architecture, Sustainable design, Green design

1. INTRODUCTION

Sustainable design and organic architecture represent similar, but not identical concepts in design that focus on the relationship between humans and nature. Frank Lloyd Wright is a pioneer of organic architecture, and his project Fallingwater is an example of this type of architecture in practice. The subject of the work is the analysis of sustainable design using the example of Frank Lloyd Wright's Fallingwater project from the perspective of three critics. The aim of the work is to establish whether Frank Lloyd Wright's Fallingwater represents a precursor to sustainable design or not, and to explore the extent to which the critics' opinions on this topic overlap. In the work, we employed basic methods of structural-functional analysis and deduction, as well as the comparative method.

2. SUSTAINABLE DESIGN AND ORGANIC ARCHITECTURE

Ecology from the second half of the 20th century experiences intense development, and in recent years, it constitutes one of the most expansive domains of contemporary theory. In order to prevent further degradation or provide space and time for the renewal of the natural environment, innovations are needed that contribute to reduction, elimination, conservation, and recycling of energy in all spheres, including design [1].
Sustainable design, or as it is otherwise called, eco-design or green design, represents an approach to design that takes into consideration the use of new materials and recycling of old ones, energy conservation in space, positioning of objects, as well as recycling of materials and spaces themselves [1]. All the aspects considered by sustainable design also relate to questions of sustainable architecture. Organic architecture, according to Slobodan Maldini, represents a "style of contemporary architecture that advocates for harmony between nature and humans through design integrated into the environment" [2]. The term "organic architecture" was first used by Frank Lloyd Wright as early as 1908 in the first of the articles "*In the Cause of Architecture*" that he wrote for the

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Architectural Record magazine. Wright offers an explanation of how a sense of the organic is essential for architects and how an understanding of the relationship between form and function, as well as the study of differentiation of forms, can best be derived directly from nature [3].

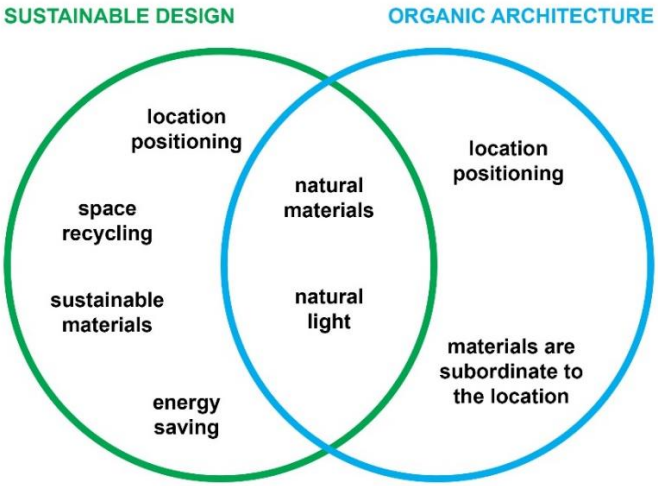

Figure 1. Chart of characteristics of sustainable design and organic architecture

From all the aforementioned, we can conclude that organic architecture shares much with sustainable design and that most of the principles belonging to organic architecture are sustainable. However, for some of them, being subordinate to the idea of unity with the environment, it's still a practical question whether they can be termed sustainable or not. We will explore this question through an example that represents the definition of organic design in practice – Frank Lloyd Wright's Fallingwater.

3. FRANK LLOYD WRIGHT AND FALLINGWATER PROJECT

Frank Lloyd Wright (1867-1959) represents one of the most prominent and influential architects of the 20th century. His works, according to the opinions of many art historians like Ljera, transcend the boundaries of a single architectural school or movement [4]. The style that Wright aimed for and is considered the inventor of is organic architecture. This architectural style presents a modern alternative to rationalism and is associated with establishing a direct connection with nature and the landscape in which the building is situated [4]. In addition to connecting humans with nature, Wright also followed the principle of his teacher Louis Sullivan that "form follows function," which was one of the slogans of the functionalist architecture of his time [5].

One of the best examples of Wright's architectural vision can be observed in his masterpiece, Fallingwater, designed and constructed between 1935 and 1939 during Wright's phase of full maturity. Fallingwater was built as a vacation home for the Kaufmann family above a valley surrounded by nature in a place called Bear Run in Pennsylvania, United States. The house was constructed on the cliffs above a waterfall and presents an entirely new vision of a home – integrated with its natural surroundings and displaying the house's openness to nature itself through terraces and cantilevered roofs [6].

Wright experimented with bold concrete platforms spanning three levels with cantilevered canopies, striving to achieve maximal physical and visual integration with the landscape. Among the materials utilized in the construction, stone and rocks found on the location were also incorporated. The chimney is positioned at the center of the grand hall, the main space of the house, from which the other rooms extend towards the exterior of the house [4]. The salon represents the largest room that occupies an entire floor of the house, except for a small kitchen for staff, and from it, the waterfall itself can be seen and heard. A concealed and narrow staircase connects it to the floor housing the bedrooms and small-sized bathrooms, unusually low-ceilinged, even as low as 195 cm in the lowest part, designed in such a way as to make the access to the terraces even more impressive. The entire house features extensive window surfaces to provide views of the surrounding nature [7].

Figure 2. Fallingwater exterior
Source: Fallingwater, https://fallingwater.org/what-is-fallingwater/

Even from the descriptions of the house's facade and its interior, we can observe how much attention Wright dedicated to the waterfall itself and its integration and permeation with each individual segment of the house. Every part of it was designed in a way that the observer could marvel at the waterfall and the surrounding nature.
Despite the harmony of the house with the surrounding nature, there are several conflicting opinions among critics regarding whether Fallingwater falls into the realm of sustainable design or not.

4. FALLINGWATER AS A PRECURSOR OF SUSTAINABLE DESIGN FROM THE CRITICS' PERSPECTIVE

4.1 Critics' perspective: Imnaculada Jiménez

Architect I. Jiménez considered Wright's works as a precursor to sustainable architecture [5]. In her essay "Frank Lloyd Wright: a Precursor of Sustainable Architecture," Jiménez wrote about Wright's pursuit of balance and harmony with nature, considering him one of the precursors of modern architecture. She noted that Wright applied principles of sustainable architecture even though he never explicitly mentioned them, attributing this to his upbringing in the natural environment on his uncle's farm. She referred to Wright's statement about how a person, the more connected to nature, increases their material and spiritual well-being, considering it an ideological principle that demonstrates Wright's inclination towards what we now call sustainable architecture. As evidence, she described his works as architecture rooted in the natural environment, in harmony with surroundings and people, a concept Wright himself defined as organic [5].
In Wright's interior design of the house, Jiménez draws our attention to the use of form, treatment of natural lighting, and the use of materials that were natural and never clashed with the environment of the house itself, as was the case with Fallingwater. She considers the design of this house as an enhancement of the environment it's situated in and describes it as an icon of the effort to connect humanity with nature [5]. From Jiménez's perspectives, we can arrive at an undeniable conclusion that Fallingwater truly serves as a splendid example of organic design. Wright's architecture and its principles were entirely aligned with nature and the environment in which he created his works. Additionally, the use of natural materials and the ample amount of daylight that Wright incorporated into his projects, including Fallingwater, are characteristics of today's sustainable design.

4.2 Critics' perspective: Order of engineers and architects (OEA)

The Lebanese magazine *Order of Engineers and Architects* drew our attention to Wright's view that architecture can transform the world and that architects should not be limited to designing "beautiful buildings." [8]. They convey their critical review of the exhibition "Frank Lloyd Wright – Organic Architecture of the 21st Century" organized by the Milwaukee Art Museum, in which speakers such as the director of the Frank Lloyd Wright Archives Bruce Brooks Pfieffer, the chief curator of the Milwaukee Art Museum Brady Roberts, and others aimed to present the argument that Wright's organic architecture foreshadowed today's enthusiasm for sustainability and green architecture. The critics of the "Order of Engineers and Architects" magazine agree that Wright respected nature throughout his life despite his modernist design, but they question whether and to what extent this

stance was related to his vision of organic design or merely his inclination towards natural materials rooted in his childhood in rural 19th-century Wisconsin. They also draw attention to the fact that Wright used reinforced concrete in his works, which certainly does not fall under natural and sustainable materials [8]. Based on the information provided by the critic of the "Order of Engineers and Architects" magazine, we can agree that Wright's concept of design and construction that takes into "consideration" the surrounding nature served as a good introduction to later sustainable design. However, due to details such as the use of concrete, it leaves us with an open question about whether his projects themselves, despite being organic, were truly sustainable.

4.3 Critics' perspective: Lloyd Alter

Lloyd Alter, an architect and a professor of Sustainable Design at Ryerson School of Interior Design in Canada, wrote an article for the magazine *Treehugger* discussing the contradictions in the sustainability of Frank Lloyd Wright's Fallingwater design [7]. Alter wrote how this house represents one of the most unsustainable ever built, a house that requires constant maintenance to combat moisture issues, which demands a significant investment of time and financial resources. Yet, paradoxically, it symbolizes the definition of green design due to its concept of the necessity of harmony between humans and nature [7].
The sheer size of the house, the fact that it was built as a vacation home rather than a permanent residence, and the information that it took four cars to transport the Kaufmann family and their staff to this wooded location all run counter to the principles of sustainable architecture. The extensive use of glass offered beautiful views of the surrounding landscape, but the heavy reliance on glass led to unusual junctions like the combination of glass and stone, which results in poor thermal insulation and contributes to higher energy consumption.

Figure 3. Representation of the Glass and Stone Junction on the Facade of Fallingwater House
Source: Fallingwater: A Contradiction in Sustainable Design, https://shorturl.at/nryLN

However, Wright integrated the house into nature by incorporating the surrounding rock formations into its interior and insisted on altering the shape of one of the main beams to accommodate a tree that was growing in that location, avoiding the need to cut it down. This decision reflects an environmentally conscious approach to construction. Another environmentally conscious choice was the use of cork tiles for the floors and walls of the bathrooms, a sustainable material.

Figure 4. Representation of the Beam 'Bypassing' the Tree at Fallingwater House
Source: Fallingwater: A Contradiction in Sustainable Design, https://shorturl.at/gpKOP

Alter doesn't come to a definitive conclusion about whether Fallingwater House is sustainable or not, but he highlights that it is undoubtedly an artistic masterpiece of exceptional importance due to the idea it conveys – the idea that humans should form a unity with nature [7]. From the perspectives presented by Alter, we can draw both "for" and "against" conclusions regarding the idea of Fallingwater House being sustainable. Undoubtedly, this house possesses numerous sustainable concepts within its design and execution, such as the use of local materials, ample daylight in the interior, and a construction approach that minimizes disruption to the surrounding nature.
However, the construction itself in a location like this—bringing machinery and workers to a waterfall in the forest—cannot be considered "beneficial" for the environment and thus contradicts sustainability principles. The emphasis on the view towards nature, extensive glass surfaces, and the house's position contribute to a high energy demand for heating and combating moisture. All of these factors are issues that could be addressed in today's context, but they still don't align with the idea of a sustainable design for this house.
All the contradictions highlighted by these three critics with varying perspectives leave us to draw our own conclusions about whether Fallingwater serves as a precursor to sustainable design or not.

5. CONCLUSION

Fallingwater by Frank Lloyd Wright undeniably stands as a masterpiece of organic architecture and embodies the essence of this style, emphasizing the harmony between humans and nature. Even Wright himself referred to this architectural approach as organic, a definition with which we wholeheartedly agree. By analyzing the opinions of critics about this project, we can come to the conclusion that this house, despite being categorized as organic architecture, still contains elements such as its location, dimensions, and maintenance methods that prevent it from aligning with the principles of contemporary sustainable design. Many of these elements could potentially be adapted to today's standards, but the house itself, as originally designed, cannot be deemed sustainable.
Furthermore, the Fallingwater house and the very idea of its construction in its intended location using materials found on-site undoubtedly represent one of the initial visions that prompted future designers and architects to think in the direction that led to the style of contemporary sustainable design. Although the house itself, by today's established criteria, may not be sustainable, it still serves as a precursor to the thinking that shaped the direction of sustainable design, and for that, we can be immensely grateful to Frank Lloyd Wright.

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CHILDREN WITHOUT PARENTAL CARE IN SOCIAL PROTECTION INSTITUTIONS – PARK OF SUPPORT DESIGN

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Abstract: *In this work, we analyze the problems that are most often faced by the marginalized group of children without parental care in social protection institutions. We use basic methods of structural-functional analysis and deduction. The purpose of the research is to identify the problems that most affect this marginalized group and to devise ways to alleviate these problems. Through the work, we analyze the concepts of marginalization and social exclusion, the working methods of social protection institutions for housing children without parental care, children in these institutions, and the problems they face. Also, we propose ways to address these issues. This research aims to offer a design of an interactive installation that would draw the attention of society to the difficulties of children in social care institutions and provide us with the opportunity to help them.*
Keywords: Children without parental care, Social protection institutions, Interactive installation, Product design, Swing

1. INTRODUCTION

Marginalization represents a situation in which groups of people are excluded from the dominant culture and power distribution of society, and social exclusion is one of its key characteristics. Children without parental care in social protection institutions represent a specific marginalized group. Residential placements for children without parental care have existed in our country since the end of the 19th century and have evolved and been regulated over time, but any form of assistance is still welcome to their beneficiaries. Many experts have conducted research on the various problems faced by children in such living conditions, and we wanted to highlight among them those that we can alleviate in some way.

Through the following work, we will explore the concepts of marginalization and social exclusion of children without parental care, residential institutions for their placement, as well as the problems they most commonly encounter. In this work, we employed basic methods of structural-functional analysis and deduction. The subject of this work is the issues faced by children without parental care in social protection institutions. The goal of this work is to identify the problems that have the most impact on this marginalized group and to devise ways in which these issues can be alleviated through design. Since we have identified three types of problems, we have also devised a design for three functional spatial elements that together form an interactive installation. By drawing society's attention to the problems of children without parental care, this installation contributes to their mitigation.

2. MARGINALIZATION AND SOCIAL EXCLUSION

Marginalization is a sociological term that describes a situation in which groups of people are excluded from the dominant culture and power distribution of society. It pertains to the differentiation of certain social groups from the values and accepted behavioral norms that are commonly acknowledged. It also refers to the fact that certain social groups possess obstructed, disabled, or

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limited life, human, or societal opportunities, rendering them excluded from social processes and relationships. Some consequences of marginalization include negative social labeling, the emergence of prejudice and stereotypes, as well as discrimination. All of these often contribute to the inadequacy of social services to meet the needs of marginalized segments [1].
Social exclusion is one of the key features of marginalization and refers to the exclusion of certain members of society from the mainstream social currents. There are various ways and levels of social exclusion, with the most recognizable being the "vicious circle" often observed between unemployment, poverty, and social isolation. Social exclusion greatly depends on which marginalized group the individuals belong to, and children without parental care, especially those placed in social protection institutions, are in a particularly vulnerable position [1].

3. CHILDREN WITHOUT PARENTAL CARE IN SOCIAL PROTECTION INSTITUTIONS

The first recorded instances of organized social care for children without parental care in the world date back to the late 19th century when a large number of children were left without one or both parents due to frequent wars and poor economic conditions. Since then, children in the territory of Serbia have been placed in extended family, foster, or adoptive families, as well as in homes for children established by various associations. Conditions within these homes have been gradually improving, more accommodation places have been opened, and various assistance programs for children have been developed. However, the number of available accommodation places remains insufficient compared to the needs, as well as the resources for their improvement, and unfortunately, the number of foster parents has not significantly increased [2].
According to data from the Republic Institute for Social Protection and the latest three population censuses, it can be confidently stated that the number of children in Serbia has been continuously decreasing year by year. In the period from 2011 to 2020, the number of children in Serbia decreased by 6.7%, reaching a total of 1,198,957 in 2020. However, the number of children in the social protection system is increasing, and over the past 10 years, it has increased by more than 15%. Data from the Republic Institute for Social Protection indicates that at the end of 2020, there were 5,837 children in institutional care (both residential and foster care). The good news is that the number of children in residential care has been decreasing in recent years, but the overall number of children in foster care placements is still increasing [3].
Children without parental care are placed in various types of care arrangements, including informal care by relatives, foster care, placement in shelters or residential care facilities. Adoption is also one more option. The number of adopted children in Serbia has varied over the past 10 years, but in 2020, there was a 50% decrease in the number of adopted children compared to 2014 [3].

4. PROBLEMS FACED BY CHILDREN WITHOUT PARENTAL CARE IN SOCIAL PROTECTION INSTITUTIONS

Research in developmental psychology shows that the absence of parental care places children at a high risk on existential, psycho-physical, social, and educational levels, especially at a younger age and if it has persisted for an extended period [4]. Vidanović's research focuses on the psycho-social issues of children in social protection institutions. In the mentioned studies, we come across data about problems that experts frequently identify as the most common issues among children without parental care in social protection institutions. For children up to 14 years of age, common problems include disinterest in school, aggressiveness towards other children, disregard for rules, academic underachievement, lack of social skills, depression, aggression towards property, a tendency for theft, loneliness, communication difficulties with staff, psychosomatic issues, and running away from the institution. Concerning children above 14 years of age, who are approaching their departure from the institution, the most common issue observed is the presence of fear regarding the future and fear of the social environment, which arise as consequences of prolonged institutional stay. Although

residential facilities are not entirely closed environments, extended stays in them can induce a certain form of social isolation. Coupled with other negative experiences outside the institution such as stigmatization and encountering prejudices, this can lead to pronounced fears about entering the social environment and beginning independence, along with a lack of self-trust and low self-esteem [4].
The care of children in institutions is provided by caregivers, educators, and psychologists. However, we come to the conclusion that, in order to reduce social exclusion, education is needed not only for the children in residential care but also for the rest of society. This can be achieved through various programs that familiarize the broader society with the issues faced by this marginalized group and the potential ways to mitigate those issues. Through previous research, we have identified three distinct sets of problems that society could significantly influence.

5. PROPOSAL FOR ALLEVIATING SOME OF THE PROBLEMS FACED BY CHILDREN WITHOUT PARENTAL CARE IN SOCIAL PROTECTION INSTITUTIONS

5.1 Gathering Support through Donations

The first and simplest way to help would be to gather donations in the form of money, clothing, shoes, school supplies, children's furniture, toys, and all other material items that could be useful. Donations of this kind are common in practice, but as long as there is a need, they should be promoted and expedited in various ways. Besides items like clothing, shoes, toys, etc., for which the donation process is fairly well-known, the idea of people coming up with their own ways to help should also be promoted. For instance, if someone owns a paint shop, they could offer to repaint the rooms where the children sleep in the nearest home, or if someone has a child who has outgrown their stroller, they could donate it, and so on. There are many examples, but the main idea is for each individual to determine what they could personally do and to what extent.

5.2 Encouraging Foster Care and Adoption

Another way of assistance that we have identified as necessary is encouraging people to establish foster families and adopt children, in order to reduce the pressure on institutions and provide more children with families. It's often the case that people are not well-informed about the ways they can become foster parents, or they perceive adoption as a lengthy and nearly impossible process, so they don't consider it even if they cannot have children in other ways. Therefore, we have concluded that these methods of caring for children should be promoted by providing clear explanations about entering the foster care or adoption process.

5.3 Encouraging Social Integration

Encouraging the integration of children without parental care in social protection institutions into society represents a third crucial issue that we can address. Just as education is provided to these children within the institutions, our goal would be to educate society about children without parental care in a way that accelerates their inclusion. Some of the ways that could aid their integration include organizing workshops for life skills, finding employment opportunities for children aged 16 and above who are within the institutions, and securing accommodation options after they leave the system. For instance, someone who runs a private math or language school could reserve a few free spots for children from the institutions. Business owners of any kind could involve children aged 16 and above in their work, such as in artisan shops, hospitality establishments, agricultural enterprises, and more. They could set aside positions for them. Similarly, those who own hotels or other types of accommodations could allocate a few accessible rooms for temporary stay for these children after they leave the institutions, or even employ them, allowing them to pay for accommodation.

Additionally, addressing the language used to differentiate children without parental care from those with parental care is crucial. Using expressions that emphasize their positive aspects, such as "parent" instead of "adoptive parent" and "child placed for adoption" instead of "unwanted child," could help shift the societal perspective towards these children. By implementing these measures, we can contribute to a more inclusive and supportive environment for children without parental care, reducing the challenges they face in their journey to social integration [5].

6. DESIGN OF THE INTERACTIVE INSTALLATION "PARK OF SUPPORT"

We have presented all the problem groups mentioned in the previous chapter through an interactive installation called the "Park of Support." This installation would consist of three parts: a seesaw, a swing, and a tunnel. Together, these three elements would create a playground with the goal of drawing attention to children without parental care in social protection institutions, their issues, and what society could do to help them. Each of the three furniture pieces would have QR codes, which, in today's age where almost everyone carries a mobile phone, would direct us to ways in which we could assist this marginalized group. Within the playground area, there would be a specially designed board with descriptions of each individual element and explanations of how to scan the QR codes located on them.
This installation is designed to be easily set up at any location that receives a significant number of visitors throughout the day – such as parks, promenades, and more. The objective is to catch the attention of as many passersby as possible who could potentially offer their assistance to children without parental care in social protection institutions.

Figure 1. 3D representation of the "Park of Support"

Figure 2 and 3. Photomontages of the "Park of Support"

6.1 Seesaw - Gathering Support through Donations

The seesaw symbolically represents the idea that while someone is "up," someone else is "down," creating an association that those who have "more" can donate and thus help those in a more challenging position. Besides serving as a playful element for two children to rock back and forth,

additional rocking could occur in the central section, even with just one child, despite no one sitting on the seats. QR codes would also be placed in the central section, leading to links upon scanning, offering suggestions for necessary assistance in the form of donations to the facilities at that moment. The QR codes would also provide phone numbers of the facilities and addresses of homes and warehouses where intended donations could be delivered.
The construction of the seesaw is envisioned as a whole structure made of 5 steel tubes with a rustic finish, symbolizing the solidity and "weight" of the situation in which children without parental care in social protection institutions find themselves. The chosen material slightly resembles the bars that remind us of their confinement, but their form from the frontal side suggests their smiles, which we could evoke with our help. The seats are designed in a simple form, made of oak, coated with transparent varnish to showcase all the virtues and flaws of the material. This wood was selected as it's difficult to bend and "stubborn," yet firm and beautiful with all the natural patterns it possesses. Similarly, the lower part of the seesaw features slats made from the same material, serving as an additional play element and hosting QR codes leading to links with phone numbers of the facilities and addresses of homes and warehouses for donations upon scanning. The backrest is consciously not included to portray the "discomfort" of these children's lives. Instead, there's only a 6-millimeter diameter thin steel rod in the front part of the seat, forcing us to struggle to hold on.

6.2 Swing - Encouraging Foster Care and Adoption

Swinging is a state that recalls a mother's soothing and calming embrace, which is why we chose this piece of furniture. The shape of the swing and its widening from the ends to the center is designed to evoke a hug. The form in which the swing would be located represents a simplified house shape, a home that is denied to these children but could perhaps be offered by us. Another reason for choosing the "house" shape is that as a person swings with a certain momentum, they have a "house in sight," only to lose it from view, which can be likened to the search of these children for a home.
The house shape is envisioned from solid wood with a square cross-section of 100 x 100 millimeters, symbolizing both a home and stability. In contrast to the "warm home," the swing is designed with "cold" steel pipes with a rustic finish, bent into full circles that would connect to each other through welding. These connections wouldn't be concealed; instead, they would intentionally be left visible, depicting both "separation" and "connection." The swing's seat would consist of oak slats, separated from each other to prevent water retention, and coated with transparent lacquer. The swing's seat, shaped like a house structure, would be connected using only one rope with a diameter of 30 millimeters, seemingly thin and fragile, as if unable to bear the weight of the situation, yet managing to do so. On the side panels of the wooden house-shaped structure, QR codes would be placed, leading to links with stories of successful foster parents and adoptive families, answers to frequently asked questions, and contact numbers of relevant services for further inquiries.

6.3 Tunnel - Encouraging Social Integration

The designed tunnel would serve several purposes: as a play element, an understanding of the magnitude of difficulties and injustices these children face, suggestions on how we can help them, and an educational aspect aimed at reducing their discrimination.
The tunnel itself is envisioned as a set of 7 frames in a simplified house shape, the same ones that we imagined as the supports for the swings. This would visually connect these parts of the installation. Each of the 7 frames would have a steel bar hanging on ropes of different lengths, creating an element of "play" where one needs to reach from one end of the tunnel to the other without falling, with the added challenge that the bars are at different heights. The entire game is intentionally designed to be difficult to perform, symbolizing the challenging path these children in care facilities face - their journey is tough and full of setbacks, but we could make it easier for them. The choice of the "house" shape for the frames also reflects the frequent changes of foster families that many children without parental care experience. Just like in the previous examples, the frames are designed from solid wood

with a cross-section of 100 x 100 millimeters, and the ropes would support steel rings with a cross-section of 10 millimeters. The frames would be interconnected by steel pipes, similar to those used in creating the seesaw and swing.
In addition to the game, the tunnel would also serve an educational purpose. Each of the 7 frames on one outer side would have a QR code that, when scanned, would lead to links containing suggestions on how someone could help integrate children without parental care into society, questionnaires that passersby could fill out about the assistance they could offer, as well as phone numbers of individuals to whom they could ask questions, express their interests, and provide suggestions. On the other outer side of each frame, there would be an example of a crossed-out "negative" expression commonly used in society to refer to children without parental care, paired with a "positive" expression that should replace it. Some examples we used include: adopted child = child; rejected child = child given for adoption; adoptive parent = parent and biological parent = real parent. Adopting a "positive" language is just one way to decrease discrimination against this group of children.

Figure 4, 5 and 6. 3D representation of Seesaw, Swing and Tunnel

7. CONCLUSION

After analyzing the research of experts regarding the issues faced by children without parental care in social protection institutions, we have identified three groups of problems that we could help alleviate by drawing attention to them through design. For each group of problems, we have envisioned conceptual solutions in the form of distinct elements. Together, they constitute an interactive installation that would draw attention to the existence of this marginalized group, the common challenges they encounter, and possible ways to mitigate these problems.
The complete installation, along with the proposed ways to mitigate the problems it would offer, would leave room for each passerby to independently think and determine what they personally could do and to what extent to help alleviate the challenges faced by children without parental care in social protection institutions.

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ANALYSIS OF THE SPATIAL ORGANIZATION OF A MODERN APARTMENT IN BELGRADE, CASE STUDY NEW DORCOL

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Abstract: *This paper deals with the analysis of residential construction in Belgrade today, with a special focus on the organization of the apartment and interior design. Today's moment is characterized by the "importation" of architecture, the interference of investors in the work of architects, and the fact that architecture is seen first and foremost through the prism of economic profitability and profitability. In Belgrade, in 2020, building permits were issued for over seven hundred thousand square meters of space, which, along with the fact that there are around two thousand active construction sites on the territory of the city, indicates the existence of extremely intensive construction activity. The subject of research in this paper are different types of organization of apartments in New Dorcol project, which speak about the daily life of the population of Belgrade.*
Keywords: Interior architecture, contemporary interior design, apartment typology, housing

1. INTRODUCTION

Architect Ivan Zdravković's words testify to the actions of architects, which must necessarily be in accordance with the moment in which they create, that when creating a house, a person strives to meet new standards and requirements, in terms of technical, aesthetic and health aspects, and that in this sense, the house should meets the requirements of durability, stability and comfort. Zdravković points out: "Architecture is the art that people come into contact with most often. Man lives in architecture, moves in it and thinks about it the most. The house is his main concern" [1].
When we talk about the overall architectural activity in Belgrade today - a true description would be extremely fruitful. Contemporary construction is characterized by the "consolidation" of projects, the construction of complexes and entire neighborhoods, such as K District, Central Garden, Belgrade Waterfront and many others. Large projects provide apartment buyers with additional facilities, and investors with more capital, and the opportunity to implement quality materials and achieve quality construction in relation to a large number of positions. Every society and epoch has an example of a typical apartment, and typical examples of spatial organization can be used to see the daily life of the middle and upper class of Belgraders today [2].
Regarding residential architecture as a reflection of the state of society, we can refer to Grlić's words: "That's why it (architecture) should not only be a picture or a reflection of the existing, but - and this already exceeds the limits of aesthetics - carried by a vision of the future and open to it. No one doubts that even then one day it will become obsolete and remain only a more or less successful document of the past. And yet, from that creativity, it will be seen how much that time, country, people, looked forward, how much it could bear to be now already in the future, and how much it was only tied to already defined tradition and built exclusively on the foundations of the known and of the existing, average and generally accepted aesthetic standard" [3].

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2. FLOORPLANS: CASE STUDY NEW DORĆOL

The Novi Dorćol complex, a residential and commercial area of approximately 100,000 m2, built on a plot of 2 ha in the Municipality of Stari Grad, in Venizelosova Street, was selected for analysis in this paper. The complex includes housing, business premises, as well as other facilities, such as a spa center, kindergarten, catering facilities, shopping facilities, green areas intended for rest and recreation. Residential units are structurally divided into square meters of different sizes, from one-room to five-room apartments [4]. The apartments are characterized by modern construction, a selection of quality materials, as well as a high level of finishing, with a special focus on energy efficiency. For the purposes of this work, one typical example of a one-room to five-room apartment was analyzed.

2.1 Studio Apartment: Spatial organization

The analyzed Studio apartment has an entrance area slightly larger than the average (6.12 m2), and includes a space for a shallow wardrobe on one side, as well as space for a washing machine on the other side, which significantly contributes to functionality in an apartment of modest size. From the corridor you enter the space, which doubles as a living room and bedroom (22.05m2), and includes an open kitchen (5.45m2). The bathroom is small, equipped with a shower cabin (4.62m2). The total area of the apartment is 39.01m2 [4].

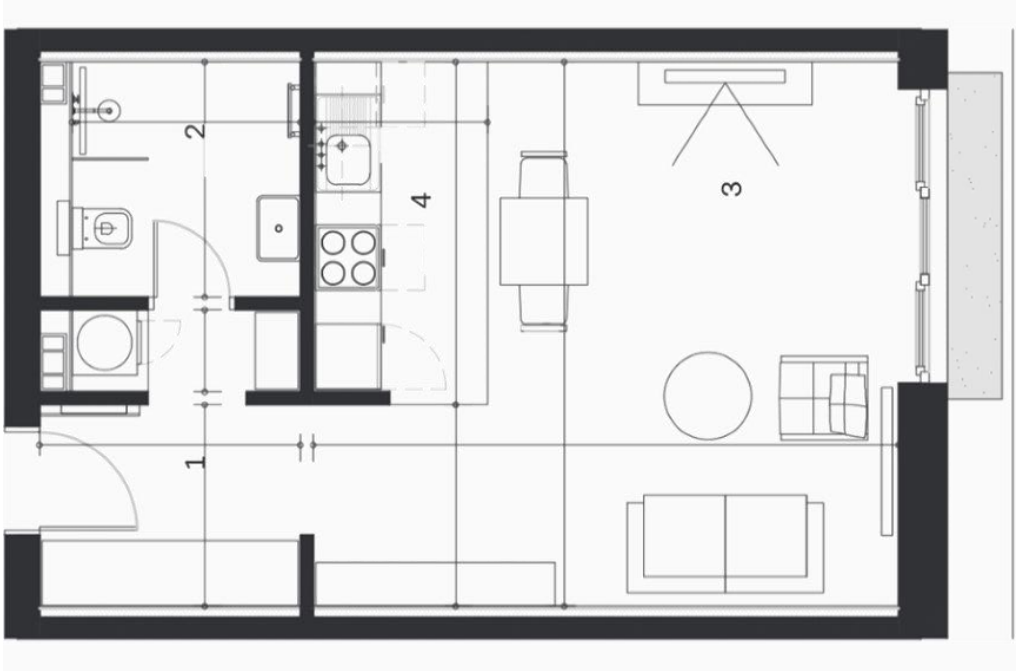

Figure 1. Floorplan: Studio apartment
Source: Novi Dorcol company site

2.2 One bedroom apartment: Spatial organization

The One bedroom apartment has an entrance area slightly larger than the average (7.9m2), which includes space for a shallow wardrobe as well as space for a washing machine and furniture storage. From the corridor you enter the living room, including open dining area (21.59m2), which represents the standard form of space organization. Also, the kitchen (5.76 m2) is part of the same space, and is not separated by a wall or any other type of visual partition. The bedroom has modest dimensions (12.43 m2), with one window, and a place for closets. The bathroom is very small, equipped with a shower cabin (4.02m2). The terrace is a significant addition to the living space, given the fact it is among frequent requests of buyers of apartments of modest size. (6.94m2). The total area of the apartment is 58.64m2 [4].

Figure 2. Floorplan: One bedroom apartment
Source: Novi Dorcol company site

2.3 Two bedroom apartment: Spatial organization

The Two bedroom apartment occupies a total area of 82.25 m2, which makes it average for the given typology. Although the entrance hall has an area of 10.68 m2, it is not a separate space, but is completely connected to the living room. Almost the same organization of the living room, integrated dining room and open kitchen that we had the opportunity to see in the example of the One bedroom apartment is also applied in the Two bedroom apartment, with very similar surfaces. (living room and dining room 22.94m2, kitchen 5.67m2). The living room opens onto a terrace of 8.28m2, and the apartment also has two balconies. From the entrance hall there is access to the shared bathroom, which also functions as a guest toilet (4.06m2). The sleeping area is separate and consists of a smaller room, usually a children's room (9.46m2), and a master bedroom (24m2), which has a wardrobe and an en suite bathroom (4.06m2) [4].

Figure 3. Floorplan: Two bedroom apartment
Source: Novi Dorcol company site

2.4 Three bedroom apartment: Spatial organization

The three bedroom apartment suitable for a family with two children has an entrance area of 9.41 m2 with built-in closets, which leads to the central area of the apartment. The kitchen is open, more comfortable than in apartments of smaller square footage, separated from the rest of the apartment by a light partition in the form of a counter (8.11m2). The living room (27.44 m2), with the adjoining dining room, has an exit to one terrace, while the other is accessed from the larger children's room,

and they occupy a total of 15.70 m2. The sleeping block is divided into two zones. The first consists of the parents' bedroom (15.06m2), with an attached bathroom (3.24m2), while the second includes two bedrooms of 12.57m2 and 15.52m2, next to which there is also a service (laundry room and storage area of 2.50m2), a guest toilet (2.04m2), as well as a children's bathroom (5.98m2). What distinguishes this apartment in terms of spatial comfort from others that we meet on the market today is the well-thought-out division of the bedrooms and the centrally placed living room with accompanying facilities. The total area of the apartment is 117.57m2 [4].

Image 3. Floorplan: Three bedroom apartment
Source: Novi Dorcol company site

2.5 Penthouse: Spatial organization

Penthouse as an apartment typology in Belgrade is somewhat newer, and represents a more formal than actual organization. It goes without saying that these are apartments of a larger area, on the last floors of buildings, however, they are not characterized by a significantly higher height, spatial comfort, or particularly luxurious equipment. The analyzed apartment occupies an area of 171.95 m2, of which the entrance and corridor are almost 21.82 m2, without any additional contents. The kitchen of 6.12 m2 is, unlike the other analyzed types of apartments in the complex, separate from the living room, which, on the other hand, just like in the other apartments, includes a space for leisure and a dining room (43.84 m2). In the bedrooms, an organization similar to that in the smaller apartments has been applied, the master's bedroom (19.92 m2) has an en suite bathroom, while the three children's bedrooms are of modest dimensions and are 14.55m2, 13.05m2 and 10.27m2. The apartment also includes a toilet for guests (3.12m2) and another bathroom intended for tenants (6.33m2) [4].

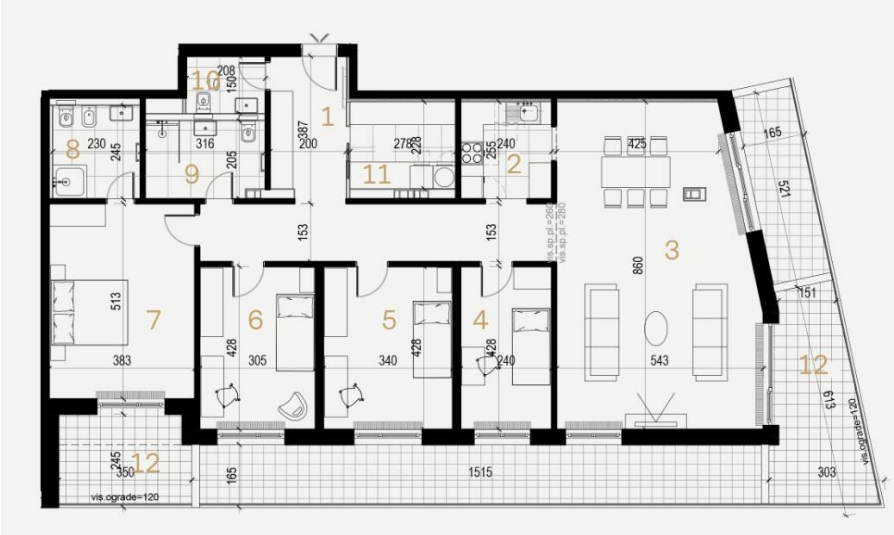

Figure 3. Floorplan: Penthouse
Source: Novi Dorcol company site

We can conclude that designers apply the following rules when designing apartments: the entrance hallway usually includes built-in closets for storage, the kitchen is open to the living room (except in the five-room apartment), which also includes the dining room. If there are several bedrooms, the largest room in the apartment has its own bathroom, while the other tenants use their own bathroom, which sometimes has a guest toilet. Apartment buyers value terraces, and almost every apartment includes them in some form and area. The apartments are simple, understandable to customers, but without any specifics, both in terms of design and organization. Grlić, although he supports the position that we should turn to modern architecture and meaningful interventions, asks the following question:
"as much as modern forms often have extraordinary, and if you want new poetic qualities, you should still not completely ignore the danger that contemporary simple lines and menacing gigantic masses can sometimes lock us in solid concrete boxes so that we will no longer be able to rest our eyes anywhere on one unforeseen detail and tear apart the iron logical and rational edifices that do not own property, capture the free flight of independent search and the possibility of individual, and that means human, human life. Will we not become constantly and against our will surrounded by those uniform silhouettes and become more and more one-dimensional people ourselves, reduced to one mold of feeling, thinking, breathing, will we not harmonize our hopes, desires and imaginations with that modern simplicity of lines and dismiss them contemptuously, as banal and pseudo-humanistic, and the questions themselves, where is the human being lost in this technical perfection?" [3].

3. CONCLUSION

Analyzing the examples, we came to the conclusion that modernization is visible in many fields, but particularly in residential architecture. This work showed that the basic principles in the construction of residential units today are constructivity, functionality and economy, which is in full accordance with the time in which the development of economy and technology is accelerated. Architecture is marked by a paradox - although an architectural work can be modern and advanced at a certain moment, in accordance with the aspirations and needs of man, it inevitably becomes obsolete, because it remains fixed at the moment of its creation, while man is constantly changing, and with him, his needs. It remains with us, and that architecture is a testimony of a certan time, of habits and wishes of the people who lived at the time of its creation.

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DESIGN TO THE MEASURE OF MARKETING

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Abstract: *In the 1970s, corporations began to understand the importance of market research and marketing. Changing policies of companies that turned to marketing allowed consumerist design to evolve. The design has been assimilated into a consumerist society dominated by a market economy based on marketing. In this paper, it will be shown how marketing played a key role in developing the ideology of consumerist design, and how marketing design was created. "Marketing design" certainly could not function without an author/designer. The author is an ideological product, an ideological figure who is actually a symbol and apparatus of marketing design. Also, one example of author will be analysed, the one who creates by marketing design rules and who is available to corporations in order to turn the dream of marketing into reality will be presented.*
Keywords: design, author, marketing, ideology, consumerism.

1. INTRODUCTION

During the seventies of the 20th century, like never before, there was a huge effort by the capitalist world to achieve complete control over the market by imposing specific policies and standards of behaviour. It was about achieving control and exerting great influence in the production and development of public opinion, by creating a new taste and unilaterally monopolizing the evolution of culture. In this sense, the role of design was by no means negligible. In the 1970s, corporations began to understand the importance of market research and the scope of the marketing approach. Changing policies of companies that turned to marketing allowed consumerist design to evolve. In further development, design has become a kind of hyperspace that acts transgressively and spectacularly on consumers. In the eighties, nineties and 2000s, design moved toward the field of branding.

Along with informatics, tourism and the entertainment industry, design has filled the world of global consumption to the limit. Its character began to correspond to the global distribution and regulation of capital. Consumerist design evolved into the so-called "brand style". Brand style is a design procedure in which a certain design with all its characteristics refers to itself. New products that are created as a result of this procedure are recognized on the search engine as families or families of designer products. Such products have a clearly defined target group and are linked to a specific brand whose name is followed by a typical appearance.

As far as postmodernism is concerned, in the 1970s it spawned new revolutionary ideologies in design, primarily due to the practical and theoretical breakdown of the modern movement. However, due to the character of the postmodern style, the design has been assimilated into a consumerist society dominated by a market economy based on marketing. In other words, design has proven to be a good ally of the spectacle society.

2. DESIGN ACCORDING TO MARKETING

According to Almeric De Angelis, the 1970s in the world of design dictated the production of a soothing climate [1]. This is conditioned by the aspiration towards a society in which less and less

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space is provided for individual initiative, and in which many responsibilities and concerns of the individual are taken away and redirected to certain centers of power. In such a system, with the help of communication techniques, advertising and self-promotion, a market dynamic is created that sustains itself with products that are not a reflection of individual needs but rather an expression of imposed desires. Dorfles wrote about the potential of advertising and self-advertising value of design, who concluded that a typical design tends to simultaneously advertise itself through the product and the product through itself [2]. This meant that the design possesses the aspect of *representational symbolism*, i.e. a symbolic element that has the ability to emphasize the characteristics that determine makes the item interesting and attractive to the consumer. It is precisely for this reason necessary that a certain design object is often subjected to a renewal process.

The way marketing played a key role in developing the ideology of consumerist design was explained by Nigel Whiteley [3]. Whiteley offered a framework for understanding the relationship between marketing and design, as well as the influence of marketing on the evolution of consumerist design by clarifying the phenomenon of creating desires, lifestyles, internationalization of design through mass media, then even greater acceleration of product development, two-dimensionality, obedience and loyalty of consumerist design to companies. Consumer design from then until its next evolutionary phase correspond to the measure of marketing.

This *tectonic change* is basically a version of the culture industry [4] that was critically analysed by Adorno and Horkheimer. The term *culture industry* refers to the similarity between popular entertainment and mass production. Adorno and Horkheimer warned that the production of cultural objects could be distributed like any other object in a capitalist society. Those objects were consumed on the mass market, which is passive because of its uncritical taste and way of accepting cultural goods. In this way, the audience is led to believe that the quality of consumed items is a reflection of the successful functioning of the state and its political economy.

Having recognized the importance of marketing in business, companies during the seventies and eighties, in the context of political events, accepted the ideas of marketing. Over the years, companies have not only changed their appearance and outlook, but also their overall business policy and organizational culture. For examples of such companies, Whiteley points out and follows the development of Sony, Philips, Ford, John Deere and Baker Perkins, which enthusiastically accepted new trends.

By studying trends in the context of lifestyle, the company was able to predict consumer desires even before consumers had any idea that they would want a new product. This influenced the development of commercial skills of companies, but also the importance of the role and evolution of *consumerist design* in that new system of gaining power and control in the market. These tendencies were also encouraged by political factors, as stated by Whiteley [3]. Thus, the creation of new desires, as opposed to satisfying the real needs of consumers, became the predominant development direction of consumerist design during the eighties.

In the 1980s, consumerist design ensured that lifestyle was a greater determinant of taste than any national or regional characteristic. The internationalization of culture through the mass media and the increase in the growth of trade in old and new markets on a global scale led to the development of companies. Technological development has made communication, transportation and travel accessible to the impoverished masses. This kind of connection has made the seductive appeal of designer products accessible to almost everyone. In this sense, the aesthetics of the product is now the predominant tool in attracting consumers.

The idea that design is a means of stimulating consumption was also put forward by Guy Julier, but supplementing it with the view that the idea of consumption is in fact a means of pacification, coercion and manipulation of the masses. Of course, these statements have their roots in the positions taken by members of the Frankfurt School, more precisely Adorno and Horkheimer. Julier saw the concept of modern consumer within neoliberal conservative ideologies [5].

Whiteley showed how consumerist design did not arise spontaneously from entrepreneurial culture, but developed as an inevitable consequence of capitalist society and market economy. Consumer design has evolved, i.e. made a shift and developed its skills in the direction of satisfying desires.

This type of design has become the prevailing cultural and social norm with values that are largely more implicit than explicit. It is a design in which the consumer is not the driving force but marketing is. Whiteley states that the *consumerist design* that has now evolved into *design by marketing*, or marketing design, offered no socio-political vision. The problems that were evident at the time, poverty in the midst of wealth, problems of minority groups, class divisions, low incomes, were not the subject of marketing design. This design does not need to deal with these kinds of problems because there is no profit in it.

Relying on research from corporations, Whiteley states that marketable designers are completely freed from their relationship with society:

To a large extent, designers are not shy about choosing sides. Conversations with designers from consulting firms and reader letters sections in design magazines are full of unrestrained and thoughtless ideological statements about design and its role in society. The common argument of designers is that the interests of their clients and the interests of the client's clients are identical: a successful product or service satisfies the customer who buys it, which in turn satisfies the company because thanks to it remains profitable [3].

Whiteley explains such attitudes by saying that asking designers in accordance with marketing, asking coherent questions can harm in a financial sense, and that they consider such issues extremely political and ideological. The opposite argument would be that the design of modernism is a failed project and that a system in which design is the handmaiden of capitalism defeats all other alternatives. Every object designed for marketing is part of a system, which has a certain appeal, but is also destructive for the environment and leads to social divisions.

3. KARIM RASHID AND THE IDEOLOGIES OF MODERN DESIGN

Marketing design certainly could not function without an author, that is a designer. The author is an ideological product, that is, an ideological figure who is actually a symbol of a certain discourse. The author does not represent only one element in the system, he plays a certain role in determining current topics and classifying quality. The author, therefore, enables the design to be defined, unified, to separate the elements from each other, that is, to establish a certain design [6].

Here we are not talking about human as such, but about a kind of symbol and apparatus whose purpose is to create. In contemporary society, the society of postmodernism, the function of the author is clearer insofar as through design he sets the ideological direction in which certain currents of discourse are revealed. In the following lines, an example of an author who creates his opus in the context of marketing design and is available to corporations in order to turn the dream of marketing into reality will be presented. Moreover, his work goes beyond marketing itself and becomes a creation in itself. An example of an author-icon, designer-star and celebrity is one of the most talented contemporary world designers - Karim Rashid.

Acquaintance with the icons of the Italian postmodernist design scene will turn out to be crucial for the development of Rashid's colourful style, which is a key element of the likeability and acceptance of his style among the widest masses. Until now, Karim Rashid has designed over 3000 products, including interiors, clothing, footwear, furniture, lighting, art, music installations, and recently entire buildings. For his design, Rashid received a large number of international awards. These included Garbo's trash can, OH Chair, Issey Miyake's bag, Umbra's plastic bowl, Nambé's kitchen utensils, and so on. He also designed interiors for Morimoto restaurant in Philadelphia, Semiramis hotel in Athens, showroom for Deutsche Bank and Audi. However, industrial products for the world's largest manufacturers are his specialty, so he worked for utility items for Method and Dirt Devil, bicycles for Biomega, furniture for Artemide and Magis, brand identities for Citibank and Hyundai, high-tech products for La Cie and Samsung, luxury accessories for Veuve Clicquot, Swarovski and Kenzo, and so on. Today, Rashid's works are part of the permanent exhibition of the world's most famous museums, such as the Museum of Modern Art in New York and the San Francisco Museum of Modern Art, Center Pompidou in Paris. Rashid has been working as a professor of industrial design for more 10 years and is a frequent lecturer at the world's largest universities and conferences.

His work is characterized by sensual curves and bright colours. Often described as *sensual minimalism* (in the words of Rashid himself) but also as a *blobject*. Blobject is an English term that refers to a designed object of industrial design characterized by gentle curves, bright colours and abstraction. This word is a coin of the words blob and object. The word was coined by journalist Phil Patton in 1993 in Esquire magazine. Paton defined the blobject as a colourful, mass-produced, plastic, postmodernist, consumerist product that in most cases invites users to an emotional connection, based on the principle of low desires and visual attributes. Blobject is a curvilinear utility object with floating shapes, and the forerunner of this style and approach to design is styling. Blobject is fluid, curvy, attractive and above all spectacular.

In the book Evolution, Peter Stathis states that Rashid's style stands out for its futuristic, contemporary, closeness to the fashion industry system, according to the principles of haute couture [7]. However, it is about ephemeral qualities. Rashid's works are not solid forms, they represent a new system of communication and connect the homogeneity and technologies of the modern world. This designer moves the design project to the level of glittering formal language, eliminating any part of a specific culture or social element. It is therefore a global language of symbols, forms that can be accepted anywhere in the world, that attract the masses and attract users based on the principle of creating desires. In other words, Rashid's design is a typical example of an *object of desire* - *blobject* is an object of desire. In the book I want to change the world [8], his works are described as colourful, sensual objects, but at the same time fresh, bright and new in concept and form, especially in the field of furniture design and industrial design. The materials and techniques that Rashid uses reflect contemporary trends in technology – plastics, surface printing and certainly computer-aided design. These objects have the characteristic of gathering symbols of the cosmopolitanism of culture, and give an indication of the future of the digital era. For this reason, Karim Rashid's work can be described with the word organicism (organically designed form). Whether it's chairs, vases, lamps or bags, curves and sensual lines dominate.

Rashid does not hide his fascination with the tendencies of globalism either in his statements or in his books. Moreover, he sees in them an opportunity for his own progress and promotion. In the large number of interviews, he gave to the world's largest media, Karim Rashid did not hide his design strategies and ideologies. What's more, he speaks freely about them and exposes his globalist design, in which a lack of awareness of the real social needs of the population can be observed, and a design approach from a purely formal-abstract point of view, which encourages the wishes of consumers. With this kind of media coverage and accessibility to other designers, Rashid promotes exactly the marketing design.

Rashid's design, based first on styling and then on postmodern Italian design, is the embodiment of contemporary global trends in contemporary design and its policies. His design and his media and professional activism are actually aimed at building and maintaining the design discourse as a dispositive dimension. In this sense, Rashid only in principle or did not include the real social aspect at all, and shyly and unconvincingly flirted with elements of ecological design. In interviews, Rashid often insists on democracy, which is actually a bizarre cannibalistic concept of contemporary global neoliberalism. As a result of his action comes a mosaic of designer products that have not only penetrated into the fabric of consumers, actually those who can pay for it, but also into the fabric of the design discourse itself, determining the ideology and values of designers around the world.

The United States and Europe, like the rest of the world, have ceded political power to the control of the biopolitical system and overall economic power. It is a time when social life is ruled by multinational corporations and their marketing policies. They require symbolic and visual representation, and Rashid's spectacular design perfectly matches the corporate logic. Rashid, as well as designers similar to him, are still growing on the wave of this dialectic, far more successfully than alternative design approaches. Ambition and self-centeredness lead Rashid to quasi-theory and criticism of the world. He foresees a colourful future painted by his projects. For him, there is neither past nor present, only a colourful future filled with blobjects.

He does not oppose the design of spectacles encouraged by corporations. In fact, we can't just talk about simple co-opting where design simply works for corporations, or swimming on the wave of investment, because such a discussion frees design from responsibility. If a fundamental turn towards an alternative design discourse is not possible, then society is in trouble. If it is not possible for the design discourse to be critical of the existing functioning systems of the world and to recognize the ideologies of alienated design.

4. CONCLUSION

Marketing design is a logical continuation of consumerism. Therefore, the purpose of design from this point on was to instill a desire for possession into the consumer. In other words, design has become a tool within the company, carefully processed. What is important for the topic of this work is that the tectonic shift in design actually marked the triumph of the ideology of American styling. The styling evolved into a consumerist design, and then by the end of the 1980s, it developed as a marketing design. Design is presented as a universal remedy for the social and economic problems of society. In the same period of the seventies and eighties, cracks appeared in the field of design, and criticism developed that exposed the values and ideology of the consumer society. A new ideology developed on the foundations of the postmodern spirit, but also in the field of social movements that began to appear at the beginning of the seventies of the twentieth century.
It is possible to distance yourself from such phenomena and focus on a more alternative approach to design, than to marketing design, that really takes into account the real interests of society. The contemporary design discourse, set up as an aid to marketing, alarmingly calls for internal transformation. The designer, if he is not captivated by egocentrism and the spectacle, truly strives both for his own freedom and for the freedom of society, which means that he wants to exclude himself from the existing discourse and avoid subjectivation that leads to the non-recognition of human and animal, to the non-recognition of tolerance, human existence, and leads to falling into antagonisms and conflicts with which modern society is filled with too much. Behind the self-centred and spectacular show-off within the design discourse are actually star authors whose ambiguity surpasses even the largest mechanisms of consumerism and marketing. In the existing system, they represent at the same time the victims of the system, but also the executioners.

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ENVIRONMENT AND SUSTAINABLE DEVELOPMENT. MECHATRONICS.
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SMART MANAGEMENT SYSTEMS. GRAPHIC ENGINEERING. DESIGN.
TRAFFIC ENGINEERING. BIOTECHNOLOGY AND HEALTHCARE.
MECHANICAL ENGINEERING. ECOTOURISM AND RURAL DEVELOPMENT.

THE EXPERIENCE AND PERCEPTION OF THE LIGHT COLOUR IN THE SPATIAL CONEXT

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Abstract: Within the realm of architecture and design, the light colour is one of the essential factors that shape and define the perception of the space. Light profoundly influences our emotional and visual perception, giving space life, depth, and meaning. This paper delves into a deep understanding of the significance of light, from the fundamental scientific principles to the sophisticated colour theories. Through the exploration of various theories from esteemed thinkers and basic scientific concepts, this study examines how the colour of light shapes our experience of space, both quantitatively and on a profound subjective level. The study addresses the technical aspects of light, its impact on our emotions, behavior, and visual experience, as well as its importance in shaping the identity of a space. While the technical attributes of light can be precisely measured and planned, its true potential lies in its ability to evoke individual and collective responses, thereby shaping the identity and ambiance of a space.
Keywords: light, light colour, spatial identity, experience, perception.

1. INTRODUCTION

In the world of architecture and design, light is one of the essential elements that breathes life into space, shapes it, and transforms our perception of it. Light plays a pivotal role in our visual perception of our surroundings and also represents an indispensable element in architecture and design thus understanding its influence becomes of utmost importance. While light, at its essence, is electromagnetic radiation visible to the human eye, its true magic lies in how it affects our perception, emotions, and memories. It molds our emotional experience of space, giving it life, depth, and meaning. From fundamental scientific principles, through colour theories established by thinkers like Newton and Goethe, to the sophisticated application of light in shaping the identity of spaces, this paper guides through a comprehensive analysis of light and its significance. In this intriguing journey through light, we explore how it, particularly its colour, shapes and influences our perception of the world around us, both on a quantitative and deeply subjective, emotional level.

2. LIGHT COLOUR AND TEMPERATURE

The nature of light has remained mysterious and challenging to comprehend for many years. Today, we know that light behaves both as a wave and a particle, a phenomenon referred to as wave-particle duality. Light, by definition, is a type of electromagnetic radiation emitted when photons are in motion. This energy characterized by its frequency of electromagnetic wavelengths is part of the broader spectrum of radiation known as the electromagnetic spectrum. Visible light is a part of that spectrum, with wavelengths recognized and processed by our eye receptors, falling between ultraviolet and infrared radiation, within the range of 380 to 780 nanometers. The primary parameters for lighting design are six visual principles of light, factors considered in illuminating architectural spaces: illumination and luminance, colour and temperature, height, intensity, direction, and

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distribution. In this study, the focus is on light temperature and colour as direct influences on the perception of space and time.

2.1 Light Temperature

Our biological rhythm is determined by the daily cycle of light and darkness. Throughout the day, the sun travels a 180-degree arc across the sky, illuminating the landscape and enabling us to see colours (red, orange, white, blue, pink, purple, and everything in between). Within interior spaces artificial light sources replace daytime light. By selecting lighting fixtures, their frequencies, colours, and temperatures, design takes on a specific atmosphere and ambiance. The Kelvin scale has been adopted as the international standard for scientifically measuring light temperature. The Kelvin is the basic unit of the Kelvin scale, an absolute temperature scale named after the British physicist William Thomson, known as Lord Kelvin. At around 800 kelvin, light appears as a dull red glow. Around 3000K, light becomes orange; at 6000K, light is bright white, and between 9000 – 10000K, we see light as blue. Light temperature significantly affects the ambiance of space. LED lights allow the choice of colour temperature to adjust lighting as needed. The images depict a significant difference in the interior ambiance when two different light temperatures are used.

Figure 1. Different light temperatures, left- 6000k cold light, right- 2700k warm light
Source: Lighting by design

2.2 Light Colour

Colors are a product of the different wavelengths of light in the visible spectrum. Different colors correspond to different wavelengths, and our perception of color is a result of how our eyes and brain process these different wavelengths of light. Small differences in the frequency or wavelength of light can indeed lead to different colors. The shortest wavelengths are purple and blue light, while red light has the longest wavelength. Our visuall experience through the colours we see is light that is a combination of different light waves and white light. White light is reflected through many different waves, creating the perceived colour. White light is composed of a continuous series of all colours in the visible spectrum. In practice, we can consider a colour of an object to be the colour the object reflects when illuminated by white light, i.e., an object will be coloured in a certain colour if its surface absorbs white light only in a specific wavelength range. Light colour adds identity and orientation to the space. It is used as a visual compass, emphasizing important places and as a guide to those places. Coloured light leaves a strong impression on a place. The primary colours we see are shown in the table. If the wavelength is of medium length from two adjacent ranges, transitional colours are created.

Colour	Wavelenght [nm]
Red	~ 635-770
Orange	~ 590-635
Yellow	~ 565-590
Green	~ 520-565
Cyan	~ 500-520
Blue	~ 450-500
Purple	~ 380-450

Figure 2. Different wavelength colours in light
Source: Architectural Lighting Designing with Light and Space

3. THEORIES BEHIND THE COLOUR OF LIGHT

3.1 Newton

In the 17th century, Isaac Newton discovered that prisms could separate and combine white light, a phenomenon he described in his book "Opticks." Newton noticed that when a narrow beam of sunlight hits a glass prism at an angle, part of the beam was reflected, and the other part passed through the glass, emerging as strips of different colours. Newton's hypothesis was that light consists of particles of different colours, with different light colours moving at different speeds in transparent materials, and red light moves faster than violet light. As a result, red light bends less sharply than violet light when passing through a prism, creating a spectrum of colours. Colour is not inherent to an object; rather, the object's surface reflects some colours and absorbs others. The human eye only sees the reflected colours. Newton, through his "Prism Experiment," discovered that white light produced by the sun separates into a rainbow of colours when passing through a prism. When white light hits a white object, it appears white to us because it absorbs no colour and equally reflects all colours. When light touches a coloured object, the light of that colour is reflected back. A black object absorbs all colours equally and reflects none, so it appears black. It is estimated that the human eye can see about a million shades of colours.

3.2 Goethe

Goethe's “Theory of Colours” ("Zur Farbenlehre") explores the phenomenon of colour and how people perceive it. Although his theory was considered less scientific than contemporary colour theories, his understanding of colour as a subjective experience that changes depending on the context, had a significant influence on artists and philosophers. In contrast to Newton's scientific approach, which studied the refraction of light through a prism, Goethe approached colours from a phenomenological perspective, studying how observers perceive them. He concluded that perception determines colour. Goethe believed that colours arise through the interaction of light (which he described as a positive force) and darkness (which he described as a negative force). For example, blue arises when darkness predominates over light, while yellow results from the dominance of light. Goethe recognized relationships between complementary colours and developed the concept of complementary colours. In this section, particular emphasis is placed on the emotional and aesthetic aspects of people's reactions to colours. Goethe detailed many emotions and atmospheres that different colours can evoke. He criticized Isaac Newton for his approach to colours, claiming that Newton's theory does not take into account the complexity of human colour perception. "People experience the effect of colours before they become aware of them. Colour possesses a powerful constitutional energy. It can lead to radical change in us." [1] Although Goethe's colour theory was not fully embraced by the scientific community, it had a significant impact on many artists, designers, and philosophers. It particularly caught the attention of Reinesance artists and philosophers of the 19th century, as well as modern artists of the 20th century who were interested in the emotional and subjective nature of colour.

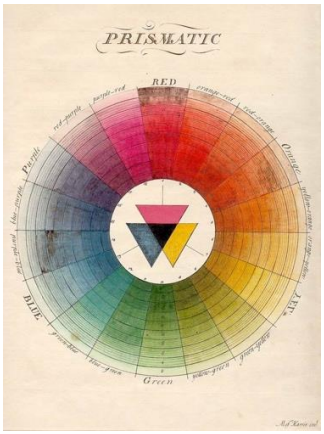

Figure 3. Goethe's colour wheel
Source: Internet

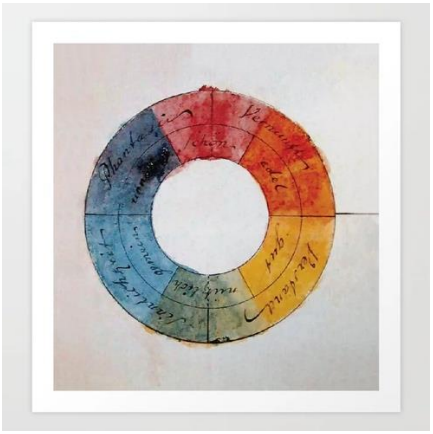

Figure 4. Goethe's colour wheel
Source: Internet

4. VISUAL EXPERIENCE THROUGH COLOURED LIGHT

Our visual experiences are not solely determined by the physical characteristics of the light; they are also influenced by our bodily and physiological reactions to the light that our retinas receive as information. Coloured light can generate powerful visual perceptions that impact our emotions, behavior, and subjective experience of space. The deliberate use of colours affects our perception of the environment and evokes various emotions. Different colours tend to provoke a wide range of psychological reactions. Red, for instance, evokes strong emotions such as passion, high energy, and excitement. Within specific contexts, red light creates a sense of warmth and comfort, while in others, it suggests danger or urgency. Blue is associated with a feeling of calm, coolness, and serenity. In lighting design, blue light can create a sense of spaciousness and tranquility. However, excessive use of blue can also convey a sense of coldness or alienation. Green is commonly linked to the nature, growth, and renewal. It often evokes a sense of peace and harmony. In the space, green light elicits a feeling of freshness and relaxation. Yellow is bright and cheerful, promoting optimism and positive energy. Yellow light creates a sense of warmth and brightness. Purple is associated with luxury, mystery, or spirituality and is often connected to creativity and imagination. Orange is a warm colour that evokes enthusiasm, energy, and warmth . When orange colour dominates the spatial ambiance it can be utterly stimulating.
The visual impression created by coloured light also depends on the intensity and strength of the light, as well as the context in which it is used. For instance, diffused blue light creates a relaxing ambiance, while sharp, directional blue light evokes a dramatic and intense effect. Regardless of the physical properties and accepted psychological and social norms related to the colour, our experience of colour also depends on the individual perception, cultural factors, and one's previous individual experiences. What may be calming to one individual may feel cold or alienating to another. The influences of the visual impression in the spatial context are explored through psychology and philosophy, broad areas of study that intersect and deal with understanding and our perception of the world around us, light, colour, and space, as well as their impact on our emotions, thoughts, and behavior.

5. IDENTITY THROUGH COLOUR

The colour of light plays a crucial role in shaping the identity of the space. Lighting dramatically alters our perception of space, its function, atmosphere, and affects an individual's sense of it. Through light, the space communicates specific emotions, values, and intentions, its colour creating the ambience of that space. Lighting emphasizes the purpose of the space; light in a workspace enhances productivity and reduces eye fatigue, whereas in a restaurant, diffused and warm lighting is used to create an intimate atmosphere. Architectural details, artwork, or other aesthetic aspects of the space

gain the importance through different lighting techniques. Through the colour of light, designers emphasize or conceal specific details within the space to achieve the desired visual effect.
In commercial spaces, the colour of light is vital for branding. Colours used in logos and marketing materials can be integrated into the lighting of the space, creating a consistent and recognizable brand identity. The colour of light also highlights the cultural or social values of the community.
In some cultures, certain colours may have symbolic meanings or are used in specific ceremonies or rituals, influencing our emotional reaction to the space. For example, spaces illuminated by soft, warmly coloured light easily evoke feelings of security and comfort, while the opposite is true for spaces illuminated by cold, harsh light. Appropriately designed lighting improves the functionality, aesthetics, and overall experience of the space, while inadequate or discordant lighting can lead to confusion or discomfort. Different light colours can provoke different emotional responses.
Warm tones like red or orange create a sense of comfort and warmth, while cool tones like blue can evoke a sense of calmness but also distance. The colour of light can influence social interactions within the space. Restaurants often use warm, diffused light to create a more intimate atmosphere that encourages conversation, while office spaces may use brighter, neutral lighting to stimulate productivity. The orientation and function of the space can be clearly defined through the colour of light. For instance, blue lighting in a specific section of a store indicates a technological department, while green lighting emphasizes natural products. The colour of light can evoke specific memories or associations.
A space illuminated with light reminiscent of a sunset can remind visitors of a beach vacation, while a space with cold, sterile lighting can resemble a hospital environment. The perception of the space's aesthetics is directly related to the colour of light. Light that highlights architectural details or artworks influences the aesthetic value of the space. Controlled use of colour within a space can induce various psychological reactions, such as euphoria with magenta or tranquility with deep ultramarine blue.
While there is a connection between colour and emotion, individual colour perception remains profoundly subjective. When coloured light defines the interior space, it also affects our perception of the space outside the illuminated area. This occurs due to our eyes' adaptation to a specific shade and the visual effect of complementary colour when viewed in different lighting. This effect results from the function of photoreceptor cells in the retina. For a full experience of colour, a visual change is required to allow the brain to adjust to the colour difference.

Figure 5. Train station interior coloured by the magenta light exceeds the limits of a ordinary station

Figure 6. Colour spectrum within the gallery interior

Source Architectural Lighting Designing with Light and Space

6. CONCLUSION

The colour of light represents a fundamental component in our perception and interpretation of the space. Its role extends from technical aspects, such as light intensity, to the subjective experiences it evokes in observers. Lighting, particularly its colour, not only shapes the visual and emotional experience of the space but also influences its identity and function. Certain theories, such as those

presented by Newton and Goethe, provide a deeper understanding of the role of the colour and light, both physically and in the context of human perception. The colour of light is a powerful tool for shaping the identity of space. Whether the goal is to create a specific ambiance, emphasize functionality, aesthetics, or brand identity, carefully chosen light colour transforms the space and influences all of its users. The perception of spatial identity through the colour of light is a complex interplay between the objective design of the space and the subjective experience of the individual using it. While the technological aspects of light can be objectively measured, planned and designed its true value and impact manifest through the individual and collective human reactions to the different illuminated spaces.

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ENVIRONMENT AND SUSTAINABLE DEVELOPMENT. MECHATRONICS. OCCUPATIONAL SAFETY AND HEALTH AND FIRE SAFETY. SMART MANAGEMENT SYSTEMS. GRAPHIC ENGINEERING. DESIGN. TRAFFIC ENGINEERING. BIOTECHNOLOGY AND HEALTHCARE. MECHANICAL ENGINEERING. ECOTOURISM AND RURAL DEVELOPMENT.

TECHNO-PRAXEOLOGICAL OPINIONS ABOUT DESIGN: VIEWS FROM PERSPECTIVE OF PROTECTION OF CULTURAL HERITAGE

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Abstract: *The focus of this research is a techno-philosophical and praxeologycal analysis of issues into field of design in relationship to connection of ideas, discourses and values of classical and contemporary approaches to intellectual heritage of design. Leitmotif of this research provided two Italian exhibitions, entitled "Design Before Design" and "Design after Design". Multidisciplinary examination especially focused to action and meta-action in thinking about design, with view to heritage conservation (materials and technologies), and protection of intangible cultural heritage. The analysis in the paper will be shown on Le Corbusier's work "The die is cast".*
Keywords: design, techno-philosophy, praxeology, cultural heritage, Le Corbusier

1. INTRODUCTION

The very wide and multi-layered field of praxeology can be explored in almost all areas of life, and in the field of design it is especially dynamic due to the penetration of new technologies that expand the concept of visuality in different directions of visual culture. That is why it is important to add a praxeological view to the observations of design from standard viewpoints, which includes the triad of criteria related to ethics, effectiveness in fulfilling the purpose, as well as the efficiency that measures the relationship of use in relation to the purpose in relation to the input used, [1]. Also, in the multidisciplinary view of design, very important the philosophical observation once made by Sellars, which drew attention to the process of multiplying sciences and disciplines on the intellectual scene, where the unification of this multiplicity takes place by building scientific bridges between them and where each separate discipline is important, and he must have a sense of how he fits into the intellectual environment as a whole, [2]. Observing from the sphere of techno-philosophy, the famous Danish architect Fisker writes that "...the ethics of functionalism says that no form is something in itself. Form only acquires the meaning it must fulfill through function...", representing the point of view that our environment should be characterized by a whole - as opposed to simply consisting of a series of individual, sensational works, [3]. However, the practical use of knowledge, as stated by Ristić in his interpretation of Habermas, "... whether it is about translating it into technologies and strategies or communicative practice, should be the subject of research into a praxeology, which includes research into the possible interaction of science and politics", [4]. Bearing in mind that it is 100 years since a significant event in the sphere that unites design, economy and politics, when Guido Marangoni (1872-1941), journalist, founder and director of "La Casa Bella", as creator, advocate and chief animator, started the project of international exhibitions of decorative arts in the Villa Reale di Monza (bienle), and then in the Palazzo dell'Arte in Milan (trienale), the research presented in this paper had as its light motive two international exhibitions from 2016: "Il design prima part design. Guido Marangoni e le Biennali di Monza 1923-1927" [5] as part of the XXI Esposizione Internazionale della Triennale di Milano, when presented the exhibition "21st Century. Design After Design". This evocative-heritological view of interwar Italian design, which developed in a critical period of Italian history dominated by the fascist regime [6], in this paper give as time

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frame of wider research, from which the initial results are presented here, related to the work "The die is cast", by the Swiss-French architect Le Corbusier.

2. VISUALITY, PRAXEOLOGY AND DISCOURSE AS PART OF METHODOLOGY

2.1 Visuality

As Davis points out [7], methodologically, visuality is the subject of research in traditional artistic, as well as scientific and philosophical disciplines, such as aesthetics, art history, psychology and visual-cultural studies in history, sociology and anthropology. In the middle of the last century, heritology was added to these sciences, as a science whose subject of research is the protection of tangible and intangible cultural, scientific and technological heritage [8]. At the beginning of the 21st century, the thought appeared that every space for writing is a "material and visual field, the properties of which are determined by the technology of writing and the ways in which that technology is used by the culture of readers and writers", [9]. Mirzoeff emphasizes that the word visuality was first formulated by Thomas Carlyle in 1841 in his lectures On Heroes [10], where he points out that„Reading Carlyle in the imperial context leads to a distinction between Visuality 1, which is proper to modernity, and a Visuality 2 that exceeds or precedes the commodification of vision". Research also shows that the phenomenon of different modalities of visuality can be observed in all historical epochs: in prehistory, in non-verbal languages, long before a verbal language emerged, [11], in ancient Plato's Κρατύλος [12, 13], then in the Renaissance double activities of viewing and representation [14], as well as in Baroque visions as palimpsests [15] and Cartesian perspectivalism, the reigning visual model of modernity [16], where "...the intellect inspects entities modeled on retinal images" [17], and so all the way to the postmodern heterochronic space heterochronic other space [18], with numerous invisible cultural layers and intermediate layers. At the same time, as stated by Kirby according to Dewey, "...the more honestly we refer to facts, the greater the importance of distinguishing between facts that condition human activity and facts that are conditioned by human activity." To the extent that we ignore this difference, social science becomes a pseudo-science", [19]. In this sense, as one of the representative tasks in the research of the mentioned complex issues, Le Corbusier's tapestry entitled "The Dice is Thrown" from 1960 [20], was chosen for the case study.

2.2 Discourse and factography

Richard Stockton Dunlap's doctoral dissertation defended at the London School of Economics in 2014, entitled *Reassessing Ronchamp: the historical context, architectural discourse and design development of Le Corbusier's Chapel Notre-Dame-du-Haut*, [21], can be considered a turning point in the understanding of the ethical relationship to factography in the research of discourse phenomena. Dunlap analyzes the primary and secondary discourse and shows the modes and strategies of Le Corbusier in his effort not to publicly reveal the facts about his creative process, about symbolic devices that carried hidden meanings within his tmysterious iconographical program, which is why he used the so-called elliptical language with the use of quasi-references. Because of this, many meanings and sources of Le Corbusier's inspiration are still insufficiently known, or are insufficiently presented to the general public, although significant monographs dedicated to the artistic, architectural and intellectual heritage of Le Corbusier, whose authors specialize in the research and interpretation of his work, are dedicated. Referring to precise factography, Richard Stockton Dunlap particularly points to the uncritical attitude of various authors towards Le Corbusier's autobiographical explanations (which he calls *parallel construction*), then to the spread of these canonical explanations in a series of texts that are not subject to criticism (which he calls *discourse enclosure*), as well as excluding those explanations from epistemological review procedures (*explanatory privilege*).

2.3 A techno-praxeological view

Another significant source for research in this work is the analysis of Le Corbusier's explanations, thinking and techno-praxeological observations (though not explicitly under that terminology), which was published in 2022 under the title *Le Corbusier Ineffable Space and Synchronism: From Architecture as Clear Syntax to Architecture as Succession of Events*, authored by Marianna Charitonidou, [22]. From the cited quotations, the sources of which are precisely listed bibliographically, it can be seen that there are several significant points on which Le Corbusier based his creativity. From the more extensive observation given by Charitonidou, quotes from Le Corbusier's thoughts that have universality, in the sense that they can be related to different aspects of his creativity beyond architecture, were selected and analyzed for this research. On the basis of the techno-philosophical analysis performed, the parameters listed here in italics can be formulated with the appropriate quote from Le Corbusier's thoughts in parentheses: ***processuality*** ("first look, then observe and finally maybe discover... and then inspiration can come"), ***the primacy of immediate experience*** ("don't photograph, draw; photography interferes with seeing, carving into the mind"), ***memory as a source*** (ideas are placed "into the interior of memory", waiting for their form to be concretized / "it is drawn in order to be pushed inside, in one's own history, seen things"), ***testimony*** (the drawing as an "impartial witness and engine of the works of the creator"), ***ineffability***, as what cannot be described in words (the work is able to cause the effect of "ineffable space" when it acquires "its maximum intensity, proportion, quality of execution, perfection"), as well as ***concordance*** "A phenomenon of concordance occurs, exactly as in mathematics") and ***illumination*** (a message to architects:"You are 'social beings' rather than artists—you are leaders, followed by millions of individuals who are ready to follow you if you seize the exact moment when 'illumination' exists between you and them", which would could be placed within the framework of the metaphysical components of Le Corbusier's thinking.

3. „LES DÉS SON JETÉS" ["THE DIE IS CAST"]

Le Corbusier's work "Les dés sont jetés" (Fig. 1) has a well-known and complex pre-history of commission by the Danish architect Jørn Utzon, who designed the Sydney Opera House, a great architectural work of the 20th century [23]. Luke Slattery, in a text entitled *Le Corbusier tapestry The Dice Are Cast comes home to Sydney Opera House*, calls Le Corbusier an architectural genius and speaks of the "vibrant proto-Cubist glory" of this tapestry, [24] concluding with the words: " Ultimately *The Die is Cast* connects with something bigger than Sydney and its Opera House: the DNA of modernism itself". This is the conclusion of the text, in which the author shows that in conversations with several credible interlocutors and experts on the work "Les dés sont jetés", he failed to get an answer about the meaning of the symbols shown in this work, where everyone indisputably recognizes only the miniature sailboat, while our the impression that everything else belongs to the domain of guesswork. The numerous questions that this work raises, both in terms of an independent artifact, and in the context of the development of the Sydney Opera House project and the final arrival of "Les dés sont jetés" in its building, due to space limitations and the unavailability of the necessary documentation, cannot be the subject of this work. Therefore, only the elements that are on the level of the relationship between actions and meta-actions (details A and B, Fig. 1) are considered here, could be a framework for analysis based on the above-mentioned sources that are internationally confirmed in the factual and bibliographic aspect. Due to the limitation of space, it is also not possible to present an integral analysis of the work here, but it is possible to present a methodological approach in connection with the selected elements of the work "Les dés sont jetés" as representative symbols important for the thematization of this work.

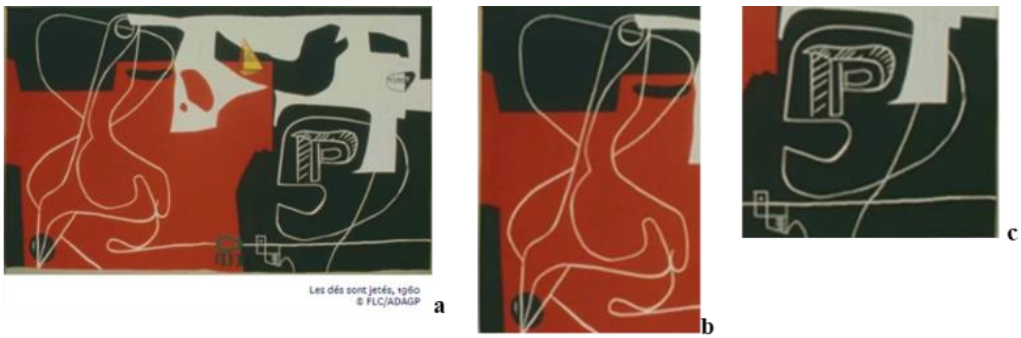


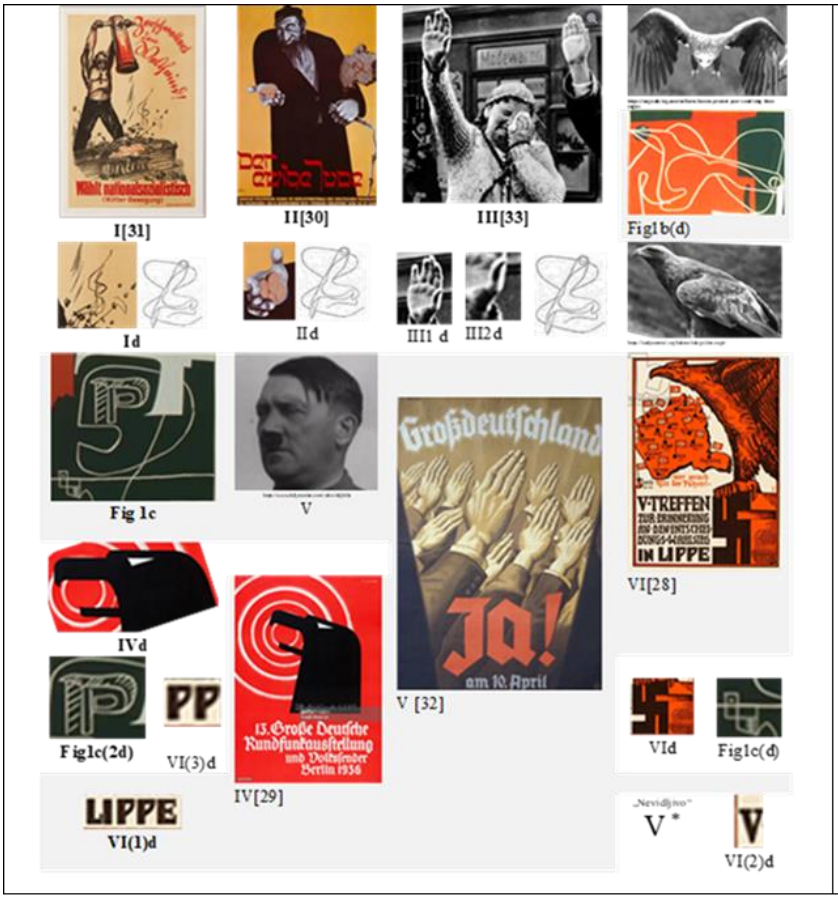
Figure 1. „Les dés sont jetés“, 1960. : Wool tapestry, H: 2,18 m x L: 3,55 m, signed and dated at top right Le Corbusier 60 Paris, Fondation Le Corbusier, [20]; b - detail A; c - detail B

3.1 Factographic analysis

"Quoiqu'il en soit, les dés sont jetés" / “Either way, the die is cast” is a phrase that Le Corbusier mentions in a letter dated 31.10.1940. wrote to his mother (1940-10-31: LC LETTER TO MARIE JEANNERET FROM OZON) [25]. As can be seen in Dunlap's research, it is a letter that documents the sensitive issue of Le Corbusier's "extensive involvement in the Vichy government during the war" as well as "the danger he faced after the fall of Péten." Among other things, Le Corbusier writes about Hitler: „We are in the hands of a winner and his attitude could be overwhelming. If the deal is sincere, Hitler can crown his life with a grandiose work: the development of Europe.” Dunlop also writes in his thesis that Le Corbusier, „to conceal his past, he created a consistent story about the period of German Occupation that obscured his involvement in Vichy”. Historiography records that in the summer of 1933, Hitler said: "The die was cast in Germany on January 30th. And I don't think the opponents who were laughing back then are still laughing today." He said it "in front of an enthusiastic crowd of ten thousand Germans" [26]. As Gregor Taxacher states, "On January 30, 1933, two weeks after the national elections, Reich President Paul von Hindenburg appointed Hitler Chancellor, a formal legal act celebrated by the Nazis as the 'seizure of power.' The fate of the Weimar democracy was sealed." [27] The fortuitous circumstance that local elections in the small province of Lippe marked that turning point immortalized the Lippe region on a Nazi poster (Fig 2-VI), called „V meeting to commemorate the decisive election victory in Lippe”, [28].

3.2 Visuality in context

The visuality of the mentioned poster calling for the celebration of the Nazi victory in the Lippe area, as well as other propaganda Nazi posters (German Poster announcing a radio broadcasting in Berlin (August-September 1936), (Fig2-IV), [29]; Poster The Eternal Jew (1938 poster advertises a popular antisemitic traveling exhibit called Der Ewige Jude, (Fig 2-II), [30]; Nazi Party election poster with a man smashing a financial building with a battering ram, (Fig 2-I), [31]; poster encouraging Germans to vote in favor of annexing Austria (The caption reads "Greater Germany: Yes on April 10th."), (Fig 2-V), [32]) represents a visual that was imprinted in the consciousness of contemporaries of the Nazi rise Germany. In addition, there were photographs that also left an indelible visual mark on memory, such as the photograph Weeping woman in the Sudetenland saluting the triumphant Hitler in 1938 (Fig 2-III),[33]. A visual analysis indicating how such visual impressions could generate the symbols A and B in "Les dés sont jetés" is shown in Figure 2. Visual analysis shows that elements - details from several posters and one photograph from the time of Nazi propaganda, which are still present in the public electronic space today, as parts of different collections, undoubtedly exist in the work "Les dés sont jetés". There are also the basic colors that are dominant in Nazi poster design: red and black.



Morphologically, detail A clearly reflects the interweaving of the projections of the eagle in flight and the eagle at rest. The eagle's head as a Nazi symbol is also common to detail B, which represents the synthesis of two forms: the eagle's head from the poster promoting radio in Berlin and the head - the portrait of Hitler. Within detail B, there is also a discrete, marked interpretation of the swastika, and the double letter P, which dominates the name of the Lippe area, is particularly dominant. A sharply defined letter V on the tapestry that is not visible in the electronic reproduction, and about which the conservator from International Conservation Services, Julian Bickersteth, speaks: "...a sharp V-shape, invisible in reproduction, has been woven into the field of white" [24] also exists on the same poster in the word "V-Treffen". The Nazi salute shown on numerous posters, photographs and films is reduced to one finger connected in the same representation of the eagle in detail A, i.e. it is a sublimation of the motif.

Figure 2. Visuality in context - analysis, [28-33]

4. CONCLUSION

The paper presents shortly observations of theoretical research in the field of techno-praxeology in the context of cultural heritage protection. Recent scientific studies show that there is a need to reexamine known results and new document research to confirm or disprove opinions and existing knowledge about design and works of art that belong to world heritage. Among such works is Le Corbusier's tapestry "Les dés sont jetés", which in a long series of years poses very serious questions to the professional and scientific public about deciphering the displayed symbols and the author's message. Due to the exceptional sensitivity of the subject and the great reputation of Le Corbusier and Jørn Utzon, as well as the reputation of the institution associated with this topic - the Sydney Opera House, which was included in the UNESCO World Heritage Site list in 2007, and in which in the Western Foyer since 2016 the work " Les dés sont jetés", the scientific community is obliged to provide a broader, multidisciplinary scientifically based interpretation, which should allow the work to be contextualized in accordance with the message provided by the author.

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INTERNATIONAL SCIENTIFIC AND PROFESSIONAL CONFERENCE
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ENVIRONMENT AND SUSTAINABLE DEVELOPMENT. MECHATRONICS. OCCUPATIONAL SAFETY AND HEALTH AND FIRE SAFETY. SMART MANAGEMENT SYSTEMS. GRAPHIC ENGINEERING. DESIGN. TRAFFIC ENGINEERING. BIOTECHNOLOGY AND HEALTHCARE. MECHANICAL ENGINEERING. ECOTOURISM AND RURAL DEVELOPMENT.

VISUALITY, METHOD, AND LABAN'S ORTOGRAPHY: ONE PARALLEL

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Abstract: *Sources of inspiration for the formation of authentic orthographic and methodological systems are a challenge for researching the emergence and logic of constituting visual opinion. In this paper, one of the possible formative influences on the work of Rudolf von Laban, the most famous movement theorists in the 20th century, which is also the author of an authentic orthographic system, is being investigated. A research on the work of this artist was conducted on the basis of electronically available documentation from several European collections. One possible parallel was presented, which is based on thesis about processes of subtraction from the archetypal content of visual impressions.*
Keywords: visuality, method, orthography, multidisciplinary, old rare manuscripts

1. INTRODUCTION

The research of cultural heritage in the field of visuality offers a view from the perspective of heritology, as a science dedicated to the future of human experience, which examines phenomena that, in their passage through time, encompass the values and qualities of visuality in different areas, harmonizing and multidisciplinary enriching scientific knowledge, [1]. In this work, in the focus of the thematization is such a phenomenon, which connects visuality with movement analysis, through orthography (dance notation), which is known today as *Labannotation* or *Kinetography Laban*, after its author and founder, movement theorist Rudolf von Laban (1879-1958), the founder of choreology, the discipline of dance analysis, [2]. The work is inspired by two studies on the work of Rudolf von Laban. The first of these, Laura F. Brandl's study explores the joint effects of the modern system of dance notation and the rise of geometric abstraction in the applied arts during the first decades of the 20th century, and supports the hypothesis of a co-constitutive relationship between visual abstraction and the dance body in the European avant-garde [3], by exploring possible similarities between the early geometric compositions of Rudolf von Laban and the visual artist Sophie Taeuber-Arp, who moved between the Laban dance school and the Dada art circle between 1916 and 1919 in Zurich. Another study by author Miklós Vojtek, a playwright, deals in detail with the biographical research of Rudolf von Laban's life in Bratislava, where this artist was born, educated and spent part of his life, [4]. In relation to the focus of the first study (geometric compositions), as well as the focus of the second study (formative influences in the artist's creativity), in this paper, the research is aimed at unifying these two focuses. Therefore, the subject of research is the formative influences from which the geometric compositions in the creation of Laban's orthography could arise. This time, the fact that Laban often stayed in the cities of Austria-Hungary at the time, Sarajevo and Mostar, is taken in to account, which is why his biographers point out that he was educated in both Western and Eastern cultures [2]. Accordingly, the hypothesis is presented and advocated that the visual abstraction of Labannotation could have been inspired by archetypal signs, characteristic of ethnological motifs that Laban could see in the mentioned cities. In this way, knowledge from the field of ethnology and ethnomusicology is introduced into the multidisciplinary framework, in addition to the history of art,

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geometry and movement, as a possible new contribution to elucidating the origin of abstract geometric figures in the orthography of Rudolf von Laban.

2. TRANSPOSITION OF MOVEMENT INTO A SEMIOTIC SIGN

Semiotics, as the study of signs and marking practice [5] provides the possibility to translate non-verbal language into a meaning adequate to the field of expression. Gillian Rose points out that semiology is thus embedded in a rich and complex set of ideas whose implications are still actively debated, and that "... a semiological analysis entails the deployment of a highly ordered set of concepts which produce detailed accounts of the exact ways the meanings of an image are produced through that image", [6]. Therefore, the transposition of movement into a semiotic sign was an important step in the scientific research of play by Rudolf von Laban, who was equally creative in both the practical and the theoretical domain, where his writings on choreutics, choreology - the analysis of dance and movement, eukinetics and observation, through thousands of drawings, they record every spatial nuance, dynamic variation and temporal relationship between individual movements. Therefore, his intellectual heritage (German Expressionist Dance or Ausdruckstanz, Labanotation or Kinetography Laban) unites contributions sublimated in theoretical methods guided by the practice of movement, as " a complex system of analysing the characteristics of movement, particularly its pathways through space, and its 'effort' and 'shape' Theoretical methods driven by movement practice", [7]. The *Encyclopaedia Britannica* notes that Laban, "After publishing a shorthand system for his theories (Choreographie, 1926), he developed a more detailed and more widely applicable notation—one that spelled out the elements that produce the movement pattern—and published it in the book Schrifttanz ("Written Dance") in 1928. This work provided the basis of the system that bears his name — Labanotations",[8]. Valerie Preston-Dunlop, author of the monograph *Rudolf Laban An Extraordinary Life*, believes that his search for the basic vocabulary of expressive movement identified the basic factors of movement flow, with weight, embodying time and space. His works were the result of researching society in the way Brecht did in their fields at that time in dramatic art, Malevitch in constructivist visual art, as well as other artists in the visual language of Dadaism, [9,3,].Bearing in mind that every individual lives and creates under the influence of his contemporaries, Jean-Gabriel De Tarde points out that: "... let us not forget that every invention and every discovery consists in the interference in somebody's mind of certain old pieces of information that have generally been handed down by others " [10], and that each discovery or craft comes from analogy with a previous discovery that copies a common principle, [11]. On the other hand, John Yolton, speaking about perception, argues that there is a constitutive moment that has to do with a natural geometry of the mind and that there is at least one element that is not simply mimetic, [12]. In addition to the influence of contemporaries and the natural constitution of the mind of a creator, as Vojtek points out, there should be an awareness that the influences of childhood, adolescence and youth, in addition to inherited tendencies, are decisive in the development of each personality and that getting to know them contributes to a better understanding of the artist's entire oeuvre, [4].
For research in this paper, from Vojtek's extensive study, we analyze here only two significant facts: i. In his early youth, in the tavern of his grandfather Antal Laban, Laban came into contact with numerous domestic and foreign newspapers and magazines, [4].Without pretensions to make any direct conclusions other than showing a possible atmosphere, here is given the example that Laban as a nine-year-old boy, in 1888, could thus see a photograph (Fig 1a) from the magazine La Nature, for which R. Krauss in his study The Im/pulse to See, states: "The zootrope illustration appears in an article on Jean - Etienne Mareys chronophotographic recording of a bird in flight, from which three-dimensional models were eventually constructed ", [13]. Such or a similar photograph could have left a trace whose reflection would have been recognized in the drawing (Fig 1b), which shows Laban's thinking about movement. As Dick McCaw points out, „The different meanings of the German word "freie" characterise Laban's philosophy of movement. He believed that everyone should practise this free, freed, and freeing dance for their mental and physical health; an idea encapsulated in the first three words of the text:'Tanz is Bewegungsfreude' – 'Dance is the pleasure of movement'", [14].

a b

Figure 1. a- Detail, from *La Nature*, 1888, [13]; b- Detail from Laban drawing, Rudolf Laban Collection compiled by Dick McCaw from archives is in Leeds Special Collections, [15]

ii. As a city child, Laban came into contact with folk art at an early age: fairs were held near his grandparents' house, he was fascinated by women dressed in colorful folk costumes, and for his puppet theater he acquired two villager dolls, which are in his presented became angels, [4]. It is reasonable that he would show such an interest for folk art in visiting other cities where he often stayed, such as Sarajevo and Mostar, from where he could take away many visual and musical impressions. Therefore, we "peek" into the treasury of the *Zemaljski muzej u Sarajevu* (National Museum in Sarajevo), through the important publication *Ornamentation des oeufs de pâques coloriés en Bosnie-Herzégovine*, by Cvetko Đ. Popović (*Ornamentation of colored Easter eggs in Bosnia and Herzegovina, in Serbian: Ornamentika šarenih jaja u Bosni i Herzegovini*) from 1966, (Fig. 2) which shows geometric and other motifs that we compare to fragments from the work of Rudolf Laban, searching for possible inspiration that this artist could get by getting to know the ethnological motifs of these regions, [16]. The Serbian expert in folklore ornamentation, Jelica Belović-Bernadžikovska (1870-1946), who was an associate of the Austrian folklorist and owner of Vienna's *Anthropophyteia museum* Dr. Friedrich Salomon Krauss (1859 – 1938), wrote in 1918 that the most beautiful collection of colorful eggs from Bosnia was held by the National museum in Prague, and museum of Dr. Kraus, [17]. How emphasizes Cvetko Đ. Popović (1896-1980) painting eggs and believing in their miraculous power is part of folk customs that are deeply rooted in the Christian tradition, which is associated with Easter. Popović cites an article by the ethnologist Tatomir Vukanović (1907-1997) from the magazine of the *Umetnički pregled* (*Art review)* from National Museum in Belgrade, published in 1940: "…just as the egg is a symbol of fertility and life force, in the same way many patterns and ornaments painted on eggs have a significant meaning in folk religion and magic role, they serve as symbols of beauty, happiness, fertility, life force..."[18,19]. The layout of the ornamental surfaces, the regularity of the production, the beauty of the motifs, as well as the motifs made with parallel lines, in the form of smaller or larger rhombuses, comparative decoration with lines and dots, which can be seen on the colorful eggs (Fig. 2), contain elements that are known from archaeology since the Stone Age: triangles, spirals, slashes, simple and double stars, crosses, swastikas, sun chariots, S-motifs, the moon, dots in different arrangements, chess motifs, etc. Most of these motifs are symbolic. Reflections of such symbols can also be recognized in the patterns of Rudolf von Laban, as shown in the comparative analysis (Figs. 3, 4).

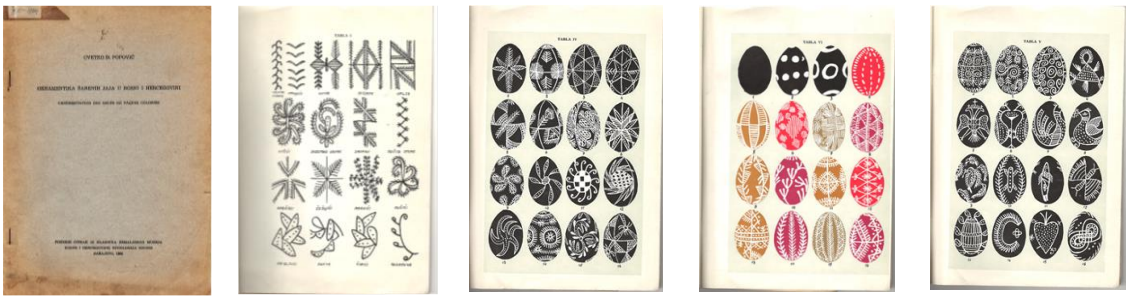

Figure 2: Title page of the publication *Ornamentika šarenih jaja u Bosni i Herzegovini* and representations from the collection of colored Easter eggs of the National Museum in Sarajevo, [16].

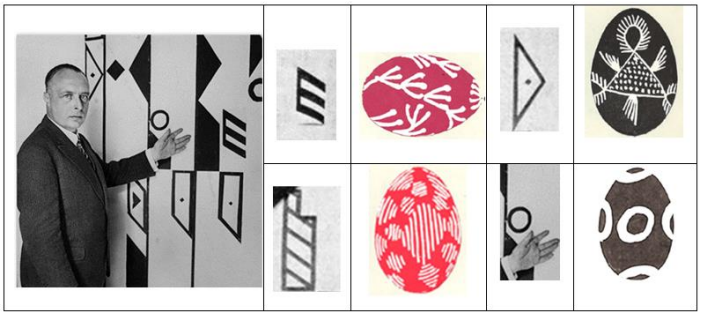

Figure 3: Rudolf Laban presenting his notation system, circa 1929, [20] and comparative view to patterns of egg from National museum in Sarajevo, [16].

When it comes to notation, returning to Jean-Gabriel De Tarde's universal opinion that every discovery comes from analogy with a previous discovery that copies a common principle, from the history of the development of notation [21], we can recognize a parameter that Tard calls a common principle. In this paper, in key study, we see common principle in medieval manuscripts based on neumes, which are interpreted in music the way word morphology is interpreted in linguistics. Just as visuality allows us to perceive deep connections between graphic and musical expression, this is also evident in the case of the connection between graphic expression and dance movement in Labannotation (Fig. 5). In the search for an archetype containing a common principle, as an example, we took one orthography from Laban's journal Schrifttanz (Fig. 5a) and compared it with a manuscript of a musical composition from the golden period of Serbian medieval culture [22], Acolouthia from the 15th century, in Serbian-Byzantine style, authored by the Serbian Orthodox hieromonk and composer Isaiah the Serb (*Fig. 5b*), whose chants were included in the well-known Anthologion 928 from the National Library of Greece. Comparing the details from Laban's orthography and Isaiah's manuscript visually confirms that this common principle exists (Fig. 5c), where we are talking about the physiognomy of the neuma and its expressive configuration, not about contextualization. It is reasonable to assume that, through a comparative analysis, similar details could be found in a large number of Neuma manuscripts, both of orthodox provenance and Gregorian, which according to the French expert in the philosophy of music and modal analysis, professor Jacques Viret, has its origins in Byzantine: "The origin of Latin neumatic notation could be located in Byzantium". As Viret concludes, "...a more specific comparatism takes into account the analogies, pointed out by C. Floros [*Die byzantinischen, slavischen und gregorianischen Tonfiguren und Formeln, Dokumentation*], between the records of Gregorian and Greek-Byzantine liturgical chants, which also includes the problem of the origin of Latin notation, and indirectly of its nature." Viret points out the graphic duality: “This graphic duality overlaps with the fundamental distinction, common to Christian liturgies, between cantilla readings – adapted to all-purpose formulas – and songs of a melodic character, composed for and on a text with which the melody is one (without excluding the occasional use common formulas)”, [23,24].

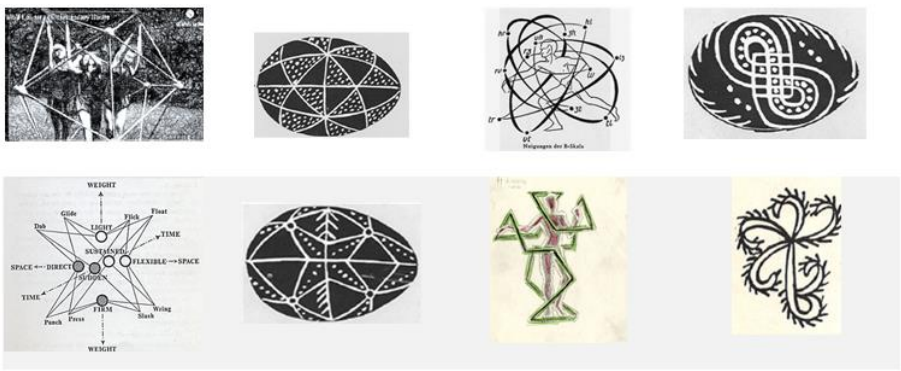

Figure 4: Comparative view to Laban’s philosophy of movement (insert from “Documentary Raitre” and drawings) and geometrical counterparts as possible sources of inspiration - patterns colored Easter eggs of the National Museum in Sarajevo, [25,26,27]

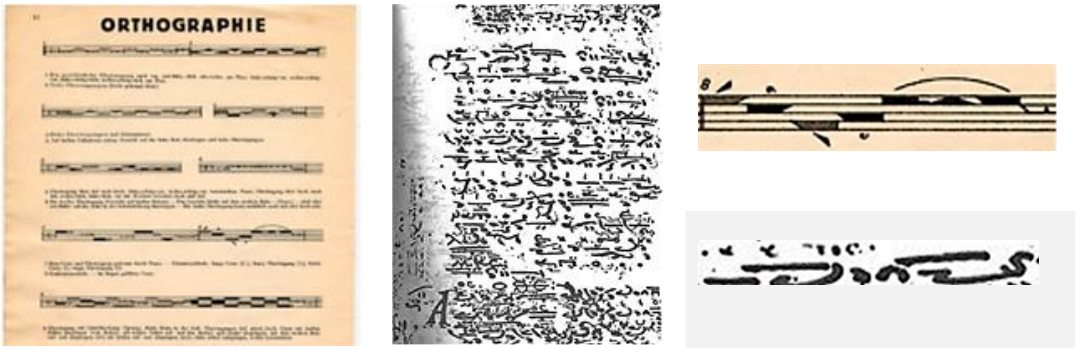

Figure 5: Detail - Excerpt from Rudolf von Laban's journal Schrifttanz, 1928, [3]; Detail from neume manuscript of music composition *Acolouthia* by Isaiah the Serb (XV sentury); comparative view to orthography and neume details, [28].

3. CONCLUSION

The research of visuality shown in this work was focused on the geometric aspects in the work of Rudolf von Laban, more precisely on the research of possible sources of influence from the formative period of this artist, based on known biographical data. The results show that Laban's universal philosophy of movement could have been inspired by the ethno-geometric motifs that, as a great fan of folk creativity, he could see in his childhood. The look at the geometric motifs on the objects in the collection of the National Museum in Sarajevo was not intended to result in any proof, but can be considered as an description of initial idea for a possible claim that folk art was the primary inspiration for the geometric expression of Laban, given that it lacks a more precise analysis of folk creativity from Bratislava, where Laban was born, educated and worked for some time and certainly acquired the most significant visual impressions. Also, an example of a comparative analysis of details from the Neum medieval manuscript and Laban's orthography, points to basically archetypal influences on the artist, where the manuscript shown is just one light-motive and example for thinking in that direction. With respect to all expert opinions that Laban's work was greatly influenced by contemporary art (constructivism / Dadaism), it can be concluded that what determined his philosophy of movement geometry in the formative period should still have been primary: in addition to the natural geometry of the mind and contemporary art, there were also most significant influences of the visuality of folk creativity.

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Belgrade, 15th December 2023

ENVIRONMENT AND SUSTAINABLE DEVELOPMENT. MECHATRONICS. OCCUPATIONAL SAFETY AND HEALTH AND FIRE SAFETY. SMART MANAGEMENT SYSTEMS. GRAPHIC ENGINEERING. DESIGN. TRAFFIC ENGINEERING. BIOTECHNOLOGY AND HEALTHCARE. MECHANICAL ENGINEERING. ECOTOURISM AND RURAL DEVELOPMENT.

BIOART AND OUR CREATIVE BIOTECHNOLOGICAL FUTURE

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Abstract: *Bioart, a growing interdisciplinary field at the intersection of biology, art, design and technology, is rapidly shaping our creative biotechnological future. This abstract explores the transformative potential of bioart as a medium for artistic expression, scientific exploration, and ethical inquiry. Bioartists employ living organisms, genetic materials, and biotechnological processes to challenge our preconceptions of life, identity, and the boundaries between art and science. This work examines the diverse manifestations of bioart, from genetically engineered sculptures to living installations, and the ethical implications that arise from manipulating life itself. Through an analysis of prominent bioart projects and the philosophical underpinnings of this genre, we illuminate the profound impact of bioart on our understanding of biotechnology, bioethics, and the creative potential of emerging scientific disciplines. As the boundaries of art and science continue to blur, bioart promises to inspire a new era of creativity, innovation, and reflection on the intricate relationship between humans and the living world. This abstract offers a glimpse into the dynamic field of bioart and its potential to shape our exciting and creative biotechnological future.*
Keywords: Bioart, Biotechnology, Plants, Art, Design, Future, Artificial intelligence

1. INTRODUCTION

Plant biotechnology is actually a very complex science that includes a large number of areas, and as a term it has been used with a much wider meaning since the beginning of the 1970s of the 20th century. It includes the entire spectrum of methods used for the manipulation of organic materials with the aim of meeting the requirements of many industries, especially food industry [1]. According to biologist Ana Simonović, "biotechnology combines disciplines such as genetics, molecular biology, biochemistry, embryology, cytology, systems biology and bioinformatics, as well as practical disciplines such as chemical engineering, information technology and robotics" [1]. It is applied in several industrial areas, but also in basic research and environmental protection. It is basically divided into traditional and contemporary. Modern biotechnology today attracts the most attention first of all because of the areas that belong to it, such as: genetic engineering, cloning and tissue engineering.

2. PLANT BIOTECHNOLOGY AND GENETIC MODIFICATION

To increase yields in agronomy, two approaches are used today:
1) crossing and selection of plants
2) spraying with pesticides and herbicides

In order to improve the quality of seeds, traditional genetic manipulations introduce desired traits into seed stocks [1]. However, in addition to certainly good results, there was a problem in the time duration of crossing the varieties. What was changed during the 20th century in relation to the

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traditional way of genetic modification and what resulted in the main achievement in this field of science is, as Simonović defines it: "the possibility of lateral transfer of genes from other organisms to cultivated plants, which then begin to produce new proteins, which was impossible to perform with traditional crossing methods" [1]. At the very beginning of the new millennium, more than half of America's total cotton and soybean crops were already genetically modified. Today, the United States is by almost any measure the globally dominant player in plant biotechnology. Almost half of global GMO production takes place in the US.

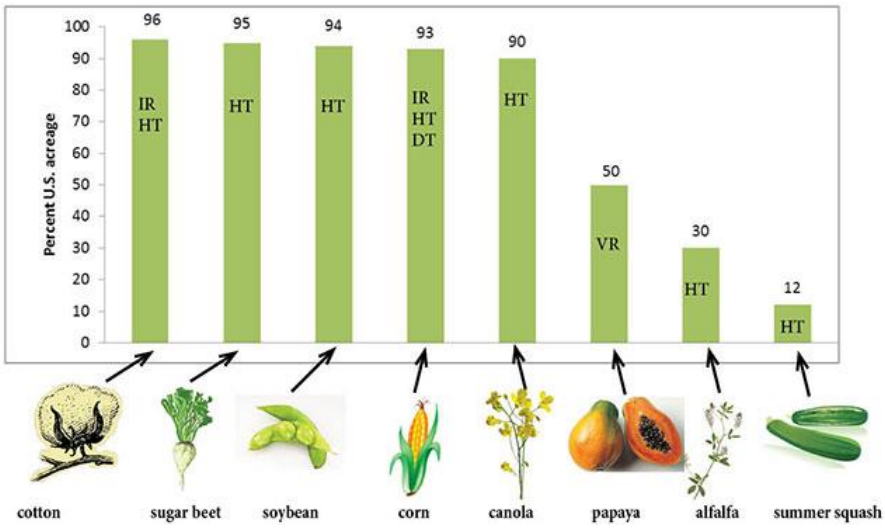

Figure 1. Figure 1. Currently grown GM crops in the U.S., traits for which they are modified, and percent of total acreage of the crop that is planted to GM varieties. IR=insect resistant, HT=herbicide tolerant, DT=drought tolerant, VR=virus resistant.

From the other side, many countries in Europe still do not approve the cultivation, sale and marketing of GM products on their markets, including Serbia, which may currently have the strictest laws on this issue. In the National Sustainable Development Strategy for the period (2009-2017), GM is mentioned in the part of the document that refers to "Biodiversity and nature protection" within the sectoral objectives, where it is stated that in this area: "the implementation of effective measures to control genetically modified organisms (GMO) in accordance with EU practice" [2].

On the other hand, within the framework of Agenda 2030, to which Serbia committed itself as a signatory in 2015, within "Goal 17", which also includes the target value for the "exchange area", it is mentioned that Serbia within the framework of the multilateral trade system, under the future auspices The World Trade Organization: "there is only one open issue of the ban on genetically modified products" [3].

It would be said that it has not been fully clarified what is specifically meant here, and whether it is an open question whether it is a positive or negative tendency for the Republic of Serbia. Or even more simply, what is actually expected of us by 2030?

3. SMART PLANTS AND BIODESIGN

Artificial intelligence, as a very advanced technology in the future, will not only affect the development of humans and animals, but also the plants themselves. Today, moreover, we have the opportunity to see the first experiments with the creation of artificial plant parts, in this case an artificial leaf that can create oxygen in space with water and light. Here we are not referring to imitation of the plants that we can buy in most stores today, but to a real invention in which the chloroplast, which is an integral part of every plant, is actually excluded. The cloned silk leaf is the invention of the British-Italian inventor and engineer Julian Melchiorri, whose profession is closely related to biotechnology and bio mimetic engineering [4].

Figure 2. Artificial leaf of Julian Melchiori (2014)

The application of biotechnology went one step further, so in 2016, a group of students from the Art Institute of Chicago, inspired by a cactus, created a concept for a roof plate structure that has a mechanism for "collecting water from fog".
Like a cactus, a "Fog catcher device" is able to collect and store water for later use [5]. Little is currently known about the specific technology or materials used to make this product, but its applications could be numerous. Biotechnological design (Biodesign) is already dealing with the issue of water management, which unequivocally indicates a very sustainable relationship between man and the ecosystem, where this is another example of technological innovation in a product inspired by Biomimicry.

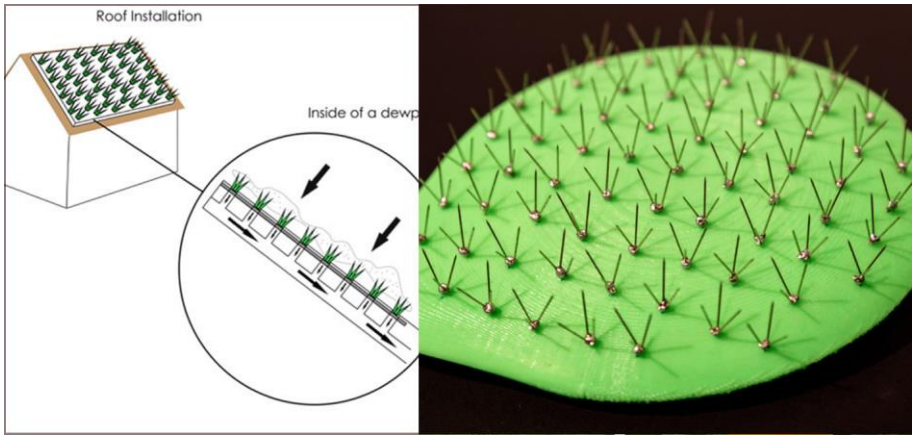

Figure 3. Fog catcher, Dew Point (2016)

It is certain that biotechnology and its processes, as well as potentials, strongly inspire art and significantly contribute to constant innovation, both in the world of applied arts and design, and in many other fields.

4. BIOART: FROM THE POINT OF VIEW OF ART AND DESIGN

In addition to many technological-industrial innovations derived from biotechnology as a base, there are also many artistic works that are very inspired by the same theme and that come to us from the artistic practice called BioArt [6]. This art actually uses the scientific processes of biotechnology, ie. creates experiments through artistic narrative that people make with bacteria, living tissues or any other life processes in the laboratory or outside. Within the group of BioArt there are, for example, Microbial art, Evolutionary art, Hybrid art and others.
One of the artworks that has recently attracted a lot of attention from the audience is Baroque Biology - Paper Theater by the Canadian bioartist Dr. Jennifer Willet. This artwork is actually a

series of Petri Dishes containing imagined biological vignettes in which non-human organisms teach humans complex biotechnological processes. These settings are very reminiscent of the serial engravings of the English painter and printmaker William Hogarth.

Figure 4. Baroque Biology with Petri Dishes, GMO Bacteria, Collage Materials (2019)

Like fairy tales from a biotechnological future, each allegory focuses on a fox or microbe, plant or fungus, trying to usefully communicate with humans about the biological processes which they use for survival, reproduction, and/or aesthetic pleasure [7].
Also, an extremely interesting and instructive artwork called From Teosinte [8] to Tomorrow, which enters to the land art zone, comes from the artists Molly Renda and William H. Dodge. They created a large one-acre corn labyrinth in the park of the North Carolina Museum of Art. The labyrinth itself is a symbolic entrance to multiple locations of this site specific land/art composition.

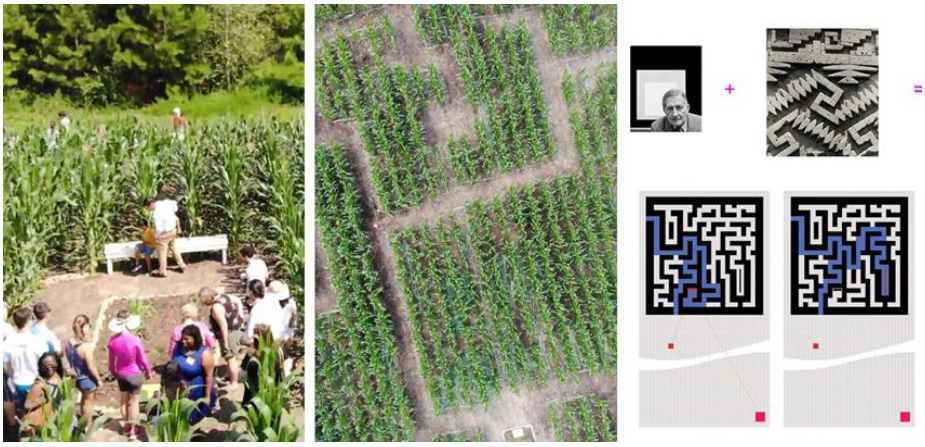

Figure 5. From Teosinte to Tomorrow, Molly Randa and William Dodge (2019)

This work of art is "rooted" in the earliest form of biotechnology, specifically in selective breeding and offers multiple ways to solve the "puzzle", and the terrain covered with teosinte plants represents thousands of years of agricultural history. As one of the earliest cultivated cultivars in the Western Hemisphere, the cultural significance of corn has invited conversations about issues such as population growth and climate change, but also about class, identity, community and genetics in society. Exploring the labyrinth was a very experiential way for a wide audience to engage with art in nature, to consider the issues that are the focus of this exhibition as well as to place themselves in a timeline that is measured in millennia [9].
What is also very common with the artistic practice of Bioart are various controversies surrounding many artworks where even in some cases the artistic narrative is being questioned. One of the those kind of works belonging to this group of art, which really does not leave anyone indifferent, is the

experiment of two British designers and artists Michiko Nitta and Michael Burton from the year 2010 under the name Algaculture [10].

Figure 6. Symbiosis of man and algae - Algaculture (2010)

In this work, they study and shape alternative ways how to power up and nourish our bodies, where they create a symbiosis of humans and algae, and where they propose that humans could actualy function according to the principles of photosynthesis, which would allow us to obtain food through light, in the same way plants obtain it. This is a very obvious example of the search not only for our self-sustainability, but also of redesigning the future human evolution which towards perhaps to some new "species" that would have the capabilities of both currently completely separate entities - man and plant.

5. CONCLUSION

In conclusion, bioart stands at the crossroads of creativity, science, and ethics, offering a fascinating glimpse into our creative biotechnological future. This interdisciplinary field has the power to transform our perception of life, art, and technology, challenging conventional boundaries and fostering a deeper understanding of the complex relationship between humans and the living world.
Throughout this exploration of bioart, we have witnessed the incredible diversity of projects and ideas that bioartists bring to life, from genetically modified organisms that serve as living canvases to thought-provoking installations that prompt us to reflect on our place in the natural world. By harnessing biotechnology and genetic manipulation as mediums for artistic expression, bioartists have demonstrated the limitless potential of human creativity and innovation. Furthermore, bioart serves as a catalyst for ethical discussions surrounding biotechnology. As we manipulate the building blocks of life in the pursuit of artistic expression, we must grapple with profound questions about the implications of our actions on ecosystems, living organisms, and the broader ethical landscape. Bioart compels us to consider the moral dimensions of biotechnological advancements, reinforcing the need for responsible and sustainable practices. In the grand scheme of our biotechnological future, bioart offers a powerful vision of creativity and introspection. It encourages us to question the nature of existence and our role in shaping it. As the boundaries between art and science continue to blur, bioart provides a compelling testament to the ingenuity and imagination of the human spirit. It invites us to envision a future where artistic expression and scientific innovation coexist, fostering a deeper appreciation for the wonders and complexities of life itself.
Ultimately, bioart transcends traditional artistic paradigms, pushing the boundaries of our creative biotechnological future, and inspiring us to explore the uncharted territory where art and science converge. As this captivating field continues to evolve, it has the potential to shape our understanding of life, technology, and the ethical considerations that will guide us in an ever-advancing biotechnological era.

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Student paper

USE OF GOLD COLOR IN INTERIOR DESIGN

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Abstract: *This paper researches the use of gold color in interior design, the types of materials used, their production, as well as their use. We will focus particularly on investigating the application of the gold color in wall decoration methods and techniques, as well as its use in glass, metal, stone, and wooden materials.*
Keywords: design, interior, gold, color, technique.

1. INTRODUCTION

The use of gold in interior design has a long history, dating back to ancient civilizations such as Egypt, where it was associated with wealth, power and divine beauty. Today, gold remains a timeless and versatile choice for adding the opulence and warmth to interior spaces. Golden color in interior design can bring a touch of luxury, warmth and timeless elegance to the space itself. Whether you choose to incorporate it subtly or boldly, gold has the power to transform an interior into a place of beauty and grandeur. The research will discuss the very techniques of using gold color on different materials that are most often used in interior decoration. Gold color, which is often associated with luxury, opulence and sophistication, has been a popular choice for interior design as a finishing touch for centuries. It can be used in a variety of ways to improve the overall aesthetics and ambiance of a space. The gold effect is used not only for its aesthetic appeal, but also for its ability to create a warm and inviting atmosphere [1]. When used judiciously, gold accents can transform a space, making it more welcoming, refined, and elegant. Gold can be implemented in the interior in different ways, such as gilded furniture, applications on the walls in the form of gold leaves, wallpaper and various wall treatment techniques. The choice of texture and finish can affect the overall feel of a space, from classic and ornate to modern and elegant [2]. Gold is a color that has stood the test of time. It has been a part of interior design for centuries and continues to be relevant in the contemporary and ~~even~~ minimalist aesthetics. This timelessness makes gold a reliable choice for those looking for lasting style.

2. CHARACTERISTICS OF GOLDEN COLOR IN THE INTERIOR

There are several types of gold colors used in interior design, each with its own unique characteristics and applications.
Classic Gold / Classic gold, often referred to as "yellow gold", is the most traditional and recognized shade of gold. It's a warm, rich shade that brings a sense of luxury and sophistication to a space. It is used in a variety of interior elements, including furniture details, lighting fixtures and decorative accessories.
Rose Gold / Rose gold is a softer and more delicate variation of gold, characterized by a pink hue. This contemporary approach to gold has gained popularity in recent years, especially in modern and minimalist interior design. Rose can be utilized in accessories, textiles, and smaller decorative items to achieve a chic and modern appearance.

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Champagne Gold / Champagne gold is a subtle and muted golden color with hints of beige or dark red. It exudes a sense of understated luxury and is often used in furniture upholstery, curtains and wall treatments. Champagne gold can add a touch of sophistication without overwhelming the space.
Antique Gold / Antique gold creates has a worn antique or old aged look appearance, which makinges it ideal for vintage or shabby-chic interior styles. It is often used in antique furniture finishes, decorative mirrors and ornate picture frames to evoke a sense of history and nostalgia.
Bronze and Copper Gold / Bronze and copper gold tones have a more pronaunced reddish or brownish undertone compared to classic gold. These variations can be used in "hardware" such as drawer pulls and doorknobs, as well as in accent pieces to create a warm and rustic atmosphere.
Metalic Gold / Metallic gold is a high shine, reflective gold commonly used in modern and contemporary interior design. It is popular for contemporary furniture, accent walls and glossy finishes. The reflective quality of metallic gold can enhance the effect of natural and artificial light in a given room.
Verdigris Gold / Verdigris gold combines the richness of classical gold with the patina it lacked. This unique finish is used in architectural details such as moldings and trim to create a sense of worn elegance.
Gold is most comonly applied to the surfaces by a technique of gilding, the application of gold leaf or gold foil to surfaces such as walls, ceilings and furniture. This technique adds a glossy and opulent finish to interior elements, often seen in luxurious, historic spaces.

3. DECORATIVE TECHNIQUES

Calce Cruda is a microporous decorative coating of mineral nature. The clay component, which is its integral part, creates a network structure of particles, adjusts the processing time and improves the workability of the product. Cellulose fibers strengthen the structure, thus contributing to the stronger binding with the other components. Calce Cruda makes it possible to achieve superior finishes with a wrinkled effect, soft and warm colors, while providing an elegant interior decoration. This technique is applicable on new and old binder-based plasters, gypsum and plasterboard surfaces, old paints as well as various absorbent mineral conglomerates, **Figure 1.**
Travertin is a material composed of the mineral raw materials that allows for various decorative techniques. It is commonly used to achieve the effect of natural Travertine stone. This material's composition prevents the growth of mold, algae and bacteria, has a low odor content, is non-flammable and is environmentally friendly. One of the significant advantages of this technique is durability and quality, as it is resistant to water, UV radiation and weather effects. This technique is suitable for both interior and exterior due to its versatile properties. It can be in one or more colors, matte or glossy finish, **Figure 2.**
Swahili, (a product of the Italian company *NovaColor*), is a decorative material whose collection consists of a water-based finish with metallized particles, producing an unparalleled crystal reflective effect with a refined and futuristic design. The inclusion of metallized particles allows this decorative coating to create varying and pleasing interplays of light and color reflections. It is available in two different bases: silver and gold. Swahili in gold is an excellent choice for interiors where a gilded effect is desired. Additionally, thanks to its rich collection of colors, it can be utilized in various other interior solutions, **Figure 3.**
Ottocento is a water-based technique for walls for interior decorative use. It was specially designed to provide new solutions in the field of interior decoration providing spaces with a highly refined elegance. Featuring a satin appearance, it includes reflective grains that, influenced by bestow a sophisticated elegance to the material. Utilizing cutting-edge technologies, Ottocento guarantees durability and washability. Notable characteristics of this include its ecological nature, non-toxicity, odorlessness, non-flammability, vapor-permeability and waterproofing (allowing the wall ~~can~~ to breathe), it holds European Union class 1 certificate. Over time, Ottocento maintains stable resistance, remaining unreactive to tobacco smoke, and proving resistant to impacts, scratches, and abrasion

(mold). Cleaning is hassle-free as it can be washed with water, and soap effectively removes alcohol, grease, and oil stains using a sponge, **Figure 4.**

Africa, a product of the Italian company *NovaColor* is an exclusive decorative material designed for interior surfaces, featuring a silk effect. It produces a silky surface that elicits exceptional sensations upon touch, imparting a surprisingly warm finesse to the space. The Africa decorative material introduces comfort and refinement to the interior. With its remarkable shine and warm color shades, it enables the creation of modernly decorated walls that, when combined with lighting, evoke a wonderful and unique ambiance in alignment with contemporary trends in interior design. Figure **5.**

The spatula technique is most often used in the decoration of the walls of prestigious buildings, and enhancing the modernity of structures and elevating the beauty of classic interiors. Often referred to as "fake marble", this decorative material yields similar final effects under various names and manufacturers encountered during our research. Its composition includes the finest stone dust mixed with colorants and oils imparting a shiny finish that reveals traces of the application process. The spatula decorative material resembles an opaque paste crafted from natural stone, offering a choice between matte or glossy effects. The final look and structure mimic polished stone or marble, contingent upon the execution technique, **Figure 6.**

Hoblio, product of the Italian company *Candis*, is a particularly pleasant decorative material for interior decor from the Antiche Terre Fiorentine line, developed to give the walls of a room a pleasant and charming look. It combines the beauty and durability of a wall that should last over the years. In terms of aesthetics, Hoblio offers different solutions: gold, silver bases, which reproduce light effects and shadows, as well as a final look reminiscent of sand dunes in the desert created by the wind. The characteristic of this decorative paint is that it is completely water-based, of moderate vapor permeability, and that it is an organic product, which tells us that the raw materials were carefully selected, **Figure 7.**

Antiche Terre Fiorentine Vintage (product of the Italian company *Candis*) is a decorative material that belongs to the "Classic" group of products in the Antiche Terre Fiorentine line. Vintage coating offers a wide range of harmonious colors that allow for creating an elegant ambience. Vintage is available in eight different color families: Vanilla, Coral, Amber, Sea Breeze, Rose, Lagoon, Parchment and Forest. These bases also contain small amounts of pearl micro-pigment, which gives the decorative paint on the wall the appearance of a soft and slightly shiny surface, the so-called. "Pearl effect". Vintage is a decorative material that is completely water-based, semi-transparent, ecological and consists of carefully selected raw materials. **Figure 8.**

Tuscania Antica (product of the Italian company *NovaColor*) is a decorative material designed as a special coating, with the aim to create creative solutions for interior spaces and achieve unique effects by combining color, shape and light. This decorative material is formulated to avoid color washes and decorative stains, typical of the Italian historical heritage. Gradual darkening of shading is easily contained thanks to the natural transparency of the use of pigment and the application of several layers of the same or different color. The surfaces aquire an antique effect or the effect of an old wall [3]. **Figure 9.**

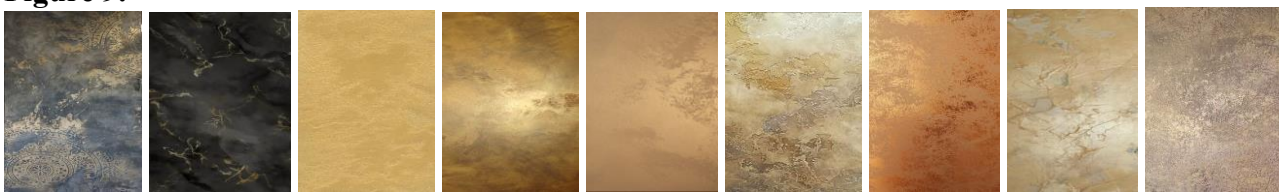

Figure 1. *Calce Cruda* **Figure 2.** *Travertin* **Figure 3.** *Swahili* **Figure 4.** *Ottocento* **Figure 5.** *Africa* **Figure 6.** *The spatula* **Figure 7.** *Hoblio* **Figure 8.** *Vintage* **Figure 9.** *Antica*

Source: https://www.wall-decor.rs

4. GLASS

Gold-colored lighting fixtures, such as chandeliers, lamps and other elements, can serve as focal point in the room. The reflective surfaces of golden lighting create a soft, warm glow, creating a pleasant and inviting atmosphere. The type of gold used as a finishing touch to lighting fixtures in interior

design can greatly affect the overall look and feel of a space. Different gold finishes offer different aesthetic possibilities and combine well with different interior design styles.
The choice of gold finish for lighting fixtures should be align with the overall design concept of the room and the ambiance we want to create. Finishing should be in accordance with the color palette, furniture and decor of the space itself. Whether polished, satin, antique, champagne, metallic, rose gold, verdigris gold or gilded, choosing the right gold finish can enhance the aesthetics and atmosphere of an interior, making fixtures both functional and visually appealing.
Creating the golden color of glass involves different techniques and processes, depending on the desired outcome. Gold glass can add a touch of elegance and sophistication to windows, mirrors and glassware. Gold pigmentation in glass is achieved by adding real gold, in the form of gold chloride or gold nanoparticles, during the glass making process. [4] Gold is a unique and valuable material that gives glass a rich and warm metallic gold color, creating a luxurious and opulent aesthetic.
Gold chloride (AuCl) is a gold compound used in the glass industry to create gold pigmentation. It is added to the glass melt during the manufacturing process. Gold chloride decomposes at high temperatures, releasing pure gold atoms that are evenly dispersed throughout the glass. This dispersion results in a characteristic golden color. The concentration of gold chloride used can be varied to achieve different shades of gold in the glass, from pale gold to deep and lustrous tones.
In recent technological advances, gold nanoparticles have been used to achieve gold pigmentation in glass. These nanoparticles are extremely tiny particles of gold suspended inside the glass. They can produce vivid and uniform gold colors in glass with the added benefit of improved transparency and reduced cost compared to using gold chloride.
Gold pigmented glass is especially prized for its luxurious appearance and is often used in architectural applications, stained glass, decorative glassware and artistic glass sculptures. Its warmth and glow make it a popular choice for adding a touch of opulence to a variety of design elements. The gold pigmentation process allows glass manufacturers to create a wide range of gold shades, meeting the diverse needs and preferences of artists, architects and designers.

5. METAL

Gold pigmentation on metal objects is most often achieved by various methods of coating, coating or alloying. Unlike glass, where gold chloride or gold nanoparticles can be added directly to achieve a golden color, metals are not usually pigmented with elemental gold. Instead, gold finishes or colors in metal objects are created using alternative techniques.
Some metal objects are coated with a gold-colored finish, which does not necessarily contain real gold. These gold-tone coatings can be made from a variety of materials, including brass, copper, or other alloys thereof, which are treated to mimic the appearance of gold. Although they may resemble the color of gold, they do not contain real gold. Some metals, such as white gold or rose gold, are created by alloying gold with other metals such as silver, copper or palladium. These alloys can result in a wide range of gold colored metal objects with different shades [5]. For example, rose gold contains a higher percentage of copper, which gives it a pink or pink hue. In certain applications, gold-colored powder or paint can be applied to metal surfaces to achieve a gold finish. These products may contain metallic pigments or other colors that create a golden appearance when applied and dried.
In architectural and interior design, gold veneer is sometimes used to cover metal surfaces to achieve a golden appearance. Veneers are thin layers of real gold adhered to a metal base, creating a golden finish.
It is important to note that the quality and durability of gold pigmentation on metal objects can vary depending on the method used. Gold plating offers the appearance of real gold, but may require maintenance over time. Gold-colored coatings will not have the same longevity or authenticity as gold plating or gold alloys. The choice of method depends on factors such as cost, aesthetics and intended use, and it is important to consider the specific application and desired level of gold appearance when dealing with metal objects.

6. WOOD

Gold pigmentation in wood finishes does not usually involve the use of elemental gold, as gold is not soluble in the solvents or chemicals commonly used in the production of wood moldings and finishes. Instead, gold pigmentation in wood is achieved by using pigments, dyes or metal powders that mimic the appearance of gold.

Metal powders, often made from materials such as bronze, brass or aluminum, are added to wood finishes to create a metallic effect. These powders can provide a gold-like appearance when combined with a clear or tinted wood finish. They are especially popular in woodworking and fine furniture making. *Paints and stains* that are specially formulated to achieve a gold or metallic effect can be used on wood. These products may contain pigments that create a metallic sheen or golden hue when applied to wood. They are often used in the craft and woodworking industry for decorative and artistic purposes.

Gold glaze is a transparent, colored finish that can be applied over a base coat of paint or stain. Gold glazes contain metallic pigments that provide a shimmering, golden effect while allowing the underlying grain of the wood to show through. Glazing is commonly used in finishing furniture and cabinets. *Fake finishing techniques* - sponge, wear or patterning. These methods involve applying layers of paint, glaze, and metal powder to simulate the appearance of gold. Faux finishes can be highly customized and artistic. When choosing a method to achieve golden pigmentation in wood, it is important to consider factors such as the level of authenticity, the desired gloss, the type of wood and the use. While some techniques, such as the use of metal powder or gold leaf, can provide a more authentic look of gold, others, such as metallic paints and stains, can offer a shimmering metallic effect without the expense and complexity of real gold [6].

5. STONE

Gold pigmentation in natural stone does not usually involve the use of elemental gold as it is expensive and impractical for this purpose. Achieving the appearance of gold in natural stone is often achieved through the use of pigments, minerals or coatings that mimic the appearance of gold.

Certain natural stones, such as granite or quartz, may naturally contain *mineral inclusions* that give them a golden or metallic appearance [7]. For example, quartz with pyrite inclusions may have a golden or brassy appearance. Although this is not a traditional pigment, it is a natural way for the gold color to appear in the stone. To enhance or change the color of natural stone, *pigmented sealants or coatings* can be applied. These products may contain pigments, including metallic powders or mica, which create a golden or metallic sheen on the surface of the stone. [8] This technique is often used to achieve specific aesthetics on countertops and floors. Skilled artisans can create *faux gold* finishes on natural stone using *painting techniques* that mimic the appearance of gold. Faux finishes often involve the use of metallic paints, glazes and artistic techniques to create a golden appearance on stone surfaces. *Gilding* is a technique in which thin sheets of real gold leaf or gold foil are applied to the surface of a natural stone to create the appearance of real gold. Gilding is a labor-intensive and artistic process often used in architectural applications and fine art. In some cases, a *custom-colored epoxy* or *resin* can be used to achieve a gold-like appearance in natural stone. This method is particularly relevant in applications where stone surfaces need to be repaired or restored. When choosing a method to achieve golden pigmentation in a natural stone, it is important to consider factors such as the type of stone, surface finish, desired level of authenticity, and intended use of the stone. Pigmented sealers, coatings and tinted resins can be applied to different types of stone to achieve a golden color, while mineral inclusions and gilding can be used in certain situations to achieve a certain aesthetic. The choice depends on the unique requirements of the individual project and the effect we want to achieve.

5. CONCLUSION

A team of designers from *Boca Do Lobo Studio* from Portugal, who create timeless pieces of furniture, said: "*Owning furniture in gold symbolizes wealth and prosperity. Our talented designers and master craftsmen create every piece of furniture that represents jewelry for the home*" [9].
The research in this ~~e previous~~ work shed light on the multifaceted role of the color gold in interior design. During the study, it was found that gold is not only a shade, but also a versatile element that has the potential to elevate and enhance interior spaces in numerous ways. Finally, the application of gold color in interior design goes beyond mere aesthetics. It serves as a means of expressing opulence, warmth and timeless elegance in interior spaces. As the study shows, it is a versatile tool that designers and homeowners can use to create stunning and luxurious environments. The findings here not only provide valuable insights for interior designers, but also inspire further research into the interplay of color and ambience in the realm of design. Gold, in all its richness, continues to shine in the world of interior design, enriching spaces with its enduring appeal.

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Student paper

USE OF COPPER IN INTERIOR DESIGN

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Abstract: *Copper is one of the oldest elements known to humankind throughout its development. Since ancient times, copper has been esteemed for its exceptional value and practicality. From ancient cultures using it for the crafting of weapons and tools to the creative masters of the Renaissance employing it in the creation of refined artistic works, copper has left an indelible mark on the history of human creativity. Throughout the centuries, its application has expanded into various domains, including architecture, art, and interior design, leaving a legacy that continues to inspire and enrich our contemporary culture and aesthetics. Through research, we have examined the rich history of copper as a material that has shaped human history and continues to define our present, through its ubiquitous role in creating inspiring and functional interiors. We have engaged in the analysis of copper properties, as well as its various applications in different parts of interiors. Additionally, we explored the global impact of this element on interior design.*
Keywords: design, copper, interior, furniture, properties

1. INTRODUCTION

In recent decades, copper has become an indispensable material in interior design, bringing warmth, luxury, and subtle charm to modern spaces. Its diverse use spans a wide range of interiors, from kitchens and bathrooms to living rooms and commercial areas. The exceptional adaptability of copper allows designers to create different styles, from modern minimalist to classic traditional, adapting to diverse preferences and client demands. By combining subtle copper tones with various textures and materials, designers craft rooms that exude authenticity and elegance. This study explores the role of copper in contemporary interior design, considering how this refined material shapes spaces, adding a touch of luxury and warmth that leaves a lasting impression on observers and space users.

2. PROPERTIES OF COPPER

Copper is a chemical element with the symbol Cu (from Latin Cuprum) and atomic number 29. The period of history from the 5th millennium to the 3rd millennium BCE, during which copper was extensively used in various fields, is referred to as the Copper Age. By mixing copper and tin, bronze, a hard alloy that gave its name to the subsequent era, the Bronze Age, was obtained, replacing the Chalcolithic period [1]. This element is characterized by many significant properties, which we will analyze individually.

High Conductivity

Copper is characterized by exceptional electrical conductivity, making it a valuable material in various industries. Its ability to efficiently conduct electric current allows for a wide range of applications in different interior aspects, from functional elements to decorative details [2].

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When it comes to interior design, the high conductivity of copper opens the door to diverse creative possibilities. The incorporation of copper electrical installations enables the efficient distribution of electrical energy in a space, ensuring optimal functionality of electrical devices and lighting. By using copper conductors in interior installations, designers can ensure a stable and safe flow of electrical energy, minimizing power losses and ensuring the reliable operation of electrical systems. For this reason, copper is often used in the production of various lighting elements, such as chandeliers, lamps, and wall sconces, due to its ability to create warm light and accentuate the beauty of the interior. Its high conductivity allows for the efficient flow of current through these elements, simultaneously providing an aesthetically appealing glow that enriches the room's ambiance.

Corrosion resistance

Copper's resistance to corrosion is a key characteristic that makes it an extremely prevalent material in interior design. Its ability to retain its original properties in various humidity conditions and chemically aggressive environments allows for a wide range of applications in spaces such as kitchens, bathrooms, and other areas exposed to moisture and changing conditions [3].

In the context of interior design, copper's corrosion resistance enables the creation of durable and aesthetically appealing furniture pieces. When used in kitchen design, copper is often applied in the fabrication of sinks and faucets, providing long-lasting luster and preserving its aesthetic form despite the daily challenges of exposure to water and chemicals. Its ability to maintain its shine and physical characteristics makes it a popular choice among interior designers aiming to create rooms that are both functional and aesthetically attractive.

In bathroom design, copper is frequently used in the fabrication of shower cabins, sinks, and other bathroom elements that require a material resistant to moisture and chemical substances. Copper's corrosion resistance allows for the preservation of the aesthetic appearance and functionality of these elements over an extended period despite exposure to a humid environment, simultaneously providing a sense of luxury and sophistication that enhances the overall experience of being in a particular space.

Simple Design

Copper stands out with its exceptional flexibility and ease of shaping, making it a suitable material in furniture design. Its ability to easily adapt to different shapes and textures allows designers to create diverse aesthetic effects and functional elements within interiors.

When it comes to interior design, copper's property of easy shaping enables the creation of unique furniture pieces and decorative elements. Designers can use copper to craft elegant lines and refined forms in furniture such as chairs, tables, and dressers. Its flexibility allows for the creation of intricate details and reliefs on the surface of furniture, adding a touch of luxury and sophistication to the space [4].

Aesthetic Appeal

The aesthetic appeal of copper is a unique characteristic that makes this metal irreplaceable in interior design. Its distinctive reddish color and natural sheen, reminiscent of the so-called rose gold effect, create an atmosphere of warmth, luxury, and authenticity.

When used in interior design, the aesthetic appeal of copper is showcased through various decorative elements and details. Integrated into lighting design, copper can create a refined and elegant ambiance, providing warm light that further accentuates the texture and color of the room. Its gleaming shine creates a visual effect that enriches the interior, making a pleasant space that captures attention and stands out in the environment.

Recyclability of Copper

The recyclability of copper is a key characteristic that makes it an environmentally friendly material in interior design. Its ability to be recycled and reused enables a reduction in the exploitation of

natural resources and contributes to a sustainable approach in design, making it a desirable choice in creating functional and sustainable interiors.

3. WAYS TO USE COPPER IN INTERIOR DESIGN

Copper is a versatile metal that is increasingly used in various aspects of interior design. Its ability to be easily shaped, aesthetic appeal, high conductivity, and corrosion resistance make it a suitable resource for use in interior design. We will list some ways in which copper can be used in furnishing spaces:

COPPER DETAILS

Copper details in interior design can include various objects and elements made from copper materials. The process of creating these details typically involves a series of steps such as cutting, shaping, welding, grinding, polishing, and finishing to achieve the desired functional and aesthetic quality. These processes are often carried out using specialized tools and techniques, and craftsmanship plays a crucial role in creating high-quality copper details in interior design.
Copper details may encompass:
Handles and Hardware: Copper is often used to craft handles, knobs, and hardware for furniture, cabinets, and other pieces. These components can be handmade or machine-fabricated, shaped from copper rods or sheets, and then processed to achieve the desired form and texture.
Lighting: Copper is used in the creation of various types of lighting, including lamps, chandeliers, wall sconces, and other lighting elements. These pieces are often crafted by combining copper elements with other materials such as glass, wood, or fabric to achieve the desired aesthetic and functional effect.
Decorative Items: Copper is also used to create various decorative objects such as vases, bowls, and other ornamental elements. These items are typically shaped from copper sheets or rods and then processed to achieve a specific shape, texture, and shine.

KITCHENS

Copper provides the kitchen with a warm and rustic aesthetic that adds a touch of luxury and elegance to the space. Its natural shine and reddish color create an appealing contrast with other materials used in the kitchen. When it comes to designing kitchens, copper is often used in the production of sinks, faucets, kitchen hoods, cookware, or decorative elements in the kitchen. This material can add contrast and warmth to the space, creating a pleasant atmosphere for cooking and gathering. Some ways in which copper can be used in kitchen design include:
Sinks and Faucets: As previously mentioned, copper is extremely resistant to corrosion, making it a durable material for kitchen elements such as sinks, faucets, and cookware. Copper's resistance to wear and damage contributes to creating a kitchen that retains its original appearance and functionality over an extended period of use. It is used to manufacture sinks and faucets, which are often produced by combining copper sheets and copper rods. These elements are shaped according to specific dimensions and shapes, then welded and processed to achieve the necessary strength and aesthetic effect. Copper sinks and faucets often undergo grinding and polishing processes to achieve a high shine and a smooth texture that highlights the metal's natural brilliance.
Cookware or Kitchen Accessories: Copper is used to make kitchen accessories such as stove lids, hoods, decorative panels, and countertops. These elements are typically made from copper sheets that are cut, shaped, and processed according to specific dimensions and design requirements. After being shaped, these elements are often polished to achieve the desired shine and texture.

FURNITURE

In interior design, copper is often used to create various pieces of furniture that emphasize the aesthetic value of the space and provide unique sophistication. These furniture pieces include:

Tables: Copper is frequently used to craft different types of tables, including dining tables, console tables, and coffee tables. Tables with copper elements typically have copper legs or frames combined with glass or wooden tops, creating elegant and modern furniture pieces.
Chairs: Copper is also used to make various types of chairs such as barstools, dining chairs, and armchairs. Chairs designed with copper often feature copper frames or details combined with fabric or leather, providing comfort and elegance simultaneously.
Beds: Copper is used to create elegant beds with copper frames or details that add sophistication and warmth to the bedroom. Copper beds often have a unique design that combines the rustic appeal of metal with the comfort and luxury of fabric.
Shelves and Dressers: Copper is frequently used for crafting shelves, dressers, and other storage elements that add functionality and style to the space. These shelves often have copper frames or details combined with wooden or glass shelves, providing a practical solution.
Mirrors: Copper is used to create decorative frames for mirrors that highlight the sophistication of the space. Copper mirror frames often have a rustic appearance that adds warmth and authenticity to the space, emphasizing the value and character of the interior [5].

WALL DETAILS

The use of copper in wall details contributes to the creation of elegant, rustic, and sophisticated interiors. Copper is often used to craft various decorative elements that add texture, depth, and visual appeal to the walls. These elements can be used as decorative coverings, panels, reliefs, or ornamental details.
Copper Panels: Copper panels are commonly used as decorative coverings on walls, providing warmth and luxury to the space. These panels are typically made from copper sheets that are shaped according to specific dimensions and design requirements. After shaping, copper is further processed to achieve the desired texture and shine, giving the walls an authentic look that highlights the sophistication of the space.
Copper Reliefs: Copper is often used to create reliefs that add depth and texture to the walls. These reliefs are crafted either manually or mechanically, shaping copper according to specific design schemes and patterns. After shaping, copper undergoes processes such as patination or oxidation to achieve the desired visual effect that emphasizes the texture and details of the relief.
Decorative Copper Details: Copper is also used to craft various decorative details such as decorative plates, moldings, and wall ornaments.

4. GLOBAL IMPACT OF COPPER ON INTERIOR DESIGN

The global impact of copper on interior design is reflected through diverse cultural interpretations and regional preferences shaping various aesthetic, functional, and stylistic approaches. Different cultures and geographic areas worldwide have specific traditions, values, and preferences influencing how copper is used in interior design. Here are a few examples of how copper usage differs on certain continents:
Asia: In countries like India, China, and Japan, copper is traditionally used in crafting decorative elements such as vessels, candles, and reliefs. These pieces reflect the rich history and culture of these regions, highlighting sophistication and elegance through intricate engravings and textures.
Europe: In European interior design, copper is often a key element in creating rustic, elegant, and luxurious interiors. Countries like Italy, France, and Spain have a rich tradition of using copper in crafting furniture, decorative details, and architectural elements that emphasize the authenticity and opulence of the space.
North America: In the United States and Canada, copper is frequently used in contemporary and industrial design approaches, adding sophistication and modern elegance to spaces. Copper is often integrated into kitchen, bathroom, and residential designs, emphasizing their functionality and aesthetic value.

Africa: In African interior design, copper serves as a crucial element highlighting traditional aesthetics, culture, and artistic heritage. In countries like Morocco, Egypt, and South Africa, copper is often used in crafting traditional vessels, artistic sculptures, and decorative details reflecting the authenticity and identity of local communities.

Through these examples, it becomes evident that the use of copper in interior design varies globally, reflecting specific cultural, historical, and sociological influences shaping aesthetic and functional preferences in different regions and parts of the world. Integrating copper into various interior design styles and traditions provides spaces with a unique appearance, emphasizing the importance of culture and local identity in creating inspirational and authentic interiors.

5. CONCLUSION

Research has shown that copper, through its ability to be shaped into different forms and textures, allows designers to create diverse interior styles tailored to the specific requirements of clients and market preferences. Its functionality, especially in kitchens and bathrooms, enables the creation of spaces that simultaneously meet the aesthetic and practical needs of users.

Furthermore, the research emphasizes the importance of sustainability and the environmental friendliness of copper, making it a desirable choice in the context of the growing awareness of environmental protection. The recyclability of copper contributes to reducing the exploitation of natural resources and minimizing the negative impact on the environment, highlighting its role in sustainable interior design.

Finally, the research clearly demonstrates that copper has a comprehensive impact on creating aesthetically appealing, functional, and sustainable interiors. Its numerous advantages, coupled with creative applications in interior design, make it an irreplaceable resource that brings elegance, warmth, and authenticity to every space. Through further research and the use of innovative approaches, new perspectives for using copper in interior design can be explored, creating spaces that reflect harmony between functionality, aesthetics, and sustainability.

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TRAFFIC ENGINEERING

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ENVIRONMENT AND SUSTAINABLE DEVELOPMENT. MECHATRONICS. OCCUPATIONAL SAFETY AND HEALTH AND FIRE SAFETY. SMART MANAGEMENT SYSTEMS. GRAPHIC ENGINEERING. DESIGN. TRAFFIC ENGINEERING. BIOTECHNOLOGY AND HEALTHCARE. MECHANICAL ENGINEERING. ECOTOURISM AND RURAL DEVELOPMENT.

ROAD SAEFTY MANAGEMENT CAPACITY REVIEW – USE OF TAILOR-MADE CHECKLISTS

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Abstract: *During Road Safety Management Capacity Reviews, researchers can employ a variety of approaches and assessment tools. Various checklists are used to make review approaches as efficient and unified as possible. This paper presents and discussesthe merging of different approaches with accompanying checklists into a single tailor-made checklist that extends any of the single approaches and provides researchers with a broader range of information for future interventions.*
Keywords: Road Safety Management Capacity Review, Checklists

1. INTRODUCTION

Prior to the implementation of any road safety interventions, it is essential to conduct a comprehensive Road Safety Management Capacity Review (RSMCR). The Road Safety Management Capacity Review (RSMCR) is crucial for gaining an in-depth understanding of the current state of road safety within a country, whether at the national or local level. It serves as a tool for conducting a thorough gap analysis between current road safety practices and the best international practices. Furthermore, the RSMCR aids in identifying adequate interventions that can be implemented to enhance road safety performance.
The use of different checklists is a common method for evaluating the current state of road safety in road safety assessments. If checklists are difficult to read and comprehend or fail to include important issues for review, problems with implementation will occur. These problems could possibly result in the absence of crucial information, consequently leading to a lack of interventions that might improve road safety. This paper presents and discusses various RSMCR checklists and proposes how they might be merged to some extent.

2. RSMCR APPROACH/METHODOLOGY

Several approaches (methodologies) are used for RSMCR at the national level, with the one promoted by the World Bank (WB) being the most prevalent. The aforementioned approach is founded on the guidelines provided by the Global Road Safety Facility (GRSF) pertaining to Road Safety Management Capacity reviews and Safe System projects [1]. The Guidelines comprise a total of 12 supporting checklists. The notion of review relies on the expertise of highly experienced reviewers who are regarded as having a profound understanding of road safety management. This is necessary due to the presence of complex questions that may be challenging to comprehend and implement. In some cases, checklists may exhibit a more generalised nature, lacking specific and clear instructions for implementers. Some questions have the potential for several interpretations,

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leaving space for different points of view. This is why it is imperative to incorporate supplementary questions and expand initial checklists in order to obtain a comprehensive and unified assessment of the road safety situation within the country, regardless of who is tasked with implementing the RSMCR methodology. The process of merging different checklists should be approached with caution in order to avoid a possible repetition of issues/questions.

2.1 About WB GRSF RSMCR

The RSMCR is an activity initiated by the World Bank that aims to gain a holistic and detailed understanding of the road safety management capacity within the researched country. The ultimate objective of this assessment is to provide assistance to the government, typically the Ministry of Transport, in developing a national Road Safety Strategy and corresponding Action Plans, that are designed to improve road safety performance within the country.

2.2 Steps in RSMCR

The Guidelines promotes several steps during RSMCR:

1. Set review objective
2. Prepare for review
3. Appraise results' focus at system level
4. Appraise results focus at interventional and institutional level
5. Assess lead agency role and identify capacity strengthening priorities
6. Assess road safety approach at local level
7. Specify investment strategy and identify Safe system implementation projects
8. Translate the above findings into comprehensive Action plan
9. Confirm review findings at high-level workshop
10. Finalize review report

Among specified steps, steps 3 through 6 are based on different assessments using accompanying checklists, which require an in-depth understanding of road safety management.

3. USAGE OFCHECKLISTS

3.1 WB RSMCR Checklists

Within the WB GRSF RSMCR Guidelines, the road safety management system is described through the so-called "Road Safety Pyramid" where three interrelated elements: institutional management functions, interventions, and results are presented (Figure 1—left, light blue shaded side).

The cornerstone of road safety management systems is established by seven key institutional management functions: coordination, legislation, funding and resource allocation, promotion, monitoring and evaluation, research and development, and knowledge transfer.

Interventions include several aspects such as the planning, design, operation, and usage of the road network, as well as the entry and exit of vehicles and road users to and from the network. These interventions are strategically formulated to efficiently achieve the targeted outcomes.

Results refer to the quantification of the desired results and their expression as targets, encompassing final outcomes, intermediate outcomes, and outputs. Targets define the desired safety performance endorsed by governments at all levels, stakeholders, and the community.

Checklists are part of the WG GRSF RSMCR Guidelines and are classified within 12 chapters[4]:

- Checklist 1: Results focus at system level (with 8 questions)
  - ✓ Are estimates of the social costs of crashes available?

[4] Due to the paper limitations, only a few of the first checklist's questions are presented.

- ✓ Are data on road deaths and injuries readily available?...
- Checklist 2: Planning, design, operation and use of the road network (5 questions)
  - ✓ Have comprehensive safety standards, rules and associated performance targets been set for the planning, design, operation and use of roads to achieve the desired focus on results?
  - ✓ Are the official speed limits aligned with Safe System design principles to achieve the desired focus on results? …
- Checklist 3: Entry and exit of vehicles to and from the road network (4 questions)
  - ✓ Have comprehensive safety standards, rules and associated performance targets been set to govern the entry and exit of vehicles and related safety equipment to and from the road network to achieve the desired focus on results?
  - ✓ For each category of vehicles and safety equipment (private, commercial, public, helmets) are compliance regimes in place to ensure adherence to the specified safety standards and rules to achieve the desired focus on results? …
- Checklist 4: Entry and exit of road users to and from the road network (4 questions)
  - ✓ Have comprehensive safety standards and rules and associated performance targets been set to govern the entry and exit of road users to and from the road network to achieve the desired focus on results?
  - ✓ For each category of driver (private, commercial, public) are compliance regimes in place to ensure adherence to the specified safety standards and rules to achieve the desired focus on results? …
- Checklist 5: Recovery and rehabilitation of crash victims from the road network (3 questions)
  - ✓ Have comprehensive safety standards, rules and associated performance targets been set to govern the recovery and rehabilitation of crash victims from the road network to achieve the desired focus on results?
  - ✓ For each category of post-crash service are compliance regimes in place to ensure adherence to the specified safety standards and rules to achieve the desired focus on results? …
- Checklist 6: Coordination (4 questions)
  - ✓ Are interventions being coordinated horizontally across agencies to achieve the desired focus on results?
  - ✓ Are interventions being coordinated vertically between national, regional, provincial and city agencies to achieve the desired focus on results?…
- Checklist 7: Legislation (2 questions)
  - ✓ Are legislative instruments and procedures supporting interventions and institutional management functions sufficient to achieve the desired focus on results?
  - ✓ Are legislative instruments and procedures supporting interventions and institutional management functions regularly reviewed and reformed to achieve the desired focus on results? …
- Checklist 8: Funding and resource allocation (4 questions)
  - ✓ Are sustainable funding mechanisms supporting interventions and institutional management functions in place to achieve the desired focus on results?
  - ✓ Are formal resource allocation procedures supporting interventions and institutional management functions in place to achieve the desired focus on results? …
- Checklist 9: Promotion (1 question)
  - ✓ Is road safety regularly promoted to achieve the desired focus on results?
- Checklist 10: Monitoring and evaluation (8 questions)
  - ✓ For each category of roads (national, regional, provincial, city) are sustainable systems in place to collect and manage data on road crashes, fatality and injury outcomes, and all related road environment/vehicle/road user factors to achieve the desired focus on results?
  - ✓ For each category of roads (national, regional, provincial, city) are sustainable systems in place to collect and manage data on road network traffic, vehicle speeds, safety belt and helmet wearing rates to achieve the desired focus on results? …
- Checklist 11: Research and development and knowledge transfer (4 questions)

- ✓ Has a national road safety research and development strategy been established to achieve the desired focus on results?
- ✓ Has an independent national road safety research organization been established to achieve the desired focus on results? …

- Checklist 12: Lead agency role and institutional management functions (9 questions)
  - ✓ Does the lead agency (or de facto lead agency/agencies) effectively contribute to the results focus management function?
  - ✓ Has a lead agency been formally established to direct the national road safety effort to achieve the desired focus on results?...

The hardest to understand and implement are checklists No. 2–4. Therefore, most of the additional questions were related to them.

3.2 EU Road Safety Policy and Checklists

In 2010, the European Commission published a road safety programme intended to span the following decade [2]. The primary objective of the programme was to reduce the total number of road fatalities in the European Union by 50% by the year 2020. The EU Road Safety Policy recognises seven strategic objectives.
In 2017, a project [3] funded by the EU developed road safety performance indicators, also known as checklists, which were used for the purpose of benchmarking and monitoring the following specified objectives:

1. Improve education and training of road users (in total 16 questions split in 5 categories)
   - ✓ Strategic basis
   - ✓ The quality of Pre-test learning…
2. Increase enforcement of road rules (17 questions/4 categories)
   - ✓ Cross-border exchange of information in the field of road safety
   - ✓ Enforcement campaigns…
3. Safer road infrastructure (18 questions/4 categories)
   - ✓ Strategic basis
   - ✓ Legal basis…
4. Safer vehicles (13 questions/3 categories)
   - ✓ Strategic basis for Safer vehicles
   - ✓ Vehicles of today…
5. Promote the use of modern technology to increase road safety -ITS (13 questions/4 categories)
   - ✓ Strategic basis for ITS
   - ✓ ITS Directive…
6. Improve emergency and post-injury services (13 questions/3 categories)
   - ✓ Emergency services
   - ✓ Monitoring of road accidents and consequences…
7. Protect vulnerable road users (13 questions/4 categories)
   - ✓ Powered-two-wheelers
   - ✓ Pedestrians, cyclists…

The EU Road Safety Policy Framework 2021–2030 [4] prioritises the Safe System Approach (SSA) and Key Performance Indicators (KPIs). Nevertheless, it is important to acknowledge that the seven policy objectives continue to hold significant value for the majority of LMICs[5].
The only potential concern relates to the lack of a road safety management objective. The reason for it can be attributed to the nearing completion of the formation of the RSM in EU countries, hence making the inclusion of such a chapter redundant in the second decade.

[5] Low and middle-income country

3.3. Global Road Safety Plan and UN Decade of Road Safety Action Checklists

The United Nations declared the Decade of Action for Road Safety 2011–2020 in March 2010. In September 2020, the UN passed a resolution titled "Improving Global Road Safety." This resolution launched the second Decade of Action for Road Safety 2021–2030. The primary objective of this programme is to reduce road traffic fatalities and injuries by at least 50% by the year 2030.
The WHO, the UN regional commissions, and other collaborating partners within the UN Road Safety Collaboration have developed a Global Plan for the Decade of Action [5,6].
The provided assessment checklists [7] pertain to the five pillars during the initial decade and the SSA components during the subsequent decade:

- Pillar 1: Road Safety Management Capacity (RSMC)
  - ✓ Implementation of UN EU road safety policy framework
  - ✓ Establishment of Lead agency and coordination mechanisms…
- Pillar 2: Safer Roads and Mobility
  - ✓ Road Safety Ownership and accountability
  - ✓ Sustainable urban planning…
- Pillar 3: Safer Vehicles
  - ✓ Minimal vehicle safety standards
  - ✓ NCAP implementation…
- Pillar 4: Safer Road Users
  - ✓ Road safety risk factors identified
  - ✓ Speed management…
- Pillar 5: Post Crash Responses
  - ✓ Pre-hospital care
  - ✓ Care in transit…

UN Decade checklists exhibit a logical and easily implementable structure, making them an ideal choice for researchers in LMICs. This checklist provides a straightforward set of questions that are user-friendly for researchers.

3.4 Compilation (Merging) of Checklists – Tailor-made Checklists

The best practice identifies the WB GRSF RSMCR Guidelines as the predominant approach/model for reviewing road management systems. Inconsistencies among researchers and practitioners have been observed throughout the implementation of guidelines and accompanying checklists. This is an opportunity to expand and improve existing checklists by including additional questions derived from other review models.These modifications have the potential to enhance the overall surveyquality and promote greater consistency in their implementation. Consequently, the process of compiling checklists involves enriching the WB checklist with additional questions from two other checklists to comprehensively elucidate every aspect of the capacity review.
Merged checklists offer a more coherent and applicable set of questions that serve as a guiding framework for researchers/practitioners throughout the review process. This also enables a more unified approach and enhances comprehension of the current road safety situation. It allows a more thorough gap analysis and ultimately guides the selection of appropriate activities that will contribute to the improvement of road safety outcomes.
Figure 1 illustrates the relationship between the WB GRSF RSMCR Guidelines checklists and additional checklists that encompass an expanded set of questions.

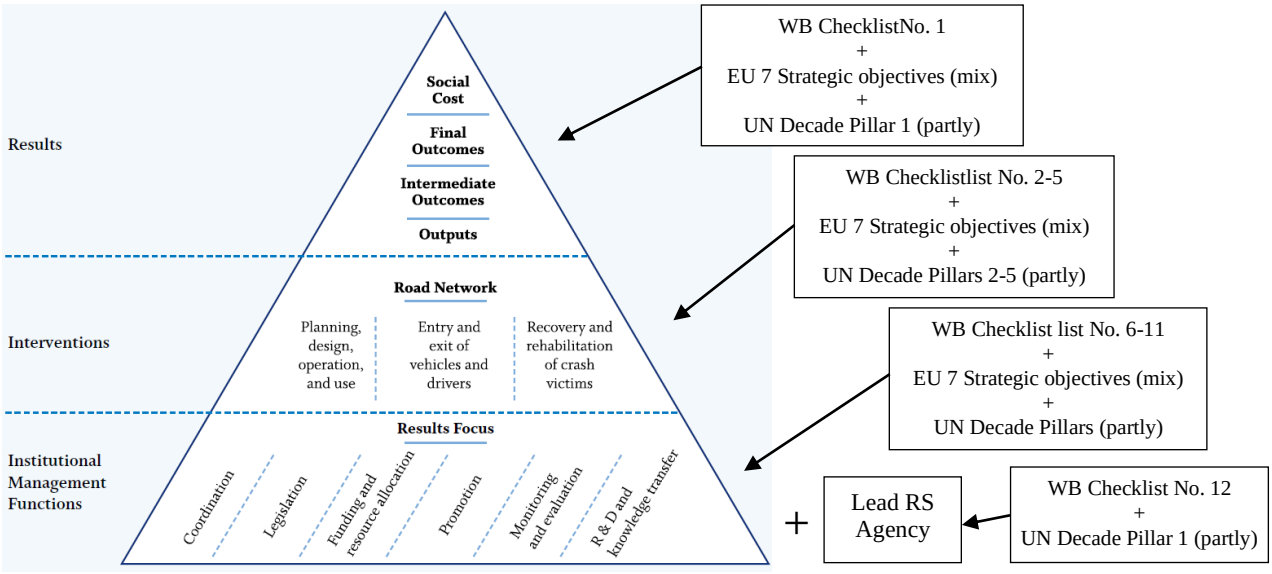

Figure 1. The Road Safety Management System

Source: *Bliss and Breen, 2013 and Project "Technical Assistance for Road Safety Management Capacity Review (RSMCR) and improvements of road safety management capacity at municipality level (Local Communities)", 2023*

4. CONCLUSION

There are several RSMCR approaches that incorporate different checklists within their framework. The authors were among researchers/practitioners who applied all approaches (checklists) and were able to identify shortcomings and propose improvements for their implementation. The significant expansion of checklists occurred within the middle part of the "Pyramid", regarding interventions. These interventions encompass the planning, design, operation, and utilisation of the road network, as well as the entry and exit of vehicles and road users to and from the road network. In order to obtain a comprehensive understanding of the current state of road safety, it was necessary to incorporate additional checklists to encompass a full spectrum of information. Furthermore, the proposed expansion of checklists has led to greater uniformity among researchers of diverse backgrounds. The proposed checklist expansion (merging) was successfully tested and implemented within recent RSMCR projects in Ukraine and North Macedonia.

This research and expansion (merging) of different checklists was successfully tested and implemented thanks to the EIB project in Ukraine[6] and the WB project in North Macedonia[7].

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ENVIRONMENT AND SUSTAINABLE DEVELOPMENT. MECHATRONICS. OCCUPATIONAL SAFETY AND HEALTH AND FIRE SAFETY. SMART MANAGEMENT SYSTEMS. GRAPHIC ENGINEERING. DESIGN. TRAFFIC ENGINEERING. BIOTECHNOLOGY AND HEALTHCARE. MECHANICAL ENGINEERING. ECOTOURISM AND RURAL DEVELOPMENT.

CONSEQUENCES OF TRAFFIC ACCIDENTS IN THE REPUBLIC OF SERBIA IN THE PERIOD FROM 2013 TO 2022 WITH PROPOSED MEASURES TO REDUCE FATAL CONSEQUENCES

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Abstract: *The degree of traffic safety is most quickly assessed on the basis of traffic safety indicators, and most often on the basis of the consequences of traffic accidents. The paper provides an overview of the number of people killed in traffic accidents in the Republic of Serbia in the period from 2013 to 2022 and a comparison of the values of those indicators between two periods: from 2013 to 2017 and from 2018 to 2022. The number of people killed in traffic accidents in the Republic of Serbia, despite many years of efforts to improve the situation, is still unacceptably high. It is particularly important to consider at which stage of the course of events the participants in traffic accidents die, i.e. whether at the scene of the accident or during transport to emergency medical centers or within a period of 30 days after the traffic accident. Based on the consideration of those three components, a proposal for preventive measures to reduce fatalities in traffic accidents during transport and during the treatment of victims of traffic accidents in the Republic of Serbia was given.*
Keywords: Traffic Safety, Traffic Accident, Traffic Safety Indicators, Fatal Consequences

1. INTRODUCTION

How to evaluate the level of traffic safety is one of the basic problems for improving traffic safety. The first method, which still occupies an important place today, is evaluation based on traffic safety indicators, i.e. based on the number of traffic accidents and their consequences. Among the consequences of traffic accidents, the indicator of the number of traffic accidents with fatalities has always had the greatest influence, that is, the number of fatalities, whose impact is evaluated in the professional literature with weights from 99 to 130 (keeping in mind that 1 is the weighting for traffic accidents with material damage). Progress in the approach to evaluating the level of traffic safety was represented by combinations of several single-criteria evaluation methods, as well as multi-criteria methods with the use of multi-criteria decision-making tools, such as the methods: Prometheus, Expert Choice, AHP or Fuzzy logic [1].

Modern views on evaluation included performance indicators of traffic safety, which in the Republic of Serbia began to be measured on the ground in 2013 in 7 groups: use of protective systems (belts and helmets), pedestrian behaviour, presence of alcohol in traffic participants, traffic violations vehicle speeds, use of child restraint systems and characteristics of emergency services after a traffic accident.The average response time of emergency medical assistance in the Republic of Serbia was investigated in 2018 for 27 police departments and ranges from 4.41 minutes (Subotica) to 21.62 minutes (Šabac). The median response time of emergency medical assistance for the Republic of Serbia is 9.71 minutes [2,3,4].

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From 2017 onwards, within the Republic of Serbia, the behaviours of road users, including motorised passenger vehicle and motorcycle drivers, as well as non-motorised users like pedestrians and cyclists, have been systematically studied. Following the launch of the inaugural Traffic Safety Strategy in the Republic of Serbia for the 2015 to 2020 timeframe, a system was established to quantify the economic and financial impact of road accidents on the nation and its local communities. This provides a tangible measure which can effectively appeal to potential investors interested in enhancing traffic safety standards.

In addition to all the mentioned methods, the method for evaluating the level of traffic safety, the number of people killed in traffic accidents is the most commonly used indicator for evaluation and as an argument for taking preventive measures and actions. Persons killed in traffic accidents are considered to be: persons whose death occurred on the spot, during transport to a medical facility or within a period of 30 days after the traffic accident. If the proportion of people killed in each of the mentioned stages is observed, it can be concluded that most people are killed at the scene of the traffic accident, but a significant number are killed during transport and in the period of 30 days after the accident [3]. This data points to the need to improve emergency medical services for victims of traffic accidents.

The subject of the work is the investigation of death immediately after a traffic accident (during transport and during treatment) from 2013 to 2022. The aim of the paper is to examine the hypotheses whether there is a significant statistical difference between the two five-year periods 2013-2017 and 2018-2022. year in the distribution of fatal outcomes of traffic accidents on the spot, on the way to the hospital and within 30 days of the accident. The paper consists of four points: Introduction, Number of persons dead in traffic accidents in the period from 2013 to 2022, Proposed measures to reduce death in road traffic and Conclusion.

2. NUMBER OF PERSONS DEAD IN TRAFFIC ACCIDENTS IN THE PERIOD FROM 2013 TO 2022

For the purpose of statistical analysis, two consecutive periods were considered: the first period from 2013 to 2017 and the second period from 2018 to 2022. Understanding the distribution of these fatalities over time can offer insights into the effectiveness of traffic safety measures and interventions.In Table 1, data is displayed regarding the total number of fatalities in traffic accidents (Fatalities), the number of individuals who died on the scene of traffic accidents (Fatalities at the scene), the number of individuals who passed away during transport to a medical facility (Fatalities en route to hospital), and the number of individuals who subsequently died within 30 days as a result of traffic accidents (Fatalities within 30 days) by year for the period from 2013 to 2022.The basic descriptive parameters (Mean, StDev, Sum, and Median) for the observed periods 2013-2017 and 2018-2022 are provided in Table 2.

In the analysis of the number of fatalities in traffic accidents in the Republic of Serbia over two consecutive five-year periods, the use of the Mann-Whitney U test was chosen as an alternative to the T-test for independent samples. This choice was motivated by several key reasons. Firstly, given that each period contains only five values, the assessment of normality and homogeneity of variances can be unreliable, making traditional parametric tests less suitable. Additionally, the Mann-Whitney U test, as a non-parametric method, does not make assumptions about the normality of data distribution, making it more robust in this context.Finally, this test demonstrates greater resilience to potential outliers that could disproportionately affect the results of the T-test, especially when dealing with small samples.Taking everything into account, the Mann-Whitney U test proved to be the optimal approach for comparing the number of fatalities in the mentioned periods, providing reliable and relevant statistical conclusions.

Table 1. Number of fatalities in traffic accidents in the Republic of Serbia for the period from 2013 to 2022.
Source: *Road Traffic Safety Agency, Republic of Serbia*

Year	Fatalities	Fatalities at the scene	Fatalities en route to hospital	Fatalities within 30 days
2013	650	398	122	130
2014	536	344	69	123
2015	599	349	63	187
2016	607	345	81	181
2017	579	336	89	154
2018	548	315	67	166
2019	534	328	48	158
2020	492	279	56	157
2021	521	300	58	163
2022	553	327	56	170
Total	5,619	3,321	709	1,589

Table 2. Descriptive parameters for the number of fatalities in traffic accidents in the Republic of Serbia for the periods 2013-2017 and 2018-2022
Source: *Authors' research*

Variable	Mean	StDev	Sum	Median
Fatalities 2013-2017	594.20	41.60	2,971	599
Fatalities 2018-2022	529.60	24.50	2,648	534
Fatalities at the scene 2013-2017	354.40	24.80	1,772	345
Fatalities at the scene 2018-2022	309.80	20.61	1,549	315
Fatalities enroute to hospital 2013-2017	84.80	23.10	424	81
Fatalities en route to hospital 2018-2022	57.00	6.78	285	56
Fatalities within 30 days 2013-2017	155.00	28.90	775	154
Fatalities within 30 days 2018-2022	162.80	5.45	814	163

The results of the Mann-Whitney U test are provided in Table 3.

Table 3. Results of the Mann-Whitney U test for comparing medians for the periods 2013-2017 and 2018-2022 (Test of $\eta 1 = \eta 2$ vs $\eta 1 \neq \eta 2$)
Source: *Authors' research*

Variable	n	Median	Point estimate $\eta 1 - \eta 2$	W	p-value
Fatalities 2013-2017	5	599	59	38	0.0367*
Fatalities 2018-2022	5	534			
Fatalities at the scene 2013-2017	5	345	36	40	0.0122*
Fatalities at the scene 2018-2022	5	315			
Fatalities enroute to hospital 2013-2017	5	81	23	39	0.0216*
Fatalities enroute to hospital 2018-2022	5	56			
Fatalities within 30 days 2013-2017	5	154	-9	25	0.6761
Fatalities within 30 days 2018-2022	5	163			

Note: * p-value is less than the usual significance threshold of 0.05, hence there is sufficient evidence to reject the null hypothesis. In other words, there is a statistically significant difference between the two consecutive periods.

Between 2018 and 2022, there was a noted decline in the total number of fatalities in traffic accidents compared to the period from 2013 to 2017, where the number decreased from 2,971 to 2,648, representing a drop of 10.87%. During the same years (2018-2022), the number of individuals who lost their lives at the accident scene reduced from 1,772 to 1,549, indicating a

decrease of 12.58%. In that span, there was also a noticeable decline in the number of individuals who passed away while being transported to the hospital, with the figure dropping from 424 to 285, a stark decrease of 32.78%. However, in the period from 2018 to 2022, there was an observed rise in the number of individuals who died within 30 days due to injuries from traffic accidents, increasing from 775 to 814, marking an increase of 5.03%.

The number of fatalities was divided in the analysis into two consecutive five-year periods based on the timing or timeframe of their death after the traffic accident. To analyse trends in the number of fatalities from traffic accidents across two consecutive five-year periods (2013-2017 and 2018-2022), the following hypotheses were set:

- H0: There is no significant difference in the distribution of fatalities in traffic accidents (Fatalities at the scene, Fatalities enroute to hospital, Fatalities within 30 days) between the two specified five-year periods;
- H1: There is a significant difference in the distribution of fatalities in traffic accidents (Fatalities at the scene, Fatalities enroute to hospital, Fatalities within 30 days) between the two specified five-year periods.

To test the set hypotheses, the Chi-square test for independence was used. This test allows for the comparison of the distribution of fatalities from traffic accidents between the two five-year periods and determining if there are significant differences in the distributions across the three categories of fatalities. The results of the Chi-square test for independence indicated a statistically significant difference in the distribution of fatalities across the two consecutive five-year periods according to categories (Fatalities at the scene, Fatalities enroute to hospital, Fatalities within 30 days). The Pearson Chi-Square value was 24.697 with 2 degrees of freedom (DF = 2), and a p-value less than 0.001 ($p < 0.001$). Similar results were obtained using the Likelihood Ratio Chi-Square, which was 24.794 with 2 degrees of freedom (DF = 2) and a p-value less than 0.001 ($p < 0.001$). In the distribution of fatalities across the two consecutive five-year periods according to categories, the most notable decrease was in the frequency related to the variable "Fatalities enroute to hospital", from 14.27% (2013-2017) to 10.76% (2018-2022). Meanwhile, the frequency increased for the variable"Fatalities within 30 days", from 26.09% (2013-2017) to 30.74% (2018-2022). The frequency for the variable"Fatalities at the scene" remained nearly unchanged, 59.64% (2013-2017) and 58.50% (2018-2022).

3. PROPOSED MEASURES TO REDUCE DEATH IN ROAD TRAFFIC

This paper does not include measures to reduce the number of people killed in traffic accidents on the spot (58.5% of all traffic accident fatalities), which are a consequence of the traffic conditions that preceded the traffic accident and elements of active and passive safety of vehicles, roads and participants in a traffic accident.

In the Republic of Serbia, from 2018 to 2022, 10.76% of traffic accident victims died during transport to a health facility. Additionally, 30.74% died within 30 days of the accident. This accounts for a total of 1,099 people killed in traffic accidents over five years. These figures suggest that non-traffic factors in the prevention of traffic accidents have been largely overlooked. This oversight is particularly significant considering that "Care after a traffic accident" is recognized as Pillar 5 in the safety management of traffic, as outlined in the Global Plan of the Decade of Action for Road Safety 2021-2030 [5]. Measures to improve traffic safety management within Pillar 5 are systematized in five levels: Legislation (improvement of standards for data collection during response and investigation after a traffic accident), Enforcement (supervision of rescue services and investigators who analyse a traffic accident), Education (service training first aid and rescue assistance), Technology (necessary equipment and modern equipment technologies) and International regulatory support, which is based on consolidated resolution by WP.1 and standards.

By implementing the above four groups of measures and international regulatory support, it is possible to achieve a reduction in fatalities in traffic accidents. Within the "Legislation" group of measures, it is necessary to improve standards and procedures, as well as their implementation. The

implementation of the EN 1789 standard (Medical vehicles and their equipment - Road ambulances) is particularly important. In addition to the application, the criteria for how emergency medical services for rescuing victims of traffic accidents, in addition to the basic type of Patient transport ambulances (Types A1 and A2), should also be equipped with ambulance vehicles of the following categories: Emergency ambulances (Type B) and Emergency ambulances (Type C). Emergency ambulances (Type B) are the most seen type of emergency ambulance. Mobile intensive care unit (Type C) is a type of ambulance which is commonly seen in the movement of high-acuity patients between hospitals. It provides adequate space for not only the medical equipment commonly seen in ambulances, but also to accommodate hospital equipment, such as ventilators, during transport [6].

A completely different approach, which can also significantly reduce the number of fatal consequences in the period after a traffic accident, is the establishment of emergency medical assistance during the so-called "Golden hour" [7]. The "Golden hour" is the term often used in trauma or emergency care to suggest that an injured or sick person must receive definitive treatment within the first 60 minutes from the time of injury or appearance of symptoms. It was believed that once this time has lapsed, the risk of death or long-term complications will significantly increase. During road traffic accidents, intervention done in the first few minutes might determine if the person will live or die. The main principle in managing the victim here is to stabilize their Airway, Breathing, and Circulation and carry them to the nearest hospital. If this is not possible, a "scoop and run" approach rather than "stay and play" is encouraged. This means rather than wasting time giving improper first aid at the site of injury (and searching for help in vain), it is better to get the victim to the hospital as soon as possible. That being said, the potentially life and limb saving interventions (a tracheostomy, an epinephrine injection, intravenous fluids, splinting the broken bones, and collecting amputated toes/fingers in ice and carrying them along with the patient) [8,9]. Activities to save the life of a traffic accident victim within the "Golden hour" are shown in Fig. 1.

In the Republic of Serbia, there were projects to create an emergency medical service based on the "Golden hour" principle, with the provision of helicopter transport of severely injured victims of traffic accidents within a radius of 100 km, but, unfortunately, that idea has not been realized to date. In the Republic of Serbia, there are all the preconditions for the return of the Helicopter Service to the roads of Serbia, which was abolished in 1990.

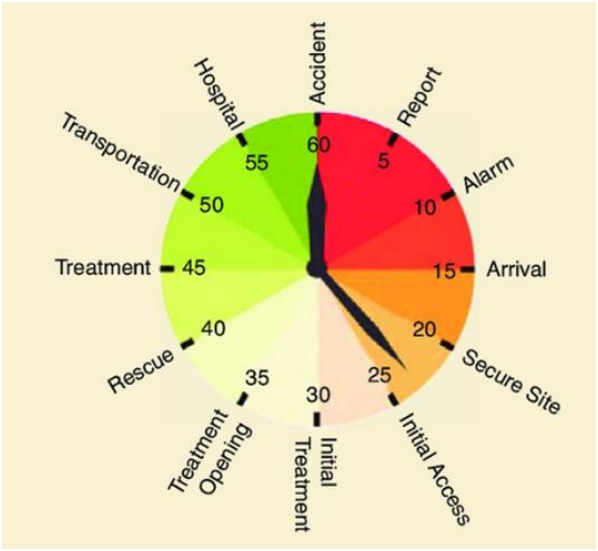

Figure 1. "Golden hour" in a car accident
Source: *Martinez F., Toh C., Cano J., Calafate C., Manzoni P.: Emergency Services in Future Intelligent Transportation Systems Based on Vehicular Communication Networks*

In the area of "Implementation" it is not only necessary to introduce the supervision of the rescue services, but it is more important to improve the coordination of those services. Within the field of "Education", the training of the population in terms of first aid, the training of all subjects in the

chain of information from the scene of the accident to the rescue services, and especially the specialist training of persons in medical institutions and ambulances of all three categories (A, B and C). Within the field of "Technology", it is necessary to improve the equipment in medical institutions and vehicles, i.e. to have in vehicles of type B and C the same equipment that will be able to be used in the field, that is, to have reliable sources of electricity and technical gases necessary for providing assistance to victims of traffic accidents.
In the Republic of Serbia, the Rulebook defines the necessary equipment for medical institutions and emergency medical assistance, including the equipment in standard emergency medical assistance vehicles of health centres, transport vehicles and special medical vehicles [10].

4. CONCLUSION

The number of fatalities has a dominant effect on the amount of damage that the state has as a result of traffic accidents. That number can and should be reduced, both in terms of persons who died at the scene of a traffic accident, as well as after the accident, in transport and during treatment. Given that, the goal of the work is directed towards measures to reduce death, especially in transport and during treatment, i.e. after the accident, it can be concluded that the share of deaths of participants in traffic accidents is about 41.5% of the total number of people killed in traffic accidents in the R. of Serbia.
The proposed measures are, in accordance with the document Global Plan of the Decade of Action for Traffic Safety 2021-2030, systematized in five levels: improvement of legislation, improvement of application, improvement of education of subjects and procurement, application of modern technologies and equipment and international regulatory support. The measures of equipping medical facilities and emergency vehicles with the necessary equipment for more advanced care and monitoring of the condition of the injured (type C vehicles) and the establishment of a system for providing assistance to victims of traffic accidents according to the "Golden Hour" model were particularly highlighted.

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ENVIRONMENT AND SUSTAINABLE DEVELOPMENT. MECHATRONICS. OCCUPATIONAL SAFETY AND HEALTH AND FIRE SAFETY. SMART MANAGEMENT SYSTEMS. GRAPHIC ENGINEERING. DESIGN. TRAFFIC ENGINEERING. BIOTECHNOLOGY AND HEALTHCARE. MECHANICAL ENGINEERING. ECOTOURISM AND RURAL DEVELOPMENT.

STATISTICAL ANALYSIS OF TRAFFIC ACCIDENTE ON STATE ROADS IN THE WORK ZONE ON THE TERRITORY OF THE REPUBLIC OF SERBIA FOR THE PERIOD FROM 2014 TO 2021

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Abstract: *Globally, road traffic accidents cause almost 1.3 million deaths and around 50 million serious injuries each year – making it the leading cause of death for children and youth in the world (WHO, 2021). As the number of motorized traffic developments has increased over time, so has the demand for better and safer roads. In order for the state to respond to the existing demands, which are almost reaching saturation, it is necessary to provide all vehicles with the appropriate capacity of roads, which leads to the need for the reconstruction of existing ones. In most cases, when carrying out works on certain sections of the road, there is no alternative direction to which traffic flows can be diverted, so in that case, the work zone becomes a potentially dangerous place. The part of the work zone that is the most risky for the occurrence of traffic accidents, especially with fatal consequences, is the construction site itself. The transition from the normal traffic regime, without interruptions and unusual situations, to the traffic regime in the work zone must be gradual, clearly marked and noticeable. The aim of this work is to present the results of statistical processing of data from the Database of the Agency for Traffic Safety, on the basis of which it is necessary to investigate which attributes, in the capacity of the road factor, can affect the occurrence of a traffic accident in the work zone on state roads. The paper will show the relationship between the attributes of traffic accidents in the work zone.*
Keywords: traffic safety, road works zone, database, statistical analysis

1. INTRODUCTION

Managing a system or process means taking management measures to bring the current state of the system closer to the target (desired) state (Vujanić, et al., 2011). As the number of motorized traffic developments has increased over time, so has the demand for better and safer roads. In order for the state to respond to the existing demands, which are almost reaching saturation, it is necessary to provide all vehicles with the appropriate capacity of roads, which leads to the need for the reconstruction of existing ones. In most cases, when carrying out works on certain sections of the road, there is no alternative direction to which traffic flows can be diverted, so in that case, the work zone becomes a potentially dangerous place. The part of the work zone that is the most risky for the occurrence of traffic accidents, especially with fatal consequences, is the construction site itself.
The transition from the normal traffic regime, without interruptions and unusual situations, to the traffic regime in the work zone must be gradual, clearly marked and noticeable. In the Republic of Serbia, there is a Rulebook on how to regulate traffic on roads in the work zone, which clearly defines what is meant by safely marked work zones, from the traffic aspect. The road as one of the traffic safety factors affects vulnerable traffic participants.

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According to road classification, highways are the safest, while city streets are the least safe. On open roads for mixed traffic, the risk of an accident is three times higher, while on city streets it is six times higher. According to world experience, the road itself or in combination with other factors is the cause of approximately one third of all traffic accidents. The aim of this work is to present the results of statistical processing of data from the Database of the Agency for Traffic Safety, on the basis of which it is necessary to investigate which attributes, in the capacity of the road factor, can affect the occurrence of a traffic accident in the work zone on state roads. The paper will show the relationship between the attributes of traffic accidents in the work zone.

2. METHODOLOGY

For work purposes, a database was created with the help of data obtained from the Agency for Traffic Safety for the period from 2014 to 2021. The created database consisted of all traffic accidents that occurred in the work zone for the period from 2014 to 2021. 394 traffic accidents were analyzed and 9 attributes were shown for each. When selecting attributes, it is necessary to clearly define those attributes that are necessary for the analysis of traffic accidents. Also, errors in the data can often occur in large databases, so before the very beginning a check of the existing data was carried out, which included a logical check of the entered data, as well as the completeness of all information necessary for further analysis.

The presented results were processed with the help of the software program for data analysis and processing SPSS Statistics version 26.0. The mentioned program works according to the principle of numbers, that is, it is necessary to assign a specific code (code) to the received data, which the program will be able to process and recognize.

Given that the subject of this paper is the analysis of traffic accidents in the work zone on state roads, the attributes related to the type of accident that occurred, the category of the road, whether the accident occurred in the settlement or outside the settlement, characteristics and condition of the roadway, lighting were analysed. At the time of the accident, as well as the existence of street lighting as well as a group of influential factors.

For further statistical analysis, the attributes related to the type of accident, road category and TA type groups are shown as independent variables, while the attributes related to settlement/non-settlement, road condition, road characteristics, street lighting, lighting, groups of influential factors viewed as dependent versus independent variables.

In order to determine the strength of the relationship between the mentioned divisions, several statistical analyses were conducted at different intersections of the obtained data (descriptive analysis, non-parametric tests and correlation).

Descriptive analysis was used as the simplest display and analysis of data, which calculates, displays and describes the characteristics (parameters) that represent the attributes of traffic accidents. Descriptive data analysis is suitable for the initial presentation, because it shows the importance of the topic of the work, as well as the obtained results, in the simplest and most transparent way. With the help of descriptive analysis, the paper shows the mean value and mean standard deviation of the attributes related to the type of accident, road category, groups of traffic accident types and groups of influencing factors.

After descriptive analysis, Spearman correlation testing between attributes was conducted to show the strength of relationships. The values that can be obtained are in the range from -1 to 1, which means that if they are negative, then by influencing the increase of one attribute, the value of the other with which it is correlated decreases, and if the value is positive, changing the value of one attribute proportionally it increases the value of the other with which it is correlated. If the correlation value between two attributes is 0, it means that there is no correlation between them.

3. RESULTS AND DISCUSSION

For the period from 2014 to 2021, 394 traffic accidents (TA) were analysed in the work zone on state roads, of which 62.7% were traffic accidents with material damage, 33.0% TA with an injured person and 4.3% TA with a dead person. The mean value of the analysed database represents the central value of the observed attribute in relation to its analysed elements, while the standard deviation represents how much on average the elements deviate from the mean value of the attribute, i.e. in what range the data can appear. The mean value of the type of accident is 2.58, and based on the standard deviation, we can see that the obtained data can most often appear in the range from 2.01 to 3.

Based on this analysis, we can come to the conclusion that the largest number of traffic accidents that occurred in the work zone for the analysed period resulted in an injured person or property damage. When it comes to the road category, based on the obtained values (1.58±0.72), the most traffic accidents occur on higher-ranked sections (state road IA and IB order). The analysis of groups of types of traffic accidents also recorded accidents with pedestrians, which are very specific in such traffic accidents (state road and work zone), that is, they are considered very rare in the literature. Also, based on the processed literature, the importance of marking and visibility of the workers themselves, who are pedestrians, in the work zone is pointed out and discussed. Even if the work zone itself is not adequately marked, it is necessary to mark the workers and provide adequate visibility to the drivers themselves in order to further reduce the number of traffic accidents in the work zone on state roads where vehicles move at high speeds. When we look at groups of influencing factors, the main influencing factor is the influence of the driver, while the next factor is the influence of the road. Because of the data obtained in this way, it is necessary to further analyse the elements of the road and the environment in order to see their correlation with the occurrence of traffic accidents in the work zone.

When it comes to the work zone, the most traffic accidents were recorded on the section of the IA state road, which represents the section of the highest rank. The largest percentage of the mentioned traffic accidents resulted in material damage, as well as the fact that they occurred on sections outside the settlement. The largest number of traffic accidents in the work zone, which occurred on sections of the settlement, were recorded on the IB state road. Also, the highest percentage of traffic accidents resulted in material damage.

By analysing the group of types of traffic accidents in the work zone on state roads, it was expected that the number of traffic accidents involving pedestrians was the lowest, but traffic accidents involving pedestrians were recorded, resulting in the death of a person. Also, these accidents occurred on state road IA and IB, where higher speeds are allowed than on other state roads, which additionally shortens the driver's reaction time, as well as increases the length of braking when an obstacle is detected. Traffic accidents with one vehicle represent the most common group of types of traffic accidents, as well as traffic accidents with at least two vehicles without turning.

Table 1 shows the values of the Spearman correlation coefficient between the attributes defined as independent and all other attributes. The highest positive correlation is achieved between the attributes related to TA type groups and the group of influencing factors (0.337), as well as between the road category and pavement characteristics (0.331), while the highest negative correlation is achieved between the attributes related to the TA type group and street lighting (-0.284).

There is almost no correlation between the attributes related to the type of accident and the characteristics of the pavement, as well as the road category and street lighting.

Table 1. Value of the Spearman correlation coefficient

	Road condition	Pavement characteristics	Street lighting	Groups of influencing factors
Type of accident	0,024	0,008	-0,047	0,099
Type groups	0,032	0,162	-0,284	0,337
Road category	0,239	0,331	0,002	-0,060

4. PROPOSED MEASURES FOR IMPROVING TRAFFIC SAFETY IN THE ROAD WORK ZONE

Due to the observed problem, it is necessary to adequately mark the road work zone. This approach increases the level of safety of all traffic participants, as well as road contractors. Given that the most common influence of traffic accidents is the human factor, it is necessary to place frontal, vertical and/or horizontal obstacles at the approach to the work zone itself, which would further increase the visibility of the work zone, as well as provide additional notice to drivers that they are encountering, finding or passing through the zone of works on the section. Also, the importance of street lighting in the occurrence of traffic accidents in the work zone has been observed, so in addition to the obstacles, it is proposed to install flashing lights that would increase the level of illumination in the work zone. In addition to the installation of light signals, adequate equipment and contractors are necessary to make them more visible to drivers. The following photos show an example of the contractor's adequate equipment.

The basic proposal of the measure refers to the application of Intelligent Transport Systems (ITS) in traffic, which would enable better coordination and self-management of all actions in the work zone, thus improving the level of service in dynamic traffic. Also, if there are no conditions for the installation of changeable traffic signals, it is suggested to install a traffic light that would stop and allow vehicles alternately in the work zone. As the most common type of traffic accident with a single vehicle, using ITS would provide drivers with all the necessary information in a timely manner, which would reduce vehicle collisions, i.e. the most common type of traffic accident.

As another form of notification to drivers in traffic that they are encountering a work zone, in addition to adequate vertical signalling, the proposed measure would refer to the installation of vibrating strips, as well as the marking of dividing lines, where a sound would be produced every time a tire passes over a colored part of the line, which would was an additional warning for all drivers.

5. CONCLUSION

On the territory of the Republic of Serbia for the analysed period from 2014 to 20201, the most traffic accidents occurred during daylight hours, due to reckless actions by drivers in traffic accidents with at least two vehicles - without turning. Driving on the part of the road where works are being carried out is one of the most dangerous traffic situations because:

- Before the start of the area where the work zone is located, there may be traffic congestion, as well as the movement of vehicles according to the start/stop principle,
- There is a change in the traffic regime - driving through the construction zone is always a "bottleneck",
- It leads to a big loss of time if the capacity of the section is filled, which can lead to a decrease in concentration and nervousness among drivers,
- If there is very little saturation of the traffic flow, a traffic accident may occur, because the driver does not expect a dangerous situation on the road.

Due to increasing demands, even a small intensity of works on the road leads to a change in the traffic flow and a new service. One of the most important factors in the work zone is the competent authorities. The competent Ministry is responsible for traffic regulation at the national level, while the local self-government is responsible for traffic affairs at the local level. In order to improve the level of traffic safety in the work zone, in 2016 the competent Ministry adopted the Rulebook on the manner of regulating traffic on roads, as well as the Public Company "Roads of Serbia", which has a contract with the competent Ministry for the maintenance and management of state roads. Which in the same year published the document Technical instructions for marking the zones of work on the maintenance of state roads in the Republic of Serbia. Everything that is defined by the mentioned documents, and refers to marking and warning with temporary traffic signals in the work zone, it is necessary to constantly monitor and check the adequacy of its application so that the observed omission can be changed or supplemented in time in order to prevent the occurrence of a traffic accident.

The number of traffic accidents, which resulted in a person being killed or injured during the previous years, constantly leads to the conclusion that it is necessary to educate all traffic participants, as well as to increase the level of control of violations and negligent actions in the work zone. It is necessary to work to ensure that warning signs for marking obstacles on the road are always in an adequate place marked with adequate traffic signals, because if the work zone is, for example, on a highway, it is necessary to place repeating signs, of larger dimensions, due to the high speeds that are allowed on the mentioned sections. The local community can greatly contribute to increasing the level of safety in the work zone, because it can demand that the Investor has adequate project documentation for the execution of road works, and that the Contractor marks temporary traffic signals in the road work zone in accordance with the project documentation. Inadequate temporary traffic signals lead to the invisibility of the road works zone, which can lead to the collision of a vehicle in a convoy due to inappropriate speed, a head-on collision with a physical obstacle if the work zone is located in the traffic lane in which the vehicle moves, aggressive driving to compensate for lost time, which represents only some of the causes of traffic accidents in the road works zone.

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ANALYSIS OF SAFETY OF CYCLISTS IN TRAFFIC IN THE CITY OF SMEDEREVO FROM 2018 TO 2022

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Abstract: *In the Republic of Serbia, on average, on an annual basis, about 60 cyclists are killed in traffic accidents, and about 1600 cyclists are injured. Every eleventh person killed in traffic is a cyclist and every fourteenth person injured is also a cyclist. Cyclists are most often killed by passenger cars, then by trucks (trucks), and a significant percentage of deaths are also due to their own carelessness or accidents and falling off their bicycles. The purpose of this work is to examine the causes of traffic accidents involving cyclists in the territory of the city of Smederevo with the help of data from the Database of the Traffic Safety Agency. The paper will show locations, critical points, as well as the main causes of traffic accidents involving cyclists in the city of Smederevo.*
Keywords: *traffic accidents, cyclist, critical points*

1. INTRODUCTION

Cyclists are often killed in traffic. There are several reasons for that. The key problem is that cyclists are the most vulnerable category in traffic, because they suffer serious injuries at relatively low speeds. This is because they have no protection. A helmet (if they have one) and shields cannot protect them from being hit by a car. The speed of vehicles involved in traffic accidents with cyclists plays an important role, because the consequences are significant. Bicycle drivers are hard to see for other road users because they are very small in comparison to the size of cars, trucks, etc. This is especially pronounced in night conditions, conditions of low visibility (fog or rain), and if they do not have appropriate lights and clothing. This is an obligation from ZoBS, Art. 81, paragraph 5that every bicycle should have a red flashing light at the rear and white at the front. Also, the bicycle rider should wear bright clothing, i.e. clothing with fluorescent, reflective details. Cyclist safety also depends on age. Younger cyclists are physically fitter, have faster reflexes and can react much more skillfully if they find themselves in trouble. Elderly drivers have reduced powers of observation, mobility and often cannot react in time. Children are a category that, apart from experience and routine, also lacks speed and reflexes. Safety is also affected by the traffic environment. Most cyclists move on the road, because there are few cities and municipalities in the Republic of Serbia that have enough and safe cycling paths. Car drivers do not look favorably on cyclists in traffic. Cyclists are seven times more likely to die than car passengers. This is confirmed by the official data of thehttps://www.abs.gov.rs/. Also, men suffer more than women.

2. SAFETY OF CYCLISTS IN TRAFFIC IN THE REPUBLIC OF SERBIA IN THE PERIOD FROM 2018 TO 2022

The key problem when it comes to the safety of cyclists in traffic is their vulnerability, given that even at relatively low speeds they often suffer serious bodily injuries, mainly because their only

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protection is their clothing. The speed of vehicles involved in a collision with cyclists plays an important role, when the severity of the consequences of the accident is in question. Cyclists are often hard to see for other road users compared to cars. Poor visibility of cyclists is a particular problem in nighttime visibility conditions, especially if the bicycle is not equipped with proper lights (white light on the front and red light on the back of the bicycle) and if the cyclists do not wear bright clothing, i.e. clothing with retroreflective materials. Traffic accidents involving cyclists, due to their great vulnerability, often result in fatalities. On average, in the period from 2018 to 2022, about 1,515 accidents were registered in the Republic of Serbia during the year in which one of the participants was a cyclist. Of all recorded accidents in the Republic of Serbia, 7.57% were cyclists. On average, about 48 cyclists are killed and about 1,468 cyclists are injured in TA in the period from 2018 to 2022 (Figure 1) [1].

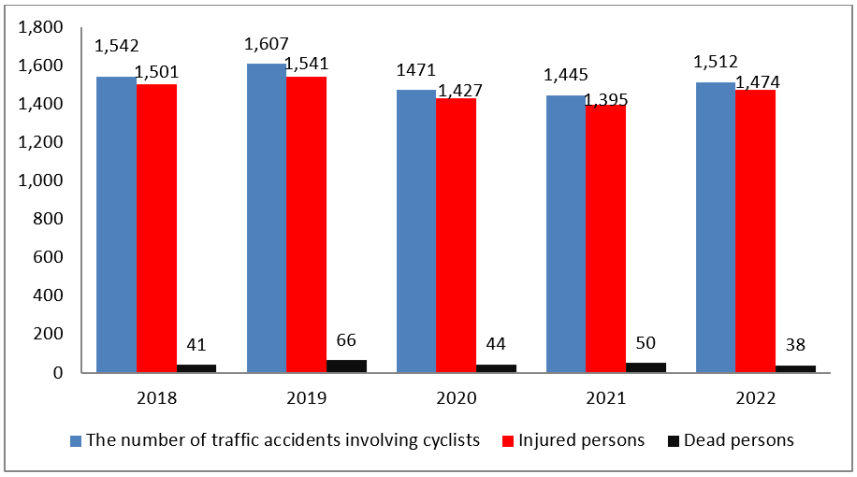

Figure 1. Number of traffic accidents involving cyclists in R. Serbia, as well as the number of dead and injured cyclists in the period from 2018 to 2022
Source: *Agency for Traffic Safety, Republic of Serbia, https://vvv.abs.gov.rs/*

3. SAFETY OF CYCLISTS IN TRAFFIC IN THE PERIOD FROM 2018 TO 2022 IN THE CITY OF SMEDEREVO

In the observed five-year period, a total of 50 traffic accidents involving cyclists occurred, of which 3 traffic accidents resulted in fatalities and 47 traffic accidents resulted in injuries, of which 11 resulted in serious bodily injuries and 36 with minor injuries. In Figure 3.1, it can be seen that there is a trend of decreasing the number of traffic accidents with injured persons in which cyclists participated. The total number of dead cyclists is 3, which is 6% of the total number of people killed in traffic accidents in the city of Smederevo in the observed period, while the number of injured cyclists is 47, which is 3% of the total number of people injured in traffic accidents in the city of Smederevo (Figure 2) [2, 3].

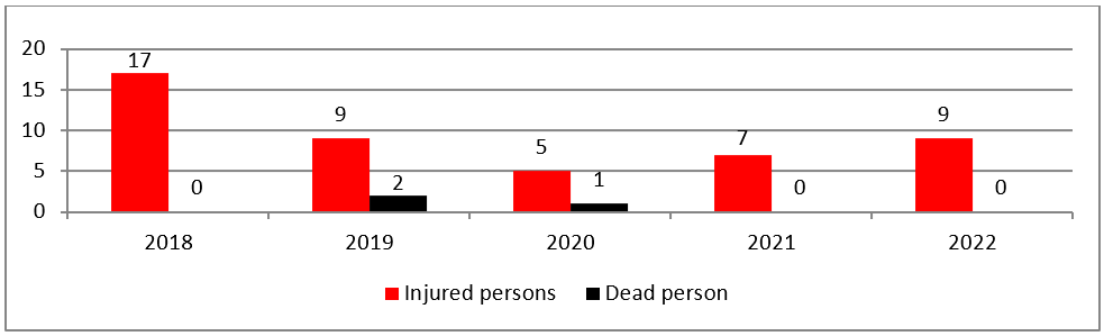

Figure 2. Number of injured and dead cyclists in the city of Smederevo, in the period from 2018 to 2022
Source: *Agency for Traffic Safety, Republic of Serbia, https://vvv.abs.gov.rs/*

In the observed five-year period, the most injured cyclists in the territory of the city of Smederevo were between the ages of 46-64 and 65+ (Figure 3).

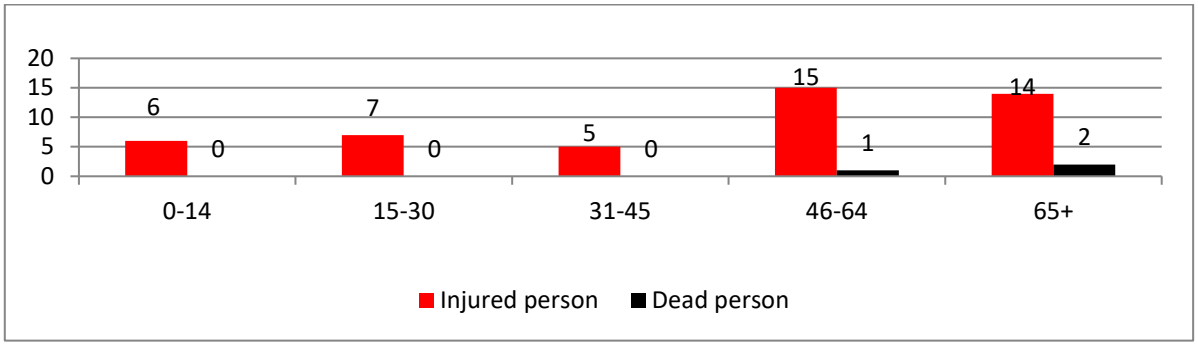

Figure 3. The number of injured and dead persons by old groups in the city of Smederevo, in the period from 2018 to 2022
Source: *Agency for Traffic Safety, Republic of Serbia, https://vvv.abs.gov.rs/*

On average, about 67% of fatal traffic accidents involving cyclists occurred outside the settlement, and about 33% of fatality occurred in the settlement. When it comes to road accidents with injuries, and in which cyclists participated, suffering is more pronounced in the settlement (89% of road accidents with injured cyclists occurred in the settlement, ie 11% outside the settlement), Figure 4 [3].

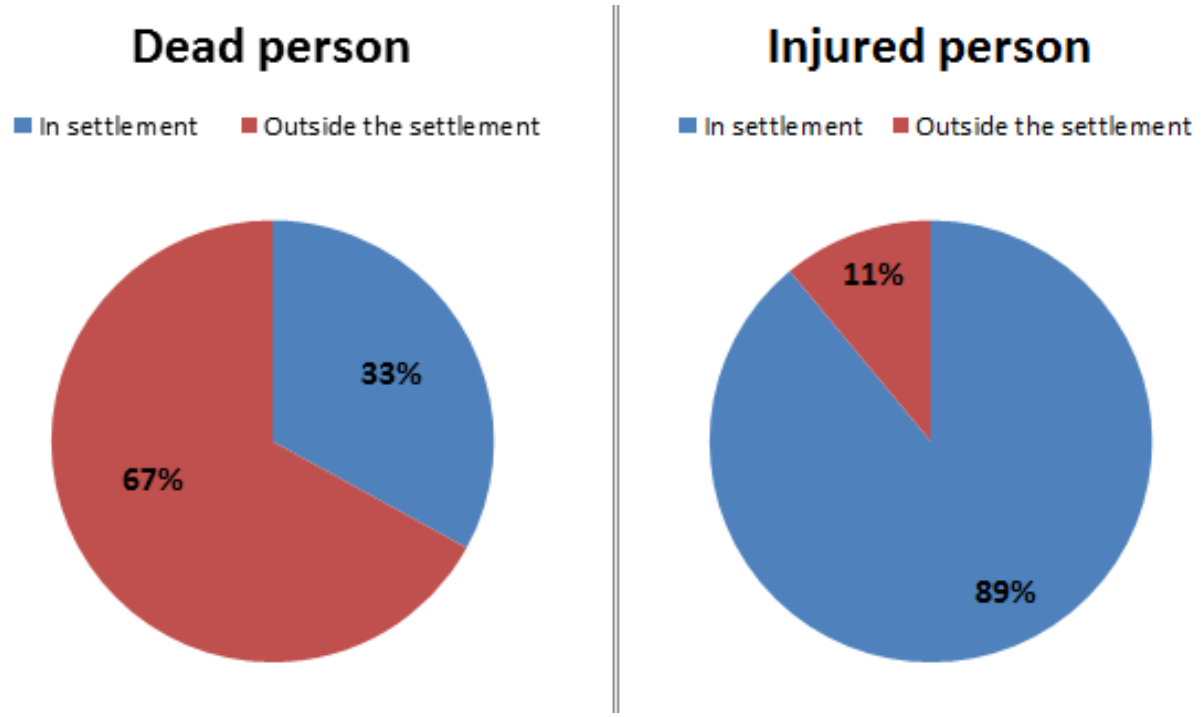

Figure 4 Distribution of traffic accidents with fatalities and injuries involving cyclists in the settlement/outside the settlement, in the period from 2018 to 2022
Source: *Agency for Traffic Safety, Republic of Serbia, https://vvv.abs.gov.rs/*

The places where traffic accidents with dead cyclists occurred in the city of Smederevo are shown in Figure 5, two cyclists died outside the settlement, while one cyclist died in the settlement [3].

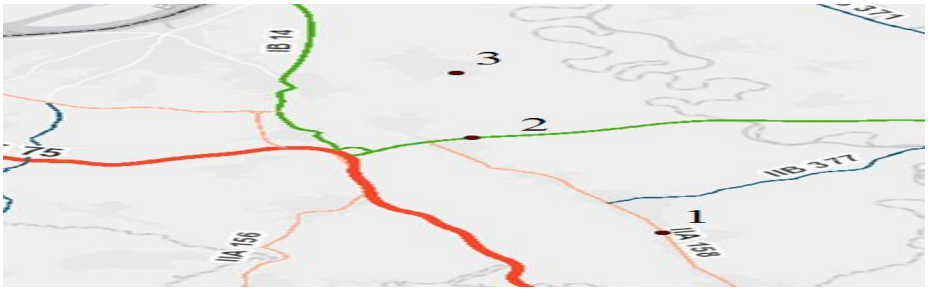

Figure 5. Places of traffic accidents with dead cyclists in the city of Smederevo, in the period from 2018 to 2022
Source: *Agency for Traffic Safety, Republic of Serbia, https://vvv.abs.gov.rs/*

Traffic accidents with dead cyclists occurred during a sudden change in the direction of movement, unadjusted speed for traffic conditions and road conditions, lack of a bicycle path or lane in the settlement and when driving under the influence of alcohol.
In the observed five-year period, the most traffic accidents with injured cyclists occurred in the settlement on the road (71%) and intersection (29%). As many as 49% of traffic accidents with injured cyclists happened in the very center of the city. Figure 6 presents traffic accidents with injured cyclists as well as critical points 1 and 2 in the city of Smederevo [3].

Figure 6. Places of traffic accidents with injured cyclists and critical points in the city of Smederevo, in the period from 2018 to 2022
Source: *Agency for Traffic Safety, Republic of Serbia, https://vvv.abs.gov.rs/*

The largest number of traffic accidents with injured cyclists at critical points 1 (intersection 17. October) and critical points 2 (state road IB 14 row) were caused by non-compliance with traffic regulations, properties of the intersection itself, as well as malfunctions of bicycle lights (white front light and red rear light), (Figure 7).

Figure 7. Critical Point 1 and Critical Point 2
Source: *https://www.google.rs/maps/*

4. CONCLUSION

The city of Smederevo does not have a single bicycle path, which is a big problem for both the safety of cyclists and other road users. Based on the data collected in this work, the biggest problem in the city of Smederevo is insufficiently illuminated roads and intersections, as well as defective bicycle lights (front white and rear red). Which leads to misjudgment of motor vehicles when catching up with bicycles, thus leading to a traffic accident with a stiff face. The causes that lead to traffic accidents with cyclists in the city of Smederevo, as well as in other cities of the Republic of Serbia, are exceeding the permitted speed of motor vehicles, failure to yield the right of way cyclists, as well as the lack of infrastructure or infrastructure in very poor condition. If there is no adequate infrastructure and if the conditions for the safe movement of cyclists are not provided, cyclists can be endangered in traffic, primarily by motor vehicles. Since protective helmets and light-reflecting vests are not mandatory for cyclists, as an alternative, cyclist associations propose the construction of more separate paths for cyclists in all cities of the Republic of Serbia, the introduction of the concept of bicycle streets in which cyclists would have priority, the expansion of zones 30 and slow traffic zones, more frequent controls speeds in cities and the introduction of speed cameras, technical measures to slow down traffic, allowing bicycles to move in two directions in some one-way streets, regulating the movement of bicycles with yellow strips, if there is no bicycle path as an alternative, and defining a mandatory safe distance for overtaking cyclists by motor vehicles vehicles. In order for cyclists to be as safe as possible in traffic in the city of Smederevo, and in the entire Republic of Serbia, apart from work on improving the cycling infrastructure, emphasis should be placed on the correctness of bicycle lights. Only about 10% of cyclists in the entire Republic of Serbia use front (white) and rear (red) lights according to regulations.

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THE LENGTH OF DILEMMA ZONE AT SIGNALIZED INTERSECTIONS

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Abstract: *Yellow traffic light at a signalized intersection is a time period during which drivers decide whether to stop the vehicle or to proceed through the intersection, according to their perception is that decision is safe or not. The aim of this paper is to investigate at what distance to the stop line drivers have a "dilemma" related to which decision they will make.This space is called "dilemma zone". The research is conducted at one approach of the signalized intersection that operate in fixed-time mode with flashing green signal.The sample was made only of vehicles caught between the stop line and camera situated at the distance of 82 m in the moment of yellow signal activation. The results show that dilemma zone is 15 m longand it is situated between 6 m and 21 m to the stop line. Also, it was found that professional drivers are less likely to proceed through the intersection and speeding drivers are more likely to take risky behaviour.The obtained results are compared with the results of other researchers. The paper ends with the most significant conclusions and discussion of research limitation and future research guidelines.*
Keywords: Dilemma Zone, Traffic Lights, Intersection, Yellow Signal

1. INTRODUCTION

Signalized intersections are common in cities with high-volume road traffic. With the expansion of traffic-actuated mode of traffic light operation the flashing green signal has been increasingly removed from signal plans due to the efficiency. So, drivers are informed about signal change when the yellow signal turns on. This short time period of three seconds presents the period during which a driver has to decide whether to continue through the intersection or to brake until he/she stops. According to Low on Road Traffic Safety of the Republic of Serbia [1], the yellow traffic light means that it is forbidden for vehicles to go through the intersection, except when they cannot safely stop in front of the traffic light. Hence, it is up to drivers to decide is it safe to stop the vehicles or not. There are many factors influencing this decision.
The aim of this paper is to investigate at what distance to the stop line drivers have a "dilemma" related to which decision they will make. This space is called "dilemma zone" and it is well known in the literature (Figure 1).
The paper is structured as follows. In the next chapter the relevant literature is reviewed. In Chapter 3 the research methodology is presented. Chapter 4 presents the results of analysis. The paper ends with conclusions and guidelines to the future research.

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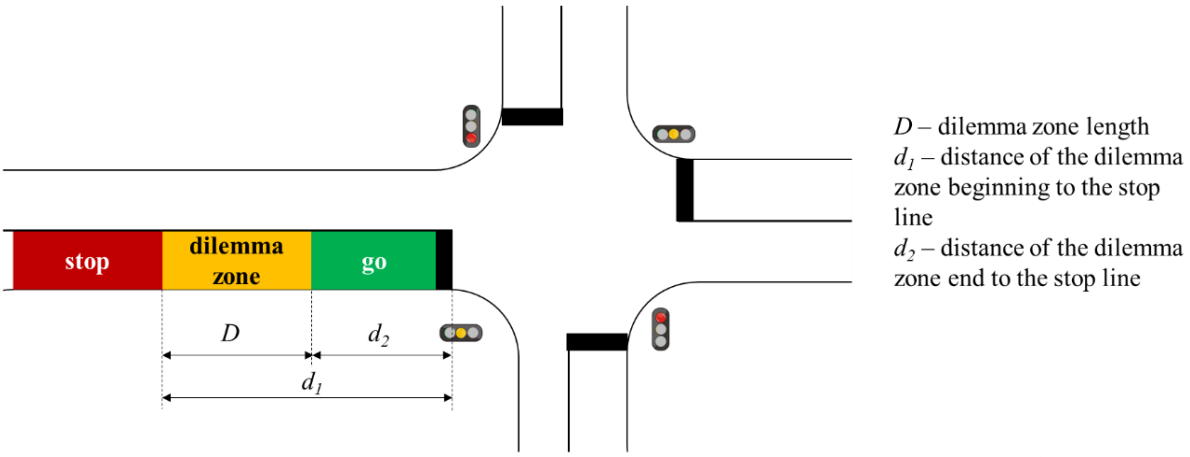

Figure 1. Dilemma zone position

2. LITERATURE REVIEW

Driver behaviour in dilemma zones was investigated both in homogeneous traffic conditions (traffic flow composed mainly of passenger cars) and mixed traffic conditions (traffic flow composed of different-type vehicles) [2]. According to the research results, the most significant factors influencing the decision made by driver in dilemma zone are: approaching speed [2, 3], distance to stop line [3], flashing green signal presence [3], driver age and gender [4], vehicle type [5] and cycle length [5].
There are also papers dealing with the estimation of road safety risk in dilemma zone. For example, Sharma et al. found that drivers base their decision on the acceleration required to pass through the intersection without conflict, not on the deceleration [6]. When it comes to the traffic light operation efficiency, Wu et al. found that the number of vehicles in dilemma zone is more sensitive to the signal coordination [7].

3. RESEARCH METHODOLOGY

3.1 Research site selection

The site was selected by applying the following criteria:

- signalized intersection with an approach that is situated on theat least 150 meters-long road segment (entrance or exit of vehicles is not possible),
- the intersection approach is suitable for camera recording (no obstacles, high visibility of vehicles and current traffic signal).

The research was conducted in Belgrade and a part of Braće Jerković street was selected as the research site (Figure 2). Its position is between two intersections: Svetozara Radojičića – Vladimira Mitrovića – Braće Jerković – Dragice Končar and Svetozara Radojičića – Ignjata Joba. The length of the analysed road segment is 255 m, measured from the centre of the first intersectionto the centre of the second one. The research included only one approach at four-leg intersection Svetozara Radojičića – Vladimira Mitrovića – Braće Jerković- Dragice Končar – this is the approach Svetozara Radojičića. Table 1 presents some important characteristics of the intersection and analysed approach.

Figure 2. Selected research site

Table 1. Characteristicsof intersection and analysed approach

Traffic light operation mode	fixed-time
Environment	urban
Speed limit	50 km/h
Yellow signal duration	3 s
Flashing green signal	yes
Speed limit at the analysed approach	50 km/h
Direction allowed from the analysed traffic lane	left and through

3.2 Research method

The research was conducted by day, during the peak time period, from 15 h to 17 h. The weather was fine, with no precipitation. Only left traffic lane on the selected approach was chosen for research becausea bus stop is situated at the right traffic lane before the intersection. Figure 3 illustrates the applied method of data collection. One camera recorded the position of vehicles 166 m in front of stop line. Another one, installed 82 m in front of stop line, recorded the position of vehicles at its location and in the moment when yellow signal turns on, as well as whether the vehicle made red light violation. The approaching speed was calculated based on travel time required to travel the road segment between cross sections situated 166 m and 82 m in front of the stop line. The positions of vehicles when yellow signal turns on are estimated based on the road markings (the distance between two continuous parts of median lineis5 m and the distance between the stop line and the first “empty” part of the median lineis measured too). The sample was made only of vehicles caught between the stop line and second camera situated at the distance of 82 m in the moment of yellow signal activation. The following data were extracted from video recordings: approaching speed, vehicle type, distance of vehicle to the stop line in the moment of turning

yellow signal on, whether the vehicle decide to cross the stop line during the yellow signal and whether the driver made red light violation.

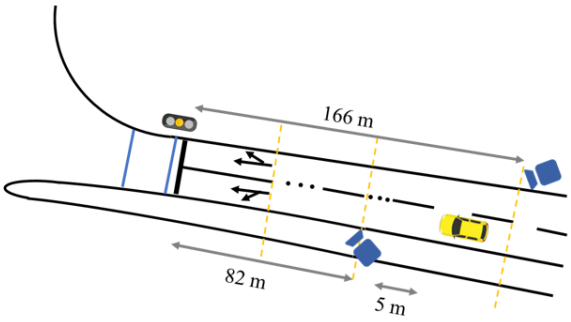

Figure 3. Layout of data collection equipment

4. RESULTS

Results of the research are based on 62 recordings of vehicles at the research site. According to the obtained data, 17,7% (11) of drivers decided to go through the intersection when the yellow signal was active and 82,3% (51) decided to stop. No driver made red-light violation.
The intersection is characterized by mixed traffic because of public transport lines and numerous construction sites at the vicinity. Table 2 shows drivers' decisions by vehicle types. As expected, drivers of heavy vehicles are lesslikely to take risky behaviour unlike passenger car and light commercial vehicle drivers. Those results are just indicative because of small share of buses and commercial vehicles in the sample.

Table 2. Drivers' decisions by vehicle type

Vehicle type	% drivers who decided to go
Passenger car	18,2
Bus	0,0
Light commercial vehicle	25,0
Heavy commercial vehicle	0,0

Figure 4 shows drivers' decisions (stop or go) in relation to the distance to the stop line and approaching speed. Dilemma zone boundaries were determined by analysing at what distance to the stop line 85% of drivers decided to cross the stop line and at what distance to the stop line 85% of drivers decided to stop. Having in mind that some researchers use 90% as a reference, boundaries were also calculated in this way in order to enable the comparison. It turns out that dilemma zone is situated between 6 m and 21 m to the stop line when taking into account the decisions of 85% of drivers. Hence, it is 15 m long. If the criterion of 90% of drivers is adopted, the dilemma zone is 22 m long and it is situated between 5 m and 27 m to the stop line.

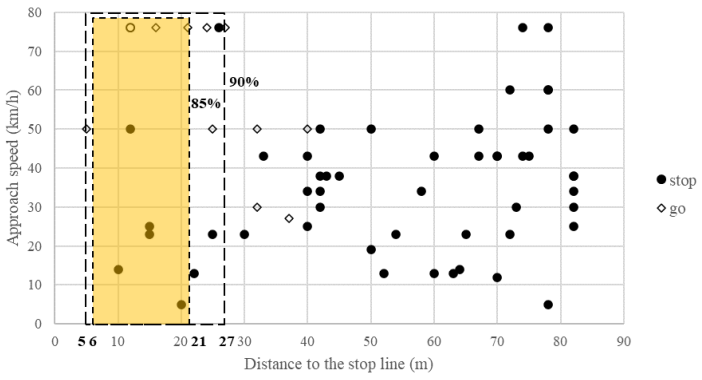

Figure 4. Drivers' reactions to yellow signal

Higher speedsat the moment of yellow signal activationare more related to decisions to go through the intersection than lower speed. Speeding drivers are generally more likely to take risk at the intersection in comparison with no-speeding drivers (Table 3).

Table 3. Drivers' decisions by speed overrun

Speed overrun	**% drivers who decided to go**
No speed overrun	11,4
Up to 10 km/h	0,0
More than 20 km/h	62,5

5. DISCUSSION

Although the most research paper refer to dilemma zone in terms of distance to the stop line, measured in meters, there are also some researches dealing with time to the stop line, measured in seconds [8]. This method takes the approaching speed of vehicle and comfortable deceleration into account [5]. Zhang et. al. made the review of research results for dilemma zone boundaries in terms of distance (ft) from the stop line in relation to the speed [9]. Their beginning is in range from 52 m to 65 m from the stop line while their end is in range from 30 m to 44 m from the stop line. Those values are results of relatively old studies, conducted in the period from 1963 to 1994. In comparison with the results of this paper, it could be concluded that the length of dilemma zone is similar, but now a days its distance is closer to the stop line. Better braking abilities of modern vehicles could be the reason. Also, drivers are previously informed about signal phase change by flashing green signal, so it is possible that different results would be obtained at the intersection without it.

Risky behaviour during yellow signal could lead to road accidents. One measure to overcome the safety problem of drivers in dilemma zone is to install a countdown timer which displays the remaining green time and assist drivers in making decision by providing them with timely information. This measure is already implemented in cities of China [9].

6. CONCLUSION

The results of this paper indicate that dilemma zone is very close to the stop line and the presence of flashing green signal could be one of influential factors. Speeding drivers are more likely to proceed through the intersection. Therefore, the approaches of signalized intersections that are characterized by high percent of speeding drivers are more at risk of red-light violation and traffic accident. Traffic calming measures at those approaches should be tested from this perspective.

The results of conducted pilot research are only indicative for conclusions. In order to get more precise results, it is necessary to enlarge the sample, especially in mixed-traffic condition, and to conduct the research in different conditions and environment (for example, by day and by night, actuated traffic light operation mode and fixed-time mode without flashing green signal, exclusive and mixed traffic lane etc.), as well as to measure time and distance in a more precise way. In terms of traffic safety, it would be useful to model driver behaviour related to red-light violation.

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ROLE OF THE RESCUE COORDINATION CENTRE IN LAND IN CASE OF AIRCRAFT ACCIDENTS

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Abstract: *Aircraft accidents are rare but very serious accidents that require quick and efficient coordination of rescue operations to save lives and minimize damages. The rescue coordination centre in land in the Republic of Croatia has a key role in coordinating and managing all aspects of the search and rescue operation. The aim of the paper is to investigate the role of the Rescue Coordination Centre in land in the Republic of Croatia in situations of uncertainty in the search for a missing aircraft. The key tasks and responsibilities of the coordination centre will be analysed, as well as the procedures used for effective search and rescue management. The paper presents the results of research aimed at the participants of the aircraft search and rescue system in the Republic of Croatia, to collect data on the current state of the aircraft search and rescue system and recommendations for improving the capabilities of the Rescue Coordination Centre in land, in part of training the staff, updating plans and procedures and the use of modern technologies for communication and monitoring the situation in the field.*
Keywords: Rescue, coordination, centre, aircraft accidents

1. INTRODUCTION

Aircraft accidents are challenging and often tragic events with potentially serious consequences for passengers, crew and the environment. In such crisis situations, a quick, coordinated and effective response can significantly influence the outcome of the accident and save lives. A key link in the organization and implementation of rescue in aircraft accidents in land is the Rescue Coordination Centre (here and after: RCC) in land.

The RCC in land is the central hub for the management and coordination of rescue operations in the event of aircraft accidents. His role includes receiving and analysing accident reports from the field, managing resources, communicating with relevant agencies, coordinating search and rescue unites (here and after: SRU), and providing support to accident investigators. The RCC in land plays a key role in providing emergency assistance and organizing all aspects of response to the accident.

The main goal of this paper is to introduce the audience with the important role of the RCC, the challenges and lessons learnt with each implemented exercise or emergency occurred. Hypothesis: Rescue Coordination Centre is the key coordination hub in aircraft accidents.

1.1. System of ASAR in the Republic of Croatia

System of Aircraft Search and Rescue in the Republic of Croatia (here and after: System) is based on international standards and regulations established by the International Civil Aviation Organization (here and after: ICAO), the European Aviation Safety Agency (EUROCONTROL) and International Maritime Organization (here and after: IMO).

The System is carried out in the manner regulated by the Regulation on the conditions and methods of conducting aircraft search and rescue (Official Gazette 129/11) and special regulations which

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regulates search and rescue activities at sea, in the area of responsibility for search and rescue of the Republic of Croatia (SRR RH), i.e. in the area of flight information (FIR) Zagreb with established lateral boundaries in accordance with ICAO doc. 7754 (Air Navigation Plan) and the Air Traffic Act (Official Gazette 96/09, 84/11, 54/13, 127/13, 92/14).
The main responsibility for the air traffic security system is on the Ministry of Transport, Sea and Infrastructure which is obligated to achieve communication with international organizations and represent the area of search and rescue in relation with the international standards. Search and rescue system is divided into two Rescue Coordination Centres – RCC in land with the responsibility of Ministry of the Interior, Civil Protection Directorate and Maritime RCC – Rijeka for the seaside with the responsibility of Ministry of Transport, Sea and Infrastructure [1].
Till the 2009, when the new Air Traffic Act enter into force, the Ministry of the Interior was responsible for conducting aircraft search and rescue activities. 2009, aircraft search and rescue responsibilities have been transferred to National Protection and Rescue Directorate. Based on the Regulation of the Government of the Republic of Croatia on the conditions and methods of aircraft search and rescue (Official Gazette 129/11), National Protection and Rescue Directorate started to develop the aircraft search and rescue system. The Regulation stipulates that the aircraft search and rescue system, must be based on the standards and recommended practice from the Annex 11 „Air traffic services“ and Annex 12 „Search and rescue“ of the Convention on International Civil Aviation and the manual Doc. 7333 – AN/859 International Civil Aviation Organization (IAMSAR Manual). On 2019 National Protection and Rescue Directorate was integrated into the Ministry of the Interior and Civil Protection Directorate was established, as a carrier of the responsibilities for further development of the aircraft search and rescue system.
In accordance with the Regulation on the conditions and methods of aircraft search and rescue, RCC is the structured organizational unit within the Civil Protection Directorate which is operative, personnel and material technically trained to accept warning message from the various organizational and individual stakeholders, analysis, processes and distribute message in order to conduct search and rescue activity by being operational 24/7 [2].
The System is composed of various, crucial institutions which are carrying important role in the emergency. Air Traffic Control is the primary point in warning system by reporting the disappearance of aircraft from the radar. Ministry of the Interior, the Civil Protection Operational Centre at the Directorate of Civil Protection, performs the role of the RCC in land which conducts coordination of resources and institutions in aircraft search and rescue, such as Directorate of Police, the Croatian Civil Aviation Agency, the Croatian Mountain Rescue Service, the Ministry of Défense, the Croatian Army through the Command Operations Centre of the Armed Forces of the Republic of Croatia by activating helicopters for purposes of searching, the Croatian Red Cross, the Ministry of Health and the Institute for Emergency Medicine, the State Hydrometeorological Institute, the Croatian Institute of Public Health, the Croatian Firefighters Association and numerous of other entities. These entities work together to ensure quick and coordinated action in case of aircraft search and rescue.
Search and rescue activities includes the use of various techniques of searching by using aircraft and unmanned aerial vehicles (UAV), the use of civilian and military radars, satellites, infrared cameras and other technologies to find aircraft and survivors. Search and rescue operation are carried out in the field, including medical assistance and treatment of the injured.

1.2. International standards

The Republic of Croatia has been a signatory of the International Convention on Civil Aviation since 1992 and is thus obliged to implement the standard and guidelines established by the ICAO, which includes the area of search and rescue in the event of an aircraft accident. The Republic of Croatia cooperates with other countries in the region and participates in international initiatives for the purpose of improving the search and rescue system [1].

In accordance to international standards, the Republic of Croatia is obliged to integrate Appendix 12 „Search and Rescue“ into its legislation. Regulations related to the system of search and rescue of buried vessels, as well as the use of aircraft for search and rescue purposes, are regulated by various international conventions that determine the conditions and manner of using aircraft for search and rescue purposes, such as the Chicago Convention, the Convention on the High Seas, the International Convention for Safety of Life at Sea (SOLAS), the Convention on maritime search and rescue. Aviation as a transport branch has the best regulated legal sector compared to other transport branches.
In order to implement Appendix 12 „Search and Rescue“ in legislation of the signatory states to the ICAO the International Manual for Aviation and Maritime Search and Rescue (IAMSAR) was created and published by the ICAO and the IMO.

2. ROLE OF THE RCC INLAND IN AIRCRAFT ACCIDENTS

The basic role of the RCC is to receive and evaluate information in the event of an aircraft accident, make and implement decisions on initiating search and rescue activities. RCC activates in the moment when it is triggered by Air Traffic Control, 112 county centre or by getting the information from the eyewitness [4].

2.1. Coordination and Communication

Coordination and communication play a vital role in aircraft search and rescue operations. These elements are critical for ensuring the swift and effective response to an emergency, the safety of both victims and rescuers, and the successful resolution of the situation.
To achieve impeccable coordination, there is a need for multi-agency collaboration because search and rescue operations often involve multiple agencies and organizations. Knowing the structure of a coordination in search and rescue activities, helps to establish a clear organizational structure with designated roles and responsibilities for search and rescue personnel, such as the role of Search Mission Coordinator (here and after: SMC), On-scene Coordinator (here and after: OSC), Aircraft Coordinator (here and after: ACO). Coordination involves identifying and dispatching the appropriate resources, including aircraft, ground teams, medical personnel, and equipment, based on the specific needs of the search and rescue operations.
Communication begins with receiving and decoding distress signals, which can arrive from various sources, including aircraft's emergency locator transmitter (ELT)[2], radar, or satellite communication systems. By developing crucial communication plan and standard operational procedures, among rescue unites and implementing the modern technologies into search and rescue activities such as communication platform for exchanging information between teams (Next Generation Incident Command System – NICS), Starlink for the areas without telecommunication network, can provide effective and successful result in search and rescue operations. One of the most important communication strategies is developed Media and Public Relations communication. Effective communication with the media and families of the victims is important for providing accurate information and managing public expectations during search and rescue operations.

2.2. Stakeholders in the search and rescue operations

The Coordination in search and rescue activities is established in three different levels; Search and Rescue Coordinator (here and after: SC), SMC and OSC.
SC is responsible for establishing, staffing, equipping, and managing the search and rescue system on the national level which includes legal and funding support, establishing RCC, Rescue Sub-Centres (here and after: RSC's), developing search and rescue policies, coordinating search and

[2] Emergency Locator Transmitter (ELT) – determines the right position of an aircraft in distress via COSPAS SARSAT satellite system.

rescue trainings, within its search and rescue region (here and after: SRR). The responsibility for conducting search and rescue operations is on the SMC which is the most qualified person in the RCC [4].
OSC is designated by SMC to facilitate support by two or more search and rescue units which are working together on the same mission. OSC will sometimes conduct the duties of the SMC if the communication could not be established with the RCC and if the OSC has better overview of the distress situation [3].
Special role of coordination is designated to ACO. In complex distress situation when the mission must be extended to other search and rescue facilities, ACO is designated by SMC or if it is not practicable by the OSC to coordinate airborne resources in defined geographical area.

2.3. Rescue Sub-Centres (RSC)

In accordance with Regulation on the conditions and methods of conducting aircraft search and rescue (Official Gazette 129/11), Rescue Sub-Centres (here and after: RSC) are the Civil Protection County Offices. In the Republic of Croatia there are five of the Civil Protection County Offices which heads are in distress situation designated as the OSC.
Main role of RSC is that in the event of an aircraft accident, receive and evaluate information, make and implement decisions on initiating search and rescue, and lead and coordinate search and rescue activity within their jurisdiction. RCC may some or all responsibilities designate to the RSC, including communications, search planning, arrangements for search and rescue facilities if it is more appropriate to conduct the effective coordination of search and rescue activities [3].

3. TRAINING AND EXERCISES

Training and exercises are crucial components of aircraft search and rescue activities. They ensure that search and rescue personnel are well prepared to respond effectively to emergencies, handle various scenarios, and coordinate efforts across different agencies. In accordance with Appendix 12 „Search and Rescue“and the International Manual of Maritime and Aviation Search and Rescue, training must be carried out for each of the roles defined by the before mentioned SMC, OSC, ACO, RCC staff and search and rescue units (here and after: SRU) [4].
Those components are not only enhancing the skills and readiness of search and rescue personnel but also help identify areas in need of improvement. Developing a productive training program and implementing the realistic Exercises are essential for maintaining a high level of preparedness in aircraft search and rescue, which is vital for the safety of passengers and crew in emergency situations.

3.1. Requirements for RCC staff

Personnel of the RCC consists of the trained and capable of planning and coordinating search and rescue activities. The number of personnel at the RCC depends on other duties, traffic density, seasonal conditions, meteorological and other search and rescue region conditions. RCC staff could be variously trained by attending specialized trainings, conferences, on-the-job training, analysing international standards and documents dedicated to aircraft search and rescue activities, search and rescue incident analysis, search planning and operations management [4].
In accordance with IAMSAR Manual edt.2022, vol.2, it is required that the RCC staff are working in 24/7 with established duty work, knowledge of the English language, means of plotting, establish communication with Air Traffic Control, know action plans, standard operational procedures, having ability to perform information management with recognition of priorities.

3.2. Exercise cycle

In accordance to Appendix 12 „Search and Rescue“, member states of the ICAO are obliged to conduct aircraft search and rescue exercises. There are three types of exercises that are carried out in search and rescue operations: communication, coordination and full-scale exercises to validate communication procedures of the participants included in the aircraft search and rescue system as well as verification of operational procedures and capabilities. At the end of the exercise, an analysis of the exercise is carried out with representatives of the participants (management and exercise group), in accordance with the goals set by the exercise. The goal of the analysis is to identify deficiencies in the operational implementation of activities during the simulated aircraft search and rescue operation and to identify lessons learned [4].

4. CONCLUSION

The role of the RCC in land in the event of aircraft accidents is of paramount importance in ensuring the safety and effectiveness of search and rescue activities. RCC serves as the central hub for coordinating efforts and resources from various agencies and organizations to respond to aircraft emergencies. The efficient functioning of the RCC significantly contributes to the success of search and rescue operations in the aftermath of aircraft accidents. It ensures that the response is well organized, timely, and focused on saving lives and mitigating the impact of the incident. Challenges and complexities are inevitable, but with the dedication and professionalism of the RCC staff, these challenges can be effectively addressed. Ultimately, the dedication, coordination, and communication of the RCC personnel contribute to the safety and security of aviation, further emphasizing the vital role they play in land-based rescue and recovery operations followed by aircraft accidents.

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TRENDS OF ARTIFICIAL INTELLIGENCE IN AVIATION: CYBER SECURITY OF ADS-B SYSTEM

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Abstract: *Since the beginning of the 21st century, aviation has been in a process of continuous transformation. The development of advanced Information Communication Technologies (ICT) and their very fast and mostly safe adoption has led to a huge increase in innovation and automation in the aviation. The approved relevant innovations, which include consolidated technologies, among other things, refer to additional values related to the Aviation industry 4.0 – industry based on Artificial Intelligence (AI) technologies, i.e. by increasing automation and data exchange, including cyber-physical systems, Internet of Things (IoT) and cloud computing. However, AI application in aviation is faced with certain challenges, which primarily relate to very high safety requirements, sofor now, AI is used as support, and the future will show how AI will be used in safety-critical aviation operations. Indeed, every new improvement in customer service/increase in the efficiency of aviationoperations opens up space for cybercriminals to take advantage of that new technology. Surely, in the non-safety-critical area, AI must be deployed rapidly and aggressively obtaining benefits and knowledge. This paper reviews of various advantages/disadvantages of AI including its applicationsin the fields of aviation cyber security, particularly for improving the security of the Automatic Dependent Surveillance – Broadcast (ADS-B) system.*

Keywords: Artificial Intelligence, Machine Learning, Cyber Security, ADS–B Aviation System

1. INTRODUCTION

The aviation industry has always been at the forefront of technological innovation, constantly pushing the boundaries to make air transport safer, more efficient and more accessible. From the earliest pioneer flights to the present day, aviation has undergone many technological revolutions, each contributing to the evolution of safer air travel. The latest revolution is the rise of AI and its potential to transform the world of aviation [1].

Namely, modern AI techniques can play an important role in the development of intelligent systems (for example smart airports or smart aviation). In the civil aviation industry, the concept of □smart□ is based on the most modern applications of the digital industry, such as the integration of devices and IoT, sensors in physical systems, the use of AI, as well as large amounts of data in the □cloud□, in order to achieve an improved user experience on reliable and sustainable way, with maximum operational efficiency, safety and security.

Various international organizations, such as European Union Aviation Safety Agency (EASA), which cooperates with all stakeholders in the aviation industry, are working very intensively and proactively on mapping the development path of AI, i.e. the approval and implementation of AI systems in aviation while maintaining the highest standards of safety, security and environmental protection [2]. In doing so, different AI techniques and approaches are considered: machine learning (data-driven AI), approaches based on logic and knowledge (symbolic AI), statistical

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approaches and combined use of all three previous approaches (hybrid AI). With all this, it is necessary to analyse the trustworthiness of the AI application, i.e. assessment of safety and security in accordance with thedeveloped ethical guidelines for the use of AI.

On the other hand, a giant step in modernizing ATM (Air Traffic Management) and improving the quality of aviation operations is the introduction of ADS□B, a multi-parameter system for air traffic surveillance [3]. As the ADS□B surveillance system does not involve a pilot or controller, it is considered as an automatic system, i.e. intelligence system. Its operation is dependent as the input is made available to the air traffic control system based on data coming from the GPS receiver of the aircraft. As a result of ADS□B broadcast protocol, immediate aircraft position, velocity, direction aswell as some other data including aircraft identification number, source, and destination are sent to nearby aircraft and ground stations over unencrypted datalink on a regular basis. Thus, ADS□B increases the safety of air traffic, enables an increase in situational awareness, as well as provides improved reports on meteorological conditions, traffic capacity, avoiding possible collisions in the air, etc. However, ADS□B has a very simple "free to air" protocol, which is its essential drawback: this system is vulnerable to various types of cyber-attacks, such as eavesdropping, jamming, message modification, message injection, i.e. spoofing [4]. Between those major design vulnerabilities of ADS□B, spoofing is the most sinister because the targeted receiver cannot detect a spoofing attack and therefore cannot warn users that its navigation solution is untrustworthy. Moreover, even if not fully successful, spoofing usually will inject hazardously misleading information and create significant Position, Velocity, Time errors. In fact, ongoing advances in compact, cost-effective software-defined radio (SDR) technologies are already lowering the barrier to conducting various types of malicious activities. Hence given the impending scope and scale of ADS□B adoption, it is imperative to consider the full range of cybersecurity threats here and devise effective mitigation strategies.

So, while vulnerable, ADS–B is not blindly exposed to defenceless cyber-attacks; attacks can be mitigated by applying various countermeasures for cyber security protection [5], such as techniques based on broadcast/message authentication and location verification. Recently, various techniques build on models of machine learning, such as Long Short−Term Memory (LSTM) networks, SODA-DNN (Deep Neural Network), fuzzy logic, etc., also have been proposed.

In addition, pilots are also trained to detect and solve problems in each phase of flight. However, due to possible more sophisticated forms of cyber-attacks, a proactive approach is necessary, increasing the robustness of the ADS□B system against different types of cyber-attacks. So, AI, or machine learning (ML), as a subset of AI, allows us to create intelligent systems that can provide advanced assistance solutions to human end users, optimise aircraft performance, improve ATM and in turn enhance safety in ways that were previously unimaginable. However, the deployment of AI in aviation brings a number of new challenges, including security and privacy, technology, cost, acceptance and regulations.

2. IMPACT OF ARTIFICIAL INTELLIGENCE ON AVIATION CYBER SECURITY

2.1.Advantages of AI technology

Multiple domains of the aviation sector will be impacted by AI emerging technology. The air transport system is facing new challenges: increase in air traffic volumes, more stringent environmental standards, growing complexity of systems, greater focus on competitiveness, for all which AI could provide opportunities.

The latest developments in AI technologies applied in the aviation industry (from production and maintenance, through aircraft and air traffic management, to innovative services for passengers) offer numerous benefits, related to [2]: a) design of aircraft parts, predictive maintenance and operability (for example, Boeing 777 is the first aircraft that was completely computerized in the design phase), b) optimization of fuel consumption, c) assistance to pilots in air operations and controllers in air traffic management (AI and ML models can be used to analyse a large amount of

data obtained from various sources and aviation systems, helping pilots to make adequate decisions, such as on an alternative route in case of bad weather conditions, g) assessing the environmental impacts (for example, AI enables route optimization and thus reducing CO_2 emissions, as well as the development of machine learning algorithms on based on ADS−B data, which could be used to estimate fuel consumption practically every flight), d) air traffic management (the ATM area foresees important applications of AI/ML, and some have already been introduced in support of ATC (Air Traffic Control) operations; by analysing data on meteorological patterns, configuration, congestion in air traffic and other factors, AI and ML models could support the optimization of flight routes in order to reduce flight time, fuel consumption and thus costs) f). passenger identification (trained AI systems, biometric scanners and facial recognition technologies can be used for quick and simple identity verification, as well as criminal activity detection), e) user experience (many airports and airlines are introducing more efficient ways to check in passengers, such as using mobile devices, e.g. Personal Digital Assistants for electronic ticketing, check-in and immigration clearance), h) pilot training, z) Unmanned Aerial System (UAS), i.e. drones (for example AI and ML models will be necessary to safely conduct UAS operations in case of unforeseen/emergency situations, as well as the effective implementation of U-space), i) detection and mitigation of cyber-attacks (latest developed techniques based on ML algorithms, such as deep learning model), etc.

A particularly significant application of AI is in the field of aviation cyber security. The effective response of the pilot to some unforeseen event, at low flight altitudes, and especially in some of the critical phases of the flight, requires a quick and efficient reaction of the pilots, who are taught to always have a way out. However, in cyber security, AI makes the response faster and more efficient. AI, i.e. machine learning techniques can be used as potential solutions for detection of avionics anomalies, achieving security of data link communications, as well as security certifications. In this context, as pointed out by Gustafsson P. (OBE, chief exec of Darktrace, a global leader in AI cyber security), ″As the aviation industry battles new threats targeting the technologies which are so critical to its business operations, the role of AI in containing and fighting back against these attacks has never been more important.″ [6]. Thus, Darktrace is based on three technology products: Detect,Respond and Prevent, which are based on ″self-learning″ AI; Darktrace separate technologies also learn from each other: each continuously inputs data into others, improving its own capabilities as well as the system's threat protection capabilities. Namely, Darktrace Respond uses Detect contextual understanding to take the optimal action (response) to mitigate the threat. The adaptability of this response is essential: a cyber-attack can come in any number of configurations, and Respond can adapt its actions accordingly. So, by using AI that takes action at machine speed, offering effective and proactive measures, as well as ″clear-sky visibility″, airlines/security teams can be confident in their ability to prevent an attack, i.e. to be/remain protected from cyber-attacks.

2.2. Machine learning approach to cyber security in ADS-B aviation system

The introduction of the mentioned ADS–B system (data link, ADS−B Out and ADS−B In applications) provides ATC and pilots with numerous benefits, such as real-time precision, shared situational awareness, advanced applications that increase safety and efficiency (in the air and on runways), as well as reducing costs and harmful effects on the environment. Now that ADS-B Out is a required standard (ADS-B In remains an optional mode), and the fact that ADS-B broadcasts the messages as unencrypted plaintexts, the most important issue is the cybersecurity of ADS–B.

ADS–B system is vulnerable to various types of cyber-attacks, such as eavesdropping (message interception), jamming (flooding) and spoofing. The latter is very dangerous and causes particular concern because affects the confidentiality and integrity of ADS-B: in spoofing, false signals are inserted into the "victim's" receiver, and the targeted receiver cannot detect the attack, norwarn the user about unreliable navigation solutions. Namely, spoofing attack is achieved by the combination of both message injection and message deletion, and the malicious hacker must eavesdrop the 1090 MHz channel (the data link which support ADS–B to enhance interoperability, regulatory and legacy purposes) in order to interpret the messages and to interfere with the required message.

In particular, potential attacks that could be carried out from the air, using UAS/drones forthe purpose of hijacking or security distraction in airspace surveillance, pose a major risk. Also, the integration of UAS and ADS−B represents a particular challenge, because in this case electronics oflower quality can be used, and the systems do not require rigorous maintenance. Because of this, there may be an unintentional transmission of wrong ADS−B data, and without a mechanism to solve these problems, unverified ADS−B data could pose a significant danger to air traffic.

Therefore, the development of robust and effective countermeasures against cyber-attacks on the ADS−B wireless communication protocol is of particular importance. To test the integrity and credibility of the received ADS-B messages, various techniques are proposed, from cryptographic and techniques that use location verification, to the most recently developed methods that are based on ML algorithms, such as, the deep learning model. For the detection of cyber-attacks on wireless aviation systems (e.g. the very dangerous spoofing attack on ADS-B), two basic machine learning approaches can be used. One is based on the classification and verification of the characteristics of certain legitimate users based on stored patterns, while the other is based on anomaly detection, whereby the parameters of the system's normal state are learned over time, and deviations from these patterns are marked as an anomaly (a potential security problem).

Thus, one of the most recently proposed methods for detecting spoofing (from the ground or from the air) [7] is a method based on the Strategic Options Development and Analysis − Deep Neural Network (SODA−DNN) detector, which consists of a message classifier and an aircraft classifier. The SODA−DNN detector allows the ground station (equipped with an ADS-B receiver, computer resources, an adequate database of received authentic ADS-B messages, etc.), to analyse each incoming message based on the characteristics of the PHYlayer (IQ samples and phases) and to note suspicious message. The message, which is not malicious, is forwarded to the aircraft classifier, which uses the phases of the received messages as input; by comparing the ICAO address with the requested one, the detector can detect a spoofing attack. To test the characteristics of the proposed detector system, it is necessary to analyse a large number of real data, i.e. have adequate equipment (ADS−B receiver and ADS-B spoofer). It should be emphasized that application of SODA−DNN allows the detection of spoofing attacks with a very high probability and a very small proportion of false alarms, which is a significant improvement over other state-of-the-art detectors.

The other/second approach [8] is based on the detection of anomalies in ADS−B messages, i.e. detection of false/manipulated ADS−B messages sent by an attacker/compromised aircraft, by analysing a series of messages and assessing their credibility. As the flights most often take place on similar routes, an LSTM (Long Short-Term Memory) encoder-decoder model, based on previous (legitimate) flights for a given route, is used and trained. Using such a model, each aircraft can independently evaluate received ADS−B messages and identify deviations from the legitimate flight path. However, the causes of anomalies in ADS−B messages can be of different nature, so their identification is only one segment in the detection of cyber-attacks. Also, very careful setup and testing of the model (calibration) is necessary to avoid false positive results.

Finally, besides the above mentioned anti-spoofing techniques, different and increasingly sophisticated ML algorithms are designed, such as neural networks, support vector machine and hybrid techniques. These different ML as well as fuzzy logic methods are proposed in the challenges of identifying and categorizing large amounts of aircraft flight data, thanks to the availability of ADS−B transponders in commercial aircraft, as well as the increase in the number of ground stationsthat provide public access to their data. These large amounts of air traffic data can be useful in a widerange of ATM analyzes that rely on operational data and statistics [9].

2.3. Some challenges of AI applications in aviation sector

Although AI technologies offer significant benefits, it can introduce new vulnerabilities and open space for cybercriminals to take advantage of this improved technology. Therefore, it is necessary to understand these new vulnerabilities (e.g. data corruption, data poisoning) and define their specific

security controls (technical or organizational). Nowadays, it is already observed that malware adaptsits behaviour depending on the operating environment. Furthermore, researchers have demonstrated the potential of a new class of AI-driven malware (e.g. DeepLocker) [2]. Cyberattacks undertaken using AI are likely to be more effective (more adaptive and autonomous), by developing AI's ability to bypass conventional detections based on system rules. Therefore, it is necessary to develop adequate countermeasures. Thus, the state-of-the-art research related to cyber-attacks based on intentional/malicious use of AI technologies significantly contributes to understanding the actions of attackers (they are constantly changing and improving their attack strategies), as well as contributingto the development of adequate defences against attacks.

Also, in future, some of the main challenges related to the application of AI in aviation, whichrequire further consideration and development guidelines, are the verification standards of AI-basedsystems and components, knowledge and data management (the need for a quality knowledge base), architecture selection models and algorithms, then, dealing with limitations in the predictability and comprehensibility of AI application behaviour (considering the model complexity), implementation of AI models in security systems (optimization of the trained model and the model embedded in the target platform), management of joint operational authorizations in new types of human-AI alliances, etc.

In all of this, the essential prerequisites for the safe development of any system, including theone with built-in AI, are the characterization of AI, i.e. safety and security assessment as well as ethics. Also, a very important aspect of future AI regulations is the level of "human oversight" in theapplication of AI. In this regard, different levels of AI application have been identified: 1) human assistance, 2) human-AI integration, and 3) advanced automation.

Advances in AI technologies are predicted to cause the AI market in the aviation industry to grow exponentially. However, it is also a fact that investing in this technology is very expensive, which is one of the primary drawbacks of its application. The necessity of numerous testing and certification by relevant organizations/regulators are key processes in the application of AI in aviation, which is why it will take time for AI to be implemented globally. Particular scepticism of experts regarding the future use of AI, i.e. by generating the concept of autonomous flight for e- Enabled planes, caused the mentioned plane accidents with fatal outcomes (in 2018 and 2019), of thesame type of plane, Boeing 737 MAX 8, because of which the Boeing company was under great pressure.

Also, and no less significant is the fact that for the successful application of AI, aviation needstrained staff who understand the issues and development process and can interact with experts both in academia and in specialised consulting companies. Extensive training programmes need to be put in place at all levels.

At the end, the most recent revolutionary invention in aviation, created by the consolidation of AI and robotics, is a humanoid robot (Pibot pilot), which is capable of independently controlling the flight process, and which was developed by the Korea Institute of Advanced Science and Technology. Taking advantage of AI, Pibot is designed to support the pilot in extreme situations, andit is expected that the full functionality of this pilot robot will be realized in the coming years.

3. CONCLUSION

Although various intelligent aviation systems will be created and the new ICT solutions for increasing the security of information and networks, as well as for the detection of cyber threats to aviation systems, including ADS–B, it is unequivocal that a human decision, based on previous knowledge, experiences and abilities, is necessary for successfully solving critical situations. Therefore, it is necessary to raise awareness of cyber-attacks through periodic training of pilots, as well as cabin crew, in order to establish a ″collective″ awareness of cyber threats, as well as training on general decision-making skills (pilots should be trained to control unforeseen and unexpected events and troubleshooting).

On the other hand, just through the AI technology, we can see significant changes in the world of aviation. Although at the beginning, these changes are already being seen, and advanced AI technologies, such as auto-pilot functions, are drastically changing the future of the airline industry. However, the idea of AI completely replacing humans/pilots is still in its infancy. But, we can conclude – adequate use of AI will significantly improve the operation and business in the aviation industry sector.

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THE IMPORTANCE OF LOW-COST AND DIFFERENTIATION STRATEGIES FOR THE BUSINESS OF TRAFFIC COMPANIES

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Abstract: *There are numerous strategies that traffic companies use depending on the results of the analysis of the external and internal environment. At the business level, there are two primary sources of competitive advantage: low costs and differentiation. Cost leadership strategy implies the ability of an individual business to gain a competitive advantage on the basis of lower costs and lower prices for the same quality. Through lower costs and lower sales prices, it will ensure a greater market share and a greater scope of traffic services. A cost advantage exists if the company has a lower cumulant cost of activities from the value chain compared to its direct competitors.*
Differentiation strategy represents a business approach to make the business of a traffic company unique and different from the competition, with the aim of standing out from the majority and providing reasons for potential customers to choose a differentiated product compared to the competition's products. Through a differentiated offer, the traffic company ensures a greater market share, a greater volume of services, and even in conditions when the differentiated product (service) has a higher price compared to the competition.
Keywords: low cost strategy, differentiation strategy, traffic business, business offer

1. INTRODUCTION

There are different definitions of strategy in the literature. Michael Porter defines strategy as a competitive position, i.e. "a conscious choice of different activities with the aim of delivering (providing) a unique mix of values". In other words, the company must know its competitors and the market in which it operates in order to be able to determine business guidelines in the future [6].
There are numerous strategies that companies use depending on the results of the analysis of the external and internal environment. The concept of "5 competitive forces" (Entry possibility, Customer power, Threat of substitutes, Supplier power and Rivalry of competitors) represents a significant method of analyzing the immediate environment in terms of opportunities and threats from the environment, that is, the strengths and weaknesses of foreign companies. Understanding the threats and opportunities that the company faces, along with its strengths and weaknesses, is a prerequisite for solving the dilemmas posed by the cascade of strategic choices. Strategy can be understood as a way to neutralize threats (and weaknesses) and turn them into advantages, as well as to take advantage of opportunities (and strengths) [1, pp 560].
At the business level, there are two primary sources of competitive advantage: (1) low costs and (2) differentiation. One of the basic strategies implemented by traffic companies is the low cost strategy (Cost leadership strategy or Low cost strategy). This type of strategy implies the ability of an individual business to gain a competitive advantage based on lower costs and lower prices for the same quality. Through lower costs and lower sales prices, it will ensure greater market share, greater volume of sales and servicing (production), greater effects of the wrong experience and, on

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that basis, lower costs again. A cost advantage exists if the company has a lower cumulated cost of activities from the value chain compared to its direct competitors [1, pp 878].
In addition to the strategy of low costs, the strategy of differentiation is a business approach to make the business of a traffic company unique and different from the competition, with the aim of standing out from the majority and providing reasons for potential users to choose a differentiated service compared to the services of the competition [1, pp 565].

2. LOW COST STRATEGY

Low costs represent one of the sources of the company's competitive advantage. Also, costs are related to the level of differentiation, another source of competitive advantage, since a differentiated competitor is not free to increase differentiation costs indefinitely. If the increase in costs fails to overcome the costs of differentiation, the differentiated competitor will be unable to financially valorise the competitive advantage [2, pp 139].
In choosing a strategy, each competitor must take into account its relative cost position. Low costs are the premise of value creation which reduces threats caused by competitive forces (degree of competition, consumer power, supplier power, threat of entry and substitutes). There are several reasons why different competitors providing the same services have different costs. The most important reasons include: (1) differences in capacity size that cause the effect of (dis)economies of scale, (2) the existence and intensity of the experience curve effect, (3) location rent (differences in access to service factors and location) and (4) frequency and the character of technological changes. It used to be thought that the size of the capacity had a decisive effect on the costs level. As seen from the previous review of factors, size is only one of the cost-reducing factors. A change in the approach to service factors, as well as the use of opportunities offered by modern information technology, enable the creation and maintenance of a competitive advantage that is not based solely on the size of capacity. Cost reduction today is decisively influenced by the organizational structure (decentralized and thin), management concept (holistic approach supported by software) and reward system (reward based on value created) [1, pp 560].
According to some authors, the prerequisites for the successful implementation of a low-cost strategy in traffic companies are as follows:
1. Access to capital for significant investments,
2. Efficiency of the service system,
3. The possibility of professional improvement of the production process,
4. Procurement of raw materials and materials at a lower price,
5. Low labour costs,
6. Effective sales and service billing.

If costs are so important, how do you track their movement? Expenses are monitored through the so-called "cost drivers". They are structural determinants that affect the costs of an activity. The costs of an activity are affected by several cost drivers. Cost drivers reflect the connections and relationships that exist between activities within the enterprise and between the enterprise and its environment. The cumulative cost of essential discrete activities determines the relative cost position. An advantage in costs exists if the company has a lower cumulative cost of activities from the value chain compared to its direct competitors [3, pp 187-213].
The first step in cost driver analysis is to allocate costs to individual activities in the value chain. The performance of each activity in the value chain involves certain costs caused by capital investments and working capital. The entry of inputs into the value chain causes a certain type of cost in each activity in the value chain through operating costs and fixed assets (capital investments). The need to tie funds to activities reflects the fact that the value of funds in activities and the efficiency of their use affect the costs of performing activities.
A low-cost strategy is a price-based, widespread marketing strategy. Companies that implement this type of strategy must be particularly efficient in engineering tasks and service delivery. Because

traffic companies using this strategy focus on a large market, they must also be able to minimize marketing and research and development (R&D) costs. On the other hand, individual traffic companies may become so focused on keeping costs low that they overlook the necessary changes in service or marketing. A low-cost strategy can be more difficult in a dynamic environment because some of the costs that traffic companies can minimize are research and development costs or marketing research costs - costs that the company may still have to incur to remain competitive [4, pp 597] .

A low-cost leader can gain significant market share by enabling a stronger position vis-à-vis suppliers and competitors. This strategy is particularly effective in the traffic area where there is limited opportunity for product differentiation and where customers are very price sensitive.

Two or more traffic companies competing for low-cost leadership can engage in price wars that drive profits to very low levels. Ideally, a business using a low-cost strategy will develop an advantage that cannot be easily copied by others. Low-cost leaders must also maintain their investments in state-of-the-art equipment or face the possible entry of more profitable competitors. Major changes in technology can drastically change business processes so that previous investments in business technology are no longer favourable [7].

3. DIFFERENTIATION STRATEGY

A traffic company that has a unique offer is not forced to accept prices (*price taker*), but has the opportunity to set prices (*price setter*). Namely, the demand for unique products and/or services depends on the price of the product, not on the ratio of supply and demand. The rule applies here: higher price, lower costs and vice versa. A traffic company that provides a unique traffic service, services the entire market, and the demand depends on it. Unlike branches with a homogeneous product or service, in branches with a differentiated product or service, the price is determined by the production or service company [1, pp 565].

Differentiation strategy represents a business approach to make the business of a traffic company unique and different from the competition, with the aim of standing out from the majority and providing reasons for potential customers to choose a differentiated service compared to the competition's services. This definition is closely related to competition in business, which Michael Porter defined as the struggle to achieve a profitable, unique position in the market [8]. This usually involves highlighting a significant difference between the business and its competitors. That difference must be recognized and appreciated by potential consumers. Also, Michael Porter believes that there are only two ways to gain a sustainable competitive advantage. One way is low cost, while emphasizing the similarities they share with their main competition: “We're just as good as our competition, but we cost less.” Unfortunately, unless businesses have a sustainable cost advantage, they can't hold on for long and implement this strategy. There is always a danger that another company (competitor) will lower the lowest price of the competitor's company. The strategy of low costs also exposes the company to the consumer's belief that all products and services are the same (commoditization) and to a much wider range of competitors [5, pp 210].

Porter's second (and more effective) way is to set the company apart, that is, to be different from the competition in a way that is important and relevant to potential customers. According to the definition above, this refers to a differentiation strategy. A point of differentiation can be broad-based and set the company apart from the rest of the industry or more narrow appealing to a niche market. This approach is often referred to as a focused or concentrated strategy. It is difficult to achieve the development of a broad-based differentiation strategy, in which one traffic company is significantly different from the industry as a whole. Even if it manages to pull it off, the question is what is stopping a competitor from imitating such an approach? This is why many businesses choose to compete with a focused strategy. In a focused strategy, the company concentrates its diversity, and thus its appeal, on a narrower audience (niche market).

There are great advantages to using a differentiation strategy in traffic companies. Some of them are [9]:

1. Price does not have to be the only strategic instrument. Since the company has distinguished itself from the competition, the potential consumer does not have to reduce his choice only to the dimension of costs, but also recognizes other differences in relation to the competition.
2. Greater attractiveness of the traffic service within the target group is created. This makes it easier to generate interest and increase sales.
3. The service has no direct replacement. Differences attract more potential customers. The lack of direct comparability forces the potential customer to focus on the unique value of the service difference.
4. Loyalty to the service (and to the company) increases. The value of the difference and the lack of comparable substitutes result in greater loyalty to the company.
5. It is possible to increase the prices of services. Assuming that the company's differentiator is one that adds value and is not available elsewhere, the company is in a position to increase the cost of the service.

According to numerous authors, differentiation strategy represents a big challenge for companies due to the following potential problems [9]:

1. In the long run, it is difficult to build differentiation on service characteristics. Any feature (or function) of a service that is significant and currently popular is easily copied. (for example, as soon as Snapchat Stories came to life, first Facebook, and then all other social networks, copied them). Even when a service has some truly innovative features, it will take time for the competition to reach that level of service. Therefore, differentiation should not be based only on the characteristics of the service, especially since there are consumer beliefs that all services are the same (commodization). Almost all smart phones have great screens. It wasn't always this way, but mobile phone manufacturers can no longer build or maintain a competitive advantage based on screens alone. They might be able to do this based on battery life, but even if a better battery is made (which will likely increase the overall cost of production), even such success will be very limited in time. The competition will produce the same battery very soon.
2. Markets are becoming increasingly saturated. Never before have there been so many brands as there are today. The barrier to entering the market and opening new businesses has never been lower.
3. Over time, competitors become increasingly similar. The greater the competition, the stronger the commitment to differentiation should be, however, the opposite is generally the case. Constant comparison and benchmarking lead to similarities between products, and competitors become less differentiated over time. As the number of products within a category multiplies, the differences between competitors become less and less visible, almost non-existent.

4. SUCCESSFUL EXAMPLES OF STRATEGIES IN TRAFFIC COMPANIES

There are numerous examples of companies in the world that implement a low-cost strategy using different instruments and methods, depending on internal opportunities (and weaknesses) and external opportunities (and threats). In the context of this work, we cite several examples of traffic companies. Although the above examples belong to air traffic companies, the low cost and differentiation strategies applied by these companies can easily be applied to companies dealing with other types of traffic.

RyanAir [10] is probably one of the most famous examples when it comes to implementing a low cost strategy. Founded in 1984, Ireland's budget airline (with a fleet of 469 aircraft including subsidiaries) carries more international passengers than any other airline in the world.

The company's competitive advantage strategy is based on their intention to outperform competitors by providing air travel services at the lowest possible unit costs. This is achieved in a variety of ways, including:

- significant bargaining power with suppliers, which helps the company to keep its operating costs at a low level;
- small variety of aircrafts (mainly Boeing 737-200), which allows them to purchase spare parts in large quantities;
- negotiating power with airport operators, demanding low landing, take-off and maintenance fees, in addition to flights to less popular airports;
- lack of differentiation services such as loyalty schemes, free food, in-flight entertainment, airport lounges, premium cabins, etc.

Emirates [11]. While airlines such as Ryan Air and Wizz Air have chosen a low-cost strategy as a competitive advantage, other companies in the industry are looking for ways to differentiate themselves. For this reason, an example of a differentiation strategy is the Emirates. Based in Dubai, Emirates is the national airline and carrier of the United Arab Emirates. The company operates about 3,600 flights per week to more than 150 cities in 80 countries. However, what really differentiates them is not the number of flights or the countries they go to, but:

- Exceptional customer service. Narrow spaces between seats, no entertainment and a limited choice of food and drinks, Emirates does not exist. The company provides exceptional service and merchandise to its passengers, taking care of them throughout the flight. Even Economy Class, the cheapest of their offerings, includes: high-quality, regionally inspired meals from the flight's destination; digital entertainment during the summer with over 4,500 movies to choose from; excellent customer service and catering; Free drinks; Wi-Fi on the plane.
- Latest technology. An important part of Emirates' differentiation strategy is the fact that they invest heavily in the latest technologies available in the market. From using advanced navigation technology for their aircraft to providing the best in-flight entertainment, their commitment to innovation is a fundamental part of the customer-centric experience.

5. CONCLUSION

From the above, it can be concluded that a low-cost strategy can help achieve a competitive advantage in the market. Traffic companies that implement a low-cost strategy have first of all created the preconditions for the successful implementation of the strategy, namely: access to capital for significant investments, efficiency of the servicing system, the possibility of professional improvement of the servicing process, supply of vehicles and spare parts at a lower price, low labour costs and efficient placement services. Such companies can gain significant market share enabling a stronger position vis-à-vis suppliers and competitors. This strategy is particularly effective for organizations in industries where there is limited services differentiation and where customers are highly price sensitive.

The low-cost strategy carries with it certain risks and dangers. Two or more firms competing for low-cost leadership can engage in price wars that drive profits to very low levels. Ideally, a business using a low-cost strategy will develop an advantage that cannot be easily copied by others. Low-cost leaders must also maintain their investments in state-of-the-art equipment or face the possible entry of more profitable competitors. Major changes in technology can drastically change servicing processes so that previous investments in servicing technology are no longer profitable. Finally, businesses can become so focused on keeping costs low that they may overlook necessary changes in processing services or marketing.

The strategy of differentiation is one of the most widely applied generic strategies in practice. Companies that implement this strategy use different ways and instruments of differentiation with the main goal of being different from the competition. Which instrument will be used depends on the results of the market research as well as on the research of one's own company, that is, on the current possibilities, the traffic company itself, and the market, i.e. company environment.

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ENVIRONMENT AND SUSTAINABLE DEVELOPMENT. MECHATRONICS. OCCUPATIONAL SAFETY AND HEALTH AND FIRE SAFETY. SMART MANAGEMENT SYSTEMS. GRAPHIC ENGINEERING. DESIGN. TRAFFIC ENGINEERING. BIOTECHNOLOGY AND HEALTHCARE. MECHANICAL ENGINEERING. ECOTOURISM AND RURAL DEVELOPMENT.

ANALYSIS OF THE COMPETITIVENESS OF LOGISTICS PROVIDERS IN THE AREA OF THE WESTERN BALKAN COUNTRIES

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Abstract: *It often happens that the critical factors of competitiveness are difficult to recognize or are incorporated within other segments, so companies or countries are not able to recognize them in a timely manner. It is for this reason that it is important to have adequate instruments both at the state level and at the global level, which will enable the monitoring and continuous improvement of performances that lead to the strengthening of competitiveness. Given the fact that competitiveness is related to many factors and that the logistics services market is extremely complex, it is difficult to compare different countries in terms of competitiveness and logistics performance. Namely, it is necessary to determine which performances are important to monitor, collect a large amount of data, and then process, analyze, and propose potential directions for improvement. However, the World Bank has introduced two important instruments for monitoring these indicators, namely the Logistics Performance Index and the Global Competitiveness Index. Based on the data published on a biannual basis, which are included in the report, one can easily assess the position on the market, the competitiveness of countries, as well as the directions for improvement. Therefore, the aforementioned indexes were considered in the paper in order to create a complete picture of the logistics services market in the area of the Western Balkan countries.*
Keywords: Competitiveness, Logistics performance, Logistics providers, LPI, GCI

1. LOGISTICS PERFORMANCE INDEX

Globalization and increased competitiveness have led to logistics becoming one of the key elements of international trade. Since logistics includes many factors, activities, and functions, the challenge is to be competitive in the market and to have a level of efficiency that meets the needs of users. Logistics is one of the most important elements of national competitiveness. Quality logistics services and infrastructure promote the exchange of goods between countries [1, 3].
In developing countries, certain aspects of logistics are not sufficiently developed, which causes an increase in costs and hinders the efficient movement of goods across borders. The reasons are numerous, from insufficiently developed infrastructure to complex customs procedures and excessive bureaucracy. It is precisely for this reason that it is complex to develop a unified model for measuring the logistics offer of a country. A tool that has proven to be useful is the Logistics Performance Index (LPI), published by the World Bank for an average of 150 countries (depending on the year). This index enables the analysis of key differences between countries, providing an overview of customs procedures, logistics costs, infrastructure, timeliness, and other dimensions of logistics service quality [1, 5]. Below are the key dimensions of the LPI index [1, 2, 4]:

- Efficiency of the customs clearance process (i.e., speed, simplicity, and predictability of formalities) by border control agencies, including customs;
- Quality of trade and transport-related infrastructure (e.g., ports, railways, roads, information technology);
- Ease of organizing shipments at competitive prices;
- Competence and quality of logistics services (e.g., transport operators, customs brokers);

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- Ability to track shipments;
- Timeliness of shipments arriving at their destination within the predicted or expected delivery time.

The Logistics Performance Index (LPI) is an interactive benchmarking tool created by the World Bank to help countries identify the logistics challenges and opportunities they face. In addition, the LPI report also provides potential guidelines, i.e., what the observed countries can do to improve their performance. The last report available on the World Bank website is from 2023. Although the data was planned to be published for two years, the previous report was published in 2018 due to the impact of the COVID-19 pandemic. According to the LPI index, the countries of the Western Balkans are partially logistically developed [2, 4].
Table 2 provides an overview of the LPI and the ranking of the countries of the W. Balkans in the period from 2014 to 2023. The largest increase in LPI in the observed period was achieved by North Macedonia, from 117th position to 57th. The country with a negative growth trend is Serbia. The leader in terms of rank on the LPI list among the countries of the Western Balkans is Croatia [2, 4].

Table 1. LPI index for the countries of the Western Balkans
Source: *https://lpi.worldbank.org/*

	in 2023		in 2018		in 2016		in 2014	
Country	Rank	In total	Rank	In total	Rank	In total	Rank	In total
Croatia	43	3.30	48	3.12	51	3.16	55	3.05
Serbia	73	2.80	68	2.83	76	2.76	63	2.96
BiH	61	3.00	78	2.76	97	2.60	67	2.88
Montenegro	73	2.80	94	2.65	123	2.38	81	2.75
Albania	97	2.50	98	2.62	117	2.41	/	/
N. Macedonia	57	3.10	99	2.62	106	2.51	117	2.50

The country received the best rating for the timeliness of shipment delivery; Croatia is the leader in this category with a rating of 3.4. The countries of the Western Balkans mostly received the lowest score for customs procedures. Certainly, this is expected considering the average time the vehicle is held during customs formalities, which is often between 4 and 5 hours. The inefficiency of the customs procedure significantly affects other attributes of the logistics service, primarily the timeliness of delivery [2, 4].

Table 2. LPI index for Western Balkan countries by category (2023)
Source: *https://lpi.worldbank.org/*

Country	Customs	Infrastructure	International shipments	The quality of the logistics offer	Timeliness	Shipment tracking
Croatia	3.0	3.0	3.6	3.4	3.2	3.4
N. Macedonia	3.1	3.0	2.8	3.2	3.5	3.2
BiH	2.7	2.6	3.1	2.9	3.2	3.2
MNE	2.6	2.5	2.8	2.8	3.2	3.2
Serbia	2.2	2.4	2.9	2.7	3.4	2.9
Albania	2.4	2.7	2.8	2.3	2.5	2.3

The LPI index showed another shortcoming of the mentioned countries, namely the quality of the infrastructure. According to the assessment, the infrastructure is the least developed in the territories of Serbia and Montenegro. The quality of the logistics offer is the best in Croatia, followed by North Macedonia and Bosnia and Herzegovina. Regarding the organization of international shipments, the countries are quite uniform. This means that international commodity flows are

taking place on the territory of the listed countries, but the question is how complex their organization is. Shipment tracking is also not at a satisfactory level. It is a fact that modern monitoring and reporting systems are insufficiently used in the countries of the Western Balkans [2,4].

2. GLOBAL COMPETITIVENESS INDEX

The World Economic Forum defines competitiveness as a set of institutions, regulations and other factors that determine the level of productivity of countries. The indicator of the level of competitiveness is called the Global Competitiveness Index (GCI) and deals with measuring the average of several microeconomic and macroeconomic components that are individually evaluated on a scale from 1 to 7. All measured indicators are grouped into twelve segments and reflect different aspects complex economic realities. The indicators are grouped into three units: the basic factors of the managed economy, the efficiency of the managed economy and the innovations of the managed economy.
The following (Table 4) shows the competitiveness index of the countries of the Western Balkans for 2019. For each country, the overall ranking is shown, as well as the ranking of each key element of the GCI. In addition, the ratings for the mentioned categories are also shown. Scores are from 1-100 and represent the sum of individual scores for each subgroup (scores from 1-7) [6].

Table 3. GCI of Western Balkan countries by category
Source: www3.weforum.org/docs/

Country	*Croatia*		*Serbia*		*BiH*		*Montenegro*		*Albania*		*North Macedonia*	
GCI 2019	Rank	Rating	Rank	Rating	Rank	Rating	Rank	Rating	Rank	Rating	Rank	Rating
IN TOTAL	**63**		**72**		**92**		**73**		**81**		**82**	
Basic factors of the managed economy												
Institutions	77	51.8	75	52.5	114	44.4	53	57.3	76	51.9	84	50.7
Infrastructure	32	78.2	51	73.8	84	63	83	63.6	98	57.7	75	66.9
Macroeconomic stability	43	90	64	75	64	75	104	70	104	70	82	74.8
Health and basic education	47	85.7	76	79	73	80.3	65	81.2	46	85.9	64	81.3
The efficiency of the managed economy												
Higher education and training	69	63.5	55	68.2	82	60	53	68.7	50	69	83	59.8
Commodity market efficiency	86	53.2	73	54.6	108	49.6	42	59.4	75	54.4	110	48.6
Labor market efficiency	94	56	54	62.1	107	53.3	26	67.7	38	65.3	82	58.3
Development of the financial market	63	61.9	82	57.4	80	57.9	44	68	102	53.3	83	57.3
Technological preparedness	60	60.7	77	52.6	80	51.6	57	62.9	75	52.9	70	57.6
Market size	78	50	74	51.8	101	42.3	134	28.8	111	39.6	109	39.7
Innovations of the guided economy												
Business sophistication	101	54.6	54	63.1	117	51.1	50	64	63	61.8	65	61.2
Innovations	73	37.8	59	40.2	117	28.4	69	38.3	110	29.8	97	31.8

A higher score reflects a country's greater success in a particular category. The best-ranked country in the Western Balkans is Croatia, followed by Serbia, Montenegro, Albania, and North Macedonia. The lowest-ranked country in the observed category is Bosnia and Herzegovina. The category in which countries received the lowest individual score is innovation and business sophistication. Namely, based on the results, it can be concluded that countries do not sufficiently follow and implement modern business trends. The market size category also supports the mentioned fact.

In terms of infrastructure, a positive picture can be seen for Croatia and Serbia. One of the reasons is certainly the membership in and the process of accession to the European Union. Namely, before its official accession to the EU, Croatia had to fulfill many conditions, and one of them was the quality of its infrastructure, which the mentioned country significantly improved. Given that Serbia is also in the process of joining the Union, it is clear that it is necessary to work on improving the infrastructure network, which is reflected in the GCI assessment. However, the LPI values show that the performance in terms of infrastructure is still not at a satisfactory level. The countries of the Western Balkans are generally rated poorly in terms of institutions. In this category, the sections dealing with corruption and bureaucracy are particularly poorly rated. Namely, it was observed that bureaucratic forms, laws, and other by-laws are often a "stumbling block" for many companies. It was observed that many activities within the institutions are carried out lapurlatistically.

In terms of health and basic education, the countries are correctly listed. This is to be expected, considering that in most of the listed countries, primary education is compulsory. However, the problem is reflected in another category, namely higher education and training. The percentage of highly educated people in these countries is still at a devastating level. This is also influenced by personnel training, which is insufficiently conducted, and as one of the reasons, the previously mentioned small percentage of highly educated people can definitely be singled out. Namely, managers who are insufficiently educated are unable to recognize the value of training and encourage employees to continuously develop. In terms of macroeconomic stability, Croatia is once again ranked the best. Of the listed countries, it stands out for having the highest average income per capita and the lowest unemployment, but also for the fact that there is little political turmoil.

3. CONCLUSION

Through the monitoring and analysis of Logistics Performance Indicators and Competitiveness Indicators, some of the basic shortcomings of the countries of the Western Balkans were observed, due to which they are limitedly competitive on the markets and logistically underdeveloped. The analysis of both indices gave similar results. The best in the region in terms of both indices is Croatia, which can be explained by the fact that it has been part of the European Union for ten years and that in the process of accession it significantly improved various segments with the intention of becoming a full member. However, Croatia, as well as other countries in the Western Balkans, should continue with continuous growth and development in various aspects. Starting with infrastructure, administration, logistics, market expansion, development of new products and services, education, and staff training.

It is necessary for companies to seriously devote themselves to the development of logistics solutions, the introduction of innovations, digitization, and the construction of system support for business. The lack of manpower will initiate faster development and the introduction of solutions based on new technologies and automation. It is necessary to work on solutions that replace human labor in the execution of the work itself. Such solutions are already widely used around the world. On the other hand, it is necessary to introduce standards, procedures, and work procedures that companies do not have or have adopted but do not implement. It is necessary for the growth and development of companies to be planned and controlled. This requires specific knowledge and skills, so it is necessary to invest in acquiring knowledge and training employees.

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SELECTION OF LOGISTICS PROVIDER IN THE FIELD OF E-COMMERCE

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Abstract: *Through the cooperation of business entities, it is possible to maximize the advantages and minimize the risks of business. Therefore, especially in the last decade with the expansion of e-business, the execution of certain logistics activities is increasingly left to specialized logistics service providers. Choosing a logistics provider is a complex task. It is necessary to know the system well and define the criteria for choosing a provider accordingly. In addition, it is necessary to apply adequate methods for solving this task. In this paper, a model for the selection of a logistics provider in the field of e-commerce was developed using the AHP (Analytic Hierarchy Process) method.*
Keywords: logistics, providers, e-commerce, AHP method

1. INTRODUCTION

In the period of globalization, gaining a competitive advantage is possible through the cooperation of business entities, with the aim of dividing tasks, risks, responsibilities, as well as specialization in the execution of certain business activities. Development of the information sector, communications and traffic has brought a series of changes in supply chains. One of those changes is the transfer of logistics jobs to specialized logistics service providers. In the beginning, tasks related to warehousing, transportation and customs formalities were left to logistics providers. Due to the numerous advantages of doing business in such a way which are primarily related to the rationalization of logistics costs, the provision of better service, greater specialization of personnel, an increasing number of activities were entrusted to the providers. After the expansion of electronic commerce, providers of logistics services in the field of e-commerce appeared on the market. This type of provider, by applying knowledge and information technologies, strives to provide the user with complete logistics solutions. The aim of this paper is to develop a model for the selection of logistics providers in the field of e-commerce.

2. LOGISTICS PROVIDERS

Expansion of market competition led to increased cooperation between companies, shared responsibilities and divided jobs and tasks, next to the specialization of their own activities. Therefore, the need to hire a provider often arises. Products and product quality are becoming more and more uniform and therefore, competitive advantage can only be achieved in the field of logistics service. Looking for a way to increase profits, quality and minimize risks, companies are increasingly turning to partnerships and outsourcing certain activities [3]. Logistics providers are companies that specialize in providing logistics services. The development of logistics also influenced the development of logistics providers. Therefore, different forms of logistics providers

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appear over time, from 1PL (First Party Logistics) to the 5PL (Fifth Party Logistics) model [14]. The main task of the 5PL provider is related to the mapping and reengineering of the entire supply chain in the field of e-commerce. The 5PL provider tries to coordinate the work of other providers in the field of electronic commerce (e-commerce) by applying knowledge and information technologies and thus offering complete logistics solutions. This type of provider does not own physical assets in the form of means of transport, warehouses, etc. Its business is mostly focused on web business, which implies that all participants in the supply chain receive information precisely from the 5PL provider and on that basis perform part of the activities within the supply chain. It is essential that the 5PL provider manages the information adequately, but also the system for integration of information received from the downstream providers needs to be reliable. The information has to be updated and available in real time. For this reason, 5PL providers have recognized the importance of digital transformation and, through the concept of IoT (Internet of Things), collect data from various sources of the supply chain [7].

3. E-COMMERCE

Electronic business means the provision of services and the exchange of goods and information through electronic systems (most often the Internet). In a broader sense, electronic business includes any form of business activity that is performed using electronic systems. The most common forms of business activity are: purchase, sale, distribution, marketing, supply chain management, money transfer, servicing, development, etc. The advantages of using e-commerce compared to traditional commerce are numerous. Some of the advantages from the seller's point of view are [6]:

- faster identification of the target market,
- global availability,
- increasing competitiveness,
- the possibility of a faster reaction to the customer's requests,
- faster turnover of capital and
- reduction of documentation in paper form

The advantages of e-commerce from the customer's point of view are primarily the convenience of shopping (the so-called armchair shopping), but also [6]:

- the seller's response time is shorter,
- easier access to information,
- faster delivery than in the case of commercial sales and
- easier price comparison of services and products of different companies

The biggest drawback of e-commerce, from both the seller's and the buyer's perspective, is related to data control and protection. Other disadvantages are [6]:

- the possibility of a delivery error,
- the possibility that delivery will not occur,
- the seller may misrepresent himself,
- reduction of direct contact between seller and user,
- sharing confidential information (address, account number, etc.) etc.

4. AHP METHOD

The AHP method was defined by Saaty in the 1980s and is used as a tool in multicriteria analysis. A complex problem is decomposed into a larger number of factors, among which a hierarchy is established. At the highest level of the hierarchy is the goal, then the criteria within which a large number of sub-criteria can be found, and finally, the alternatives [5, 13]. The application of the AHP method can be presented in four steps. The first step involves structuring the problem, the next step involves forming a decision matrix. In the third step, it is necessary to define the priority of each element in relation to the higher level of the hierarchy. In the last step, all priority values are synthesized. Below, the steps are described in more detail [4, 12]. During the application of the

AHP method, the expert can add or eliminate hierarchical levels and elements depending on the impact they have on the achievement of the defined goal [10, 11].
The second step involves the formation of a decision matrix. It is assumed that there are elements of the same hierarchical level. It is necessary to compare them in pairs in order to determine their importance for achieving the defined goal. For comparing pairs of elements, experts most often use the Saaty scale [10, 12]. The expert defines the values for the elements of the square matrix $A = [a_{ij}]_{nxn}$, where for each a_{ij} based on the rule of reciprocity is valid [12]:

$a_{ij} = \frac{1}{a_{ji}}$ for $\forall i, j = 1, \ldots n \; i \; a_{ij} = 1 \; za \; \forall i = j$, where n is the number of criteria. (1)

In the third step, the priority of each element is defined in relation to the higher level of the hierarchy (w_{ij}). Priority w_{ij} shows the importance of alternative i in relation to criterion j, where $i = 1, \ldots m$ and $j = 1, \ldots n$ where m represents the number of alternatives [4].
The last step entails the synthesis of all priority values in order to obtain the priority of each element in relation to a predefined goal. W_i is the priority of alternative i and is determined as [4]:

$W_i = \sum_{j=1}^{n} c_j w_{ij}$ (2)

where c_j is the priority of criterion j, and w_{ij} is the priority of alternative i in relation to criterion j.
A significant characteristic of the AHP method is that during the evaluation of the elements of the hierarchy, the consistency of the expert's reasoning can be checked side by side, and thus the correctness of the obtained weight values and ranks of alternatives and criteria can be monitored. This is done by monitoring the consistency index CI. The index measures the deviation of n from λ_{max} where λ_{max} represents the highest eigenvalue of the decision matrix. If $CR \leq 0.10$, it means that the evaluations of the decision makers are consistent, that is, that the deviation in the experts evaluations is less than 10%. The consistency index is calculated as [4, 12]:

$CI = \frac{\lambda_{max} - n}{n-1}$ (3)

Based on the presented relations, the CR consistency ratio is calculated. The consistency ratio represents the quotient of the consistency index and the random consistency index RI [12]:

$CR = \frac{CI}{RI}$ (4)

The AHP method is applied in various fields, and it has also found its place in logistics. It is used for the selection of logistics providers, solving location problems, improving the quality of logistics services, etc. The AHP method can be combined with QFD, COPRAS, TOPSIS and other methods [1, 2, 8, 9].

5. MODEL FOR SELECTING A 5PL PROVIDER

In this paper, the criteria and alternatives for selecting a logistics service provider in the field of e-commerce are analyzed. After that, a hierarchy was established, that is, the structuring of the problem was carried out, which is shown in Figure 1.

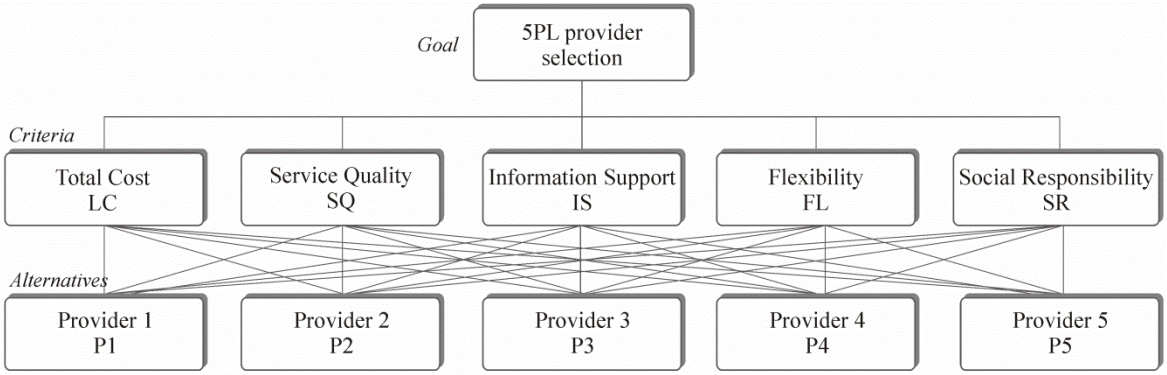

Figure 1. Hierarchical structure of the model for selecting a logistics provider

At the highest level within the presented hierarchical structure is the goal - the logistics provider selection in the field of e-commerce. On the second level, there are the criteria on the basis of which

the logistics provider is selected, namely: logistics costs, service quality, information support, flexibility and social responsibility. On the third level there are five alternatives, that is, five logistics providers that are shown in Figure 1.

6. NUMERICAL EXAMPLE

The model for choosing a logistics provider was tested on a concrete example that includes $n = 5$ criteria and $m = 5$ alternatives. The criteria are logistics costs (LC), service quality (SQ), information support (IS), flexibility (FL) and social responsibility (SR), and the alternatives are providers P1, P2, P3, P4 and P5. The input data for the application of the AHP method were obtained by surveying experts.

Table 1 shows the criteria comparison matrix and the calculated priorities for each criterion. The table shows the values of λ, CI and CR. The value CR is less than 10%, which means that the priority vector can be accepted.

Table 2 shows the comparison matrices of providers in relation to the criteria and values of local priorities for each provider. Global priorities are calculated based on the obtained values of local priorities. Table 3 shows the local and global priorities for each provider. The output results of the proposed model include the importance of all criteria and proposed alternatives. Figure 2 shows the values of importance of criteria and alternatives graphically.

Table 1. Comparison matrix and priorities of criteria

	LC	SQ	IS	FL	SR	W
LC	1	1/3	1/3	1	1	0.105
SQ	3	1	2	3	5	0.393
IS	3	1/2	1	3	5	0.300
FL	1	1/3	1/3	1	3	0.132
SR	1	1/5	1/5	1/3	1	0.071
	λ_{max} =5.158		CI =0.040		CR =0.036	

Table 2. Comparison matrices and local priorities for providers

		P1	P2	P3	P4	P5	w
LC	P1	1	1/3	1/4	1/5	1/3	0.062
	P2	3	1	1/3	1/2	1/3	0.118
	P3	4	1/2	1	3	2	0.388
	P4	5	1/3	1/3	1	1	0.211
	P5	3	1/5	1/5	1/3	1	0.221
	λ_{max} =5.221		CI =0.055		CR =0.050		
SQ	P1	1	3	3	3	2	0.398
	P2	1/3	1	1	1	3	0.175
	P3	1/3	1	1	1	3	0.175
	P4	1/3	1	1	1	2	0.157
	P5	1/2	1/3	1/3	1/2	1	0.095
	λ_{max} =5,259		CI =0.065		CR =0.058		
IS	P1	1	4	3	3	2	0.114
	P2	1/4	1	3	2	1	0.398
	P3	1/3	1/3	1	1	1/2	0.080
	P4	1/3	1/2	1	1	1/4	0.192
	P5	1/2	1	2	4	1	0.216
	λ_{max} =5.233		CI =0.058		CR =0.053		
FL	P1	1	3	1/2	1/2	1	0.177
	P2	1/3	1	1/3	1	1	0.115

	P3	2	3	1	3	4	0.395
	P4	2	1	1/3	1	3	0.207
	P5	1	1	1/4	1/3	1	0.106
	λ_{max} =5,364		CI =0.091		CR =0.082		
SR	P1	1	1	1	2	3	0.246
	P2	1	1	1	2	3	0.246
	P3	1	1	1	3	4	0.283
	P4	1/2	1/2	1/3	1	5	0.158
	P5	1/3	1/3	1/4	1/5	1	0.066
	λ_{max} =5,220		CI =0.055		CR =0.050		

Table 3. Local and global priorities of criteria and alternatives

	LC	SQ	IS	FL	SR	
	0.105	0.393	0.299	0.132	0.071	← W ↓
P1	0.062	0.398	0.399	0.177	0.246	0.323
P2	0.118	0.175	0.188	0.115	0.246	0.170
P3	0.388	0.175	0.097	0.395	0.283	0.211
P4	0.211	0.157	0.091	0.207	0.158	0.150
P5	0.221	0.095	0.225	0.106	0.066	0.147

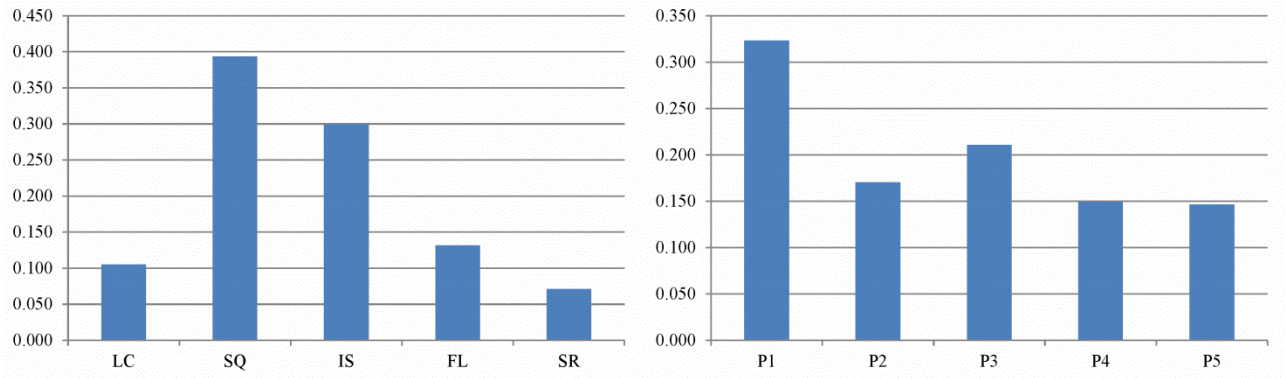

Figure 2. Importance of criteria and alternatives

Analysis of the results indicates the following conclusions:

- The most important criterion is service quality – SQ (39.3%) and the least important is social responsibility – SR (7.1%).
- The provider ranking is P1, P3, P2, P4 and P5.
- Provider P1 is the best because it is rated best by experts according to the most important criteria (SQ and IS).
- Other providers have approximately similar scores for all criteria.

7. CONCLUSION

There is increasing interest in the application of different methods for selecting logistics providers, and in recent years the focus has been on the expanding e-commerce sector. It is important to emphasize that there is no universal tool for selecting logistics providers. The criteria are chosen depending on the needs and way of functioning of the observed system. In addition to the AHP method, it is possible to apply other methods, and often a combination of several methods is applied.

Fulfilling the increasingly complex demands of customers and maintaining a position in the market is a real challenge. Therefore, companies increasingly decide to entrust part of their activities to specialized logistics service providers - logistics providers. Choosing an adequate provider is a

complex task, and a wrong assessment can affect many aspects of business, primarily the end user's dissatisfaction with the service or product. Therefore, it is necessary to choose reliable business partners, but also to monitor your own system in order to determine which features the provider should have in order to fulfill all requirements.

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ENVIRONMENT AND SUSTAINABLE DEVELOPMENT. MECHATRONICS. OCCUPATIONAL SAFETY AND HEALTH AND FIRE SAFETY. SMART MANAGEMENT SYSTEMS. GRAPHIC ENGINEERING. DESIGN. TRAFFIC ENGINEERING. BIOTECHNOLOGY AND HEALTHCARE. MECHANICAL ENGINEERING. ECOTOURISM AND RURAL DEVELOPMENT.

MARKET RESEARCH AIMED TOWARDS THE ANALYSIS OF THE POSSIBILITY OF LAUNCHING AN OPERATIONAL START UP IN THE FIELD OF LCL (LESS THAN CONTAINER LOAD) TRANSPORT AT THE PORTS OF BARI AND/OR TARANTO (ITALY)

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Abstract: *The competitive advantage of the Less Container Load (LCL) solution consists in a significant reduction in transport costs, compared to the booking of a complete container or air transport but it's notable that today, within the Italian territory, the main LCL departure hubs are predominantly located in Northern Italy. Therefore, the purpose of this market research done by ITS Logistics Class 2022-2024 GDO was the analysis of a possible start-up of an LCL shipping service in Southern Italy at the Ports of Bari or Taranto, as well as its possible implications in terms of growth of the territory, implementation of innovative technologies and environmental sustainability. Its statistical survey showed that the creation of an LCL service located at the Port of Bari is in total harmony with the current demands of the neighboring markets (Apulia, Basilicata, Campania),with the leading product sectors being wine and agri-food. It has also been shown that there would be wide room for opportunity with the introduction of cold chain in LCL service. But on the other hand, statistical tecniques we used demonstrated the absolute need to spread the concept of LCL and also made evident that there is still a remarkable chunk of the market which does not appear to be educated on the subject.*
Keywords: Market research, LCL, Southern Italy, Start up

1. INTRODUCTION - PREMISE

In the field of transport systems which make use of containers, the acronym LCL (Less than Container Load)is the term which identifies, in the field of logistics, the frequent shipment type of "partially loaded containers", also known as "groupage": the load coming from different senders, suitably consolidated and grouped, stowed in a standard container, is sent for shipment by sea.The competitive advantage of the LCL solution therefore consists in a significant reduction in transport costs, compared on the other hand to booking a full container (FCL - Full Container Load) or Air Transport [1]. By a visual scrutiny of the geographical location of the service, it should be noted that within the Italian territory as of today, the main LCL departure hubs are mainly located in northern Italy. The purpose of this market research therefore consists in analyzing the possibility of launching an LCL shipping service at the Ports of Bari or Taranto, as well as to evaluate the possible implications in terms of growth of the territory, implementation of innovative technologies and environmental sustainability [2].

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2. METHODOOGICAL APPROACH OF THE RESEARCH

The phase of identifying the statistical collective was preceded by a qualitative-quantitative analysis which defined the categories of operators active in the field of international shipments and the producers operating in the agri-food, mechanical, pharmaceutical, fishing, chemical, construction. It has been here for proceeded to extrapolate 600 names of Companies located in the regions of Apuglia and Basilicata (Italy) from the main sources available on the net, together with their relative classification by product sector and cataloguing of the significant salient data. An appropriate verification and reclassification work was then carried out on the selected collective through Excel spreadsheets and use of the functions: VLOOKUP, COUNTIF, COUNTVALUES. Upon completion of the aforesaid phase, the sample purified by analysis was obtained, consisting of 400 statistical units. For the purposes of an efficient outcome in the administration of the questionnaires and data collection processes it was therefore decided to proceed with the drafting of two groups of Google Forms made available to the interviewer, for the registration of the primary sources. The group of questions to be submitted was distributed as follows: 18 questions for the category of producers and 13 questions for the category of shippers. For the purposes of greater efficiency of the process, specific guided logical paths were identified during the drafting of the questionnaires, also aimed at collecting data useful for marketing and profiling activities as well as the feasibility study for its own sake, also through the proposal of some open-ended questions. The administration of the questionnaires was carried out through the method of the outbound telephone call preceded by an e-mail explaining the initiative, with indication of the person in charge of the processing of sensitive data, also in compliance with the provisions in force regarding privacy pursuant to Italian law 675/96 “Text Unico” of 2003. The consent to participate in the survey also constituted the consent to the processing of data. To encourage broad acceptance and understanding of the survey, the aforementioned email was accompanied by a graphic and captioned representation of the initiative in the form of "storytelling" **(Figure 1)**.

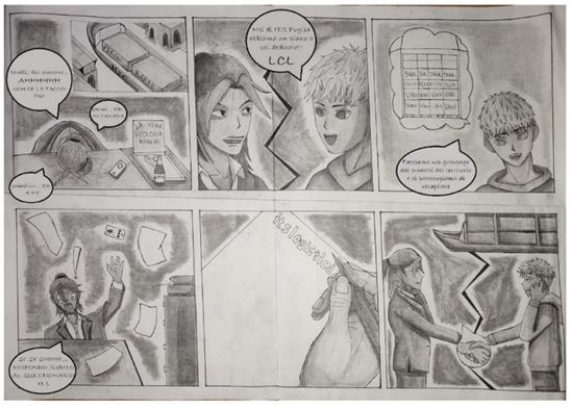

Figure 1. Storytelling board

The effective yield at the end of the administration phase, carried out in about 6 hours with 26 active operators including interviewers and co-opted, produced a total of 96 complete interviews (corresponding to about 1/4 of the total statistical collective).The data reclassification was subsequently carried out through the use of Excel sheets extracted from Google Forms and the built-up of the Pivot tables. With a view to improving the quality of the survey, it was deemed necessary to resort to statistical inference for the estimation of inclusive oscillation intervals of the processed percentage data. The Confidence Interval was opted and supported by the calculation of the corresponding percentage of reliability through the use of the Mean Squared Deviation and the application of an appropriate correction factor K for widening the aforementioned interval, for the purposes of being able to ensure the survey the strongest correspondence to the real data **(Figure 2).**

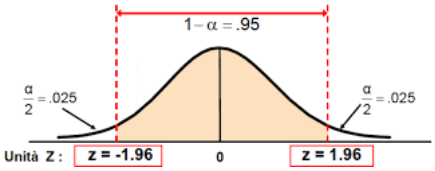

Figure 2. Mean Squared Deviation

As a useful guide tool in support of the interpretative phase, the SWOT Analysis technique was used for a more precise assessment of the aspects related to strengths, limitations, opportunities and threats.To complete and summarize the data analysis and the interpretation phase, a canvas of the "Value Proposition" type was also drawn up.

3. OUTCOME, ANALYSIS AND INTERPRETATION OF DATA PRODUCERS SECTION

The data elaborated highlights a mainly qualitative factor of the sample interviewed, characterized indeed by the substantial totality of companies that have shown a marked capacity for resilience against the critical phase of the Covid-19.
From the point of view of financial analysis, the figure is therefore assumed to be plausibly correlated to more than satisfactory balance sheet ratios.
More than half of the sample analyzed was found to be operating in the agricultural sectors of viticulture and agri-food.
The data is comforting for the purposes of our study since it is closely related to a stand-out interest, subsequently shown by this sample, in willing to receive further useful information on the subject. In fact, the characteristic peculiarity of the distribution of the local wine and agri-food sector in general is well placed, in a strategic perspective, to the use of the LCL mode of transport [3].
The analysis highlights the strong vocation of the local productive fabric, in Puglia in particular, to export to foreign markets. These destinations, as will be highlighted below, are mainly directed towards Asian routes (**Figure 3**).

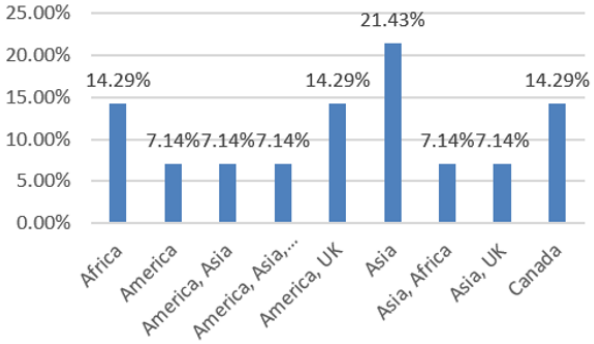

Figure 3. Which macro geographical area do you predominantly cover up with your shippings?

Table 1. Range of confidence for Figure 3 results

	Range of confidence		
Africa	4,93%	**14,29%**	33,88%
America	0,00%	**7,14%**	20,91%
America, Asia	0,00%	**7,14%**	20,91%
America, Asia, etc	0,00%	**7,14%**	20,91%
America, UK	4,93%	**14,29%**	32,99%
Asia	10,46%	**21,43%**	43,36%
Asia, Africa	0,00%	**7,14%**	20,91%
Asia, UK	0,00%	**7,14%**	20,91%
Canada	4,93%	**14,29%**	32,99%

The previous three questions goal was to extract useful information aimed at understanding the size and propensity of manufacturing companies to resort to professionals in the transport sector and the perception of the level of satisfaction with the service offered [4].
The figure shows a greater tendency to outsourcing the service to multitransport operators, as confirmed later in a specific control question reserved for shippers in the second module (**Figure 4**).

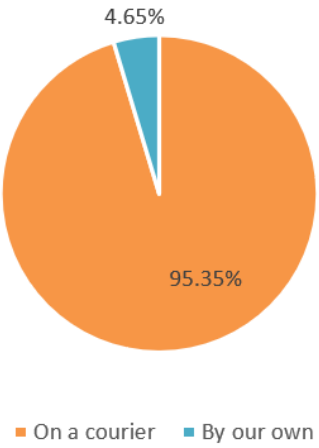

Figure 4. Do you ship by your own means or you rely on a courier?

Table 2. Range of confidence for Figure 4 results

	Range of confidence		
On a courier	92,14%	**95,35%**	100,00%
By your own	1,44%	**4,65%**	7,86%

With reference to the latter aspect, an economic-financial assessment aimed at identifying the specific turnover/outsourcing ratios of the service would be worthy of further study.[5] As a particularly peculiar feature for the purposes of the survey, we evaluated the market share of producers who direct exports to non-EU countries. It was therefore noted that over 32.56% of the interviewees carry out activities towards this destination, even if they do not have a foreign branch (**Figure 5**).

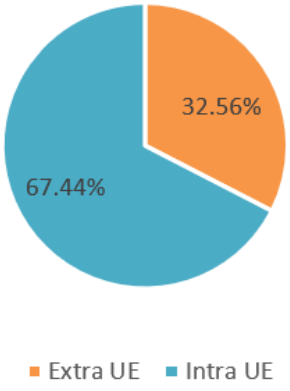

Figure 5. Where do you mainly export your products to?

Table 3. Range of confidence for Figure 5 results

	Range of confidence		
Extra UE	25,41%	**32,56%**	39,70%
Intra UE	60,30%	**67,44%**	74,59%

With reference to the assessment of the degree of interest in a possible temperature-controlled consolidation and transport service, it was found that over 1/3 of the sample expressed their consent.
The survey also highlights the presence of a large portion of the market that intends to increase the production quotas for export in the near future. For the purposes of the survey, the data is of particular interest since a demand for more qualified and innovative services seems to emerge distinctly in the field of freight forwarding activities.

4. SHIPPERS SECTION

As part of the questions administered to professional transport operators, it was decided to investigate the existence of opportunities to expand the range of services offered by them, currently lacking in the LCL transport sector. The data show that 48 operators declared themselves willing to receive updates on the subject in the future, also with reference to a highly specific service such as 'under controlled temperature' LCL transport (**Figure 6**).

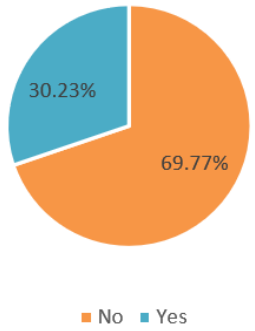

Figure 6. Do your transportations need to be under controlled temperature?

Table 4. Range of confidence for Figure 6 results

	Range of confidence		
No	62,76%	**69,77%**	76,77%
Yes	23,23%	**30,23%**	37,24%

Data analysis reveals that the main actor towards which strategically concentrate the LCL transport service is Asian, properly integrated with intermodal transport systems. For the purposes of the survey, the data reveals that the port of Bari is the most appropriate location for the establishment of an LCL service hub. It is hoped that in the short period the adjustments relating to the extension of the draft limits of this infrastructure will be definitively completed.

5. CONCLUSION

This statistical survey, performed by the scientific method, demonstrates with plausible truthfulness that starting of an LCL freight transport service located at the Port of Bari is in total harmony with the current service requests of the neighboring markets (Puglia, Basilicata, Campania).
The reference product sectors of maximum instance are included in the wine and agri-food sectors.
In terms of the innovative quality of the system, it has been shown that there are ample margins of opportunity with the introduction of the 'under controlled temperature' LCL service.
For the purposes of an effective territorial distribution of the service, the absolute need also emerged to set up an effective commercial and consultancy network aimed at the specific dissemination of the LCL shipping service since it is evident that there are stilllarge market shares that are not educated on the subject. To this end, it is desirable to draw up an appropriate marketing plan for which the use of the Value Proposition method should be proposed.

Acknowledgement: Research was conducted by the Class "Tecnico Superiore della Logistica per la GDO" biennio 2022-24, Michele Minenna and Natasa Gojkovic Bukvic, ITS Logistica Puglia Bari, Italy

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A SURVEY ON THE VEHICLE ROUTING PROBLEM WITH OCCASIONAL DRIVERS AND ITS VARIANTS

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Abstract: *Freight pickup and delivery processes are increasingly based on the concept of crowd logistics. One of the most well-known vehicle routing problems based on this concept is the Vehicle Routing Problem with Occasional Drivers (VRPOD). The first paper describing this problem was published in 2016. Since then, this problem has begun to attract more and more attention from researchers around the world. Until now, many papers related to this problem have been published. In this paper, we make a detailed review and analysis of papers published between 2016 and 2020 that dealt with this vehicle routing problem.*
Keywords: Vehicle Routing Problem, Occasional Drivers, Crowd Logistics

1. INTRODUCTION

The concept of last mile refers to the stage of the shipment when delivery occurs. Last mile also involves all the tasks necessary for the arrival of the parcel to the recipient. This is the last step of the entire distribution chain, hence the importance of last-mile delivery.The last mile delivery has always attracted the attention of researchers. The reason for this is primarily the large costs that these activities generate. The common practice for the implementation of the last mile delivery in the market is to use specialized companies that deal with it. The development of modern information technologies has led to the increasing use of alternative ways of realizing the distribution of goods to users. In recent years, companies and researchers have been paying more and more attention to the possibilities of hiring ordinary people who can provide certain services in the field of logistics. In this way, we came to the relatively new concept of crowd logistics, which implies the engagement of a large group of individuals in the realization of logistics activities.
One of the forms of crowd logistics in distribution problems is the inclusion of occasional drivers who can make part of the deliveries instead of companies that deal with it professionally. Hiring occasional drivers with certain amounts of compensation can lead to an overall reduction in costs for companies. Whether the goods should be sent using occasional drivers or their own vehicles, and what the routes should look like in those cases, are some of the most important questions that companies are looking for answers to. One of the vehicle routing problems, the solution of which would provide answers to the questions posed, is the vehicle routing problem with occasional drivers (VRPOD). Within this paper, we analysed the literature between 2016 and 2020 in which the authors treatedthe VRPOD.
The remaining part of the paper is organized as follows: in the second part of the paper a description of the vehicle routing problem with occasional drivers is given, in the third part an overview of the relevant literature is presented, and in the last, fourth part concluding remarks are shown.

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2. VEHICLE ROUTING PROBLEM WITH OCCASIONAL DRIVERS

The VRPOD is a problem on the network $G = (N, A)$, where N represents the set of nodes and Arepresents the set of links. The set$C$ consists of users who submitted service requests. Each request is characterized by the amount of goods q_i that the regular vehicle or occasional driver needs to deliver. The user's request should be realized either by a regular vehicle or by an occasional driver, whereby only one visit to the user is allowed. Occasional drivers can fulfiljust some of the customers' requests. Information on whether an occasional driver can fulfil a request is given as input data. Taking into account the costs of the regular vehicles deliveries, and compensation for the occasional drivers' deliveries, it is necessary to determine the best plan for the realization of the stated requirements in order to minimize the total costs.
For the considered problemArchetti et al. [1] proposed a mathematical formulation in which, in addition to the introduced notations, the following are also used:
K – the set of the occasional drivers,
c_{ij} – the cost for travelling the regular vehicle from the node i to the node j,
p_{ik} – the compensation to occasional drive k for making delivery to the customer i,
β_{ik} – equals 1 if the occasional driver k can serve the customer i,
Q – the capacity of the regular vehicle,
x_{ij} – a binary variable equals 1 if the regular vehicle going from the node i to the node j, otherwise equals 0,
y_{ij} – a variable that represents the quantity of the load that regular vehicle carries from the node i to the node j,
z_i – a binary variable equals 1 if the customer i will be served by the regular vehicle, otherwise it equals 0,
w_{ik} – a binary variable equals 1 if the customer i will be served by occasional driver, otherwise it equals 0.

The mathematical formulation of the problem can be presented as follows [1]:

Minimize

$$F = \sum_{(i,j)\in A} c_{ij}x_{ij} + \sum_{i\in C}\sum_{k\in K} p_{ik}w_{ik} \tag{1}$$

subject to

$$\sum_{j|(i,j)\in A} x_{ij} = \sum_{j|(j,i)\in A} x_{ji} = z_i \qquad \forall\, i \in C \tag{2}$$

$$\sum_{j|(0,j)\in A} x_{0j} - \sum_{j|(j,0)\in A} x_{j0} = 0 \tag{3}$$

$$\sum_{j|(j,i)\in A} y_{ji} - \sum_{j|(i,j)\in A} y_{ij} = \begin{cases} q_i z_i & \forall\, i \in C \\ \sum_{i\in C} -q_i z_i & i = 0 \end{cases} \tag{4}$$

$$y_{ij} \le Q\, x_{ij} \qquad \forall\, (i,j) \in A \tag{5}$$

$$y_{i0} = 0 \qquad \forall\, i \in C \tag{6}$$

$$w_{ik} \le \beta_{ik} \qquad \forall\, i \in C, k \in K \tag{7}$$

$$\sum_{i\in C} w_{ik} \le 1 \qquad \forall\, k \in K \tag{8}$$

$$\sum_{k\in K} w_{ik} + z_i = 1 \qquad \forall\, i \in C \tag{9}$$

$$x_{ij} \in \{0,1\} \qquad \forall\, (i,j) \in A \tag{10}$$

$$z_i \in \{0,1\} \qquad \forall\, i \in C \tag{11}$$

$$w_{ik} \in \{0,1\} \qquad \forall\, i \in C, k \in K \tag{12}$$

$$y_{ij} \ge 0 \qquad \forall\, (i,j) \in A \tag{13}$$

An objective function (1) represents the total cost to make the deliveries to the customers. It includes the cost for delivering with regular vehicles and the occasional drivers.Constraint (2) defines that the variable z_i will have value 1 if the regular vehicle is going to serve the customer i. Also, this constraint ensures that the vehicle after visits the customer i must leave it. Constraint (3) guaranties that all routes of the regular vehicles that starts from the depot must finish at the depot. Constraint (4) ensure that customer demands will be satisfied, and it prevents subtours. Constraint (5) takes care about the regular vehicle capacity. According to Constraint (6) the regular vehicles must return empty to the depot. Constraint (7) guaranties that the occasional driver is going to serve the customer only if he/she can do that. Constraint (8) defines that the occasional driver can serve only one customer. Constraint (9) ensure that one customer can be served only by the regular vehicle or the occasional driver. Constraints (10)-(13) define the decision variables.

3. LITERATURE REVIEW

The first ideas about hiring ordinary people to make deliveries, rather than professional companies, appeared in Walmart and Amazon [2, 3]. However, authors of [1]were the first to define the vehicle routing problem with occasional drivers. As we mentioned in previous section these authors proposed a mathematical formulation of integer programming for the considered problem. They also developed a multi-start heuristic to solve defined problem. Performed numerical examples showed that the solutions obtained by heuristics deviate very little from the optimal ones, which are obtained by solving integer programming models with professional software. The authors also pointed out the importance of analyzing the determination of the compensation offered to occasional drivers in order to realize certain deliveries.

Generally speaking, all relevant papers from this area could be divided into three groups: papers that takes into account dynamic occasional drivers, papers that analyze problems with time windows and the one that considered the green vehicle routing problem with occasional drivers.

The vehicle routing problem with dynamic occasional drivers is considered in [4]. In this variant of the problem, occasional drivers appear to be available to fulfill requests in a stochastic manner. At the moment when new drivers come forward to fulfill some requests, the company should consider changing the previous delivery plan because the new plan would be more profitable. For this problem, the authors proposed a new mathematical formulation of the problem. Also, the authors have given a way to avoid symmetry that can occur so that it is possible to solve examples of larger dimensions.

In [5] a multistage stochastic model for the vehicle routing problem with dynamic occasional drivers was proposed, and compared with a two-stage stochastic model from [4]. The proposed multistage stochastic model takes into account the dynamic behaviour of occasional drivers where in various stages information about availability of particular driver may or may not be accessible to decision maker in the company using occasional drivers.

The next few papers dealt with the scheduling problem with occasional drivers and time windows. For the considered problem, the authors of [6] proposed a mathematical formulation. The objective function consists of three parts and represents the total costs that need to be minimized. The first part of the objective function represents the costs related to the company's vehicles, the second part includes the costs when performing tasks by occasional drivers and the third part includes the costs of occasional drivers when they do not perform tasks. The authors generated instances based on well-known instances for VRPTW. The tests were performed using CPLEX 12.5 software.

Same type of problem as in [6] was analyzed in [7]. The focus was on the application of the developed model in the distribution of bread. The model was tested on a small example, where three scenarios were discussed depending on the amount of compensation for occasional drivers. The author used the LINGO 11.0 software to solve mixed integer problems.

Lalang et al. [8] considered a vehicle routing problem with occasional drivers and multiple depots and time intervals. Within this paper, the authors proposed a mathematical formulation in which the objective function represents the sum of the total costs of shorting the company's vehicles and the

total costs of moving the vehicles of occasional drivers. This objective function needed to be minimized. The constraint set guaranteed that the assumptions of the model would not be violated. For testing, the authors used the LINGO 11 software, which uses the branch and bound method to solve mixed-integer programs. The tests were performed in three scenarios. These scenarios differ in relation to the costs of fulfilling requests from the occasional drivers. The tests were performed on a small example that has two bases and eight users.

Unlike assumption from [1] that occasional drivers will always accept to make deliveries for certain compensation amounts, the authors of [9] used a certain probability for this acceptance. The probability of acceptance is directly related to the compensation amount (the higher the compensation amount, the higher the probability that the occasional driver will accept to make the delivery). The amount of compensation is fixed and does not depend on the location of the occasional driver, nor on his final destination. The authors considered the problem as a bi-level model and proposed a heuristic algorithm to solve it. They tested the algorithm on the example which consists of a depot and 15 users.

The pickup and delivery problem with time windows and occasional drivers was solved in [10]. These authors based their work on the problem analyzed in [1]. For the considered problem, they proposed two mathematical formulations of mixed integer programming. The first mathematical formulation was based on the work of [11], and the second used variables for flows of several types of goods. Within the description of the mathematical formulations, the authors indicated how reduction tests and symmetry avoidance tests (breaking symmetry) could be performed for this problem. They also analyzed the impact of different compensation costs of occasional drivers on the optimal solutions. Additionally, the authors proposed a model for parameter optimization in compensation schemes. The tests were performed on the examples used by [12] for the pickup and delivery problem with time windows.

The authors of [13] applied Variable Neighbourhood Search (VNS) metaheuristic to solve VRPOD problem with time windows and multiple deliveries previously proposed in [6]. The authors performed several computational tests on various network sizes using CPLEX 12.5. Besides testing on small-size instances, which were addressed in the previous paper, VNS was also implemented to solve large-scale networks. In comparing small-size instances with previous work, authors performed test with up to 15 customers and five occasional drivers for which an optimal solution can be obtained using CPLEX. Large-scale instances included 25, 50 and 100 customers, and up to 10, 15 and 29 occasional drivers respectively. Authors showed that VNS outperformed CPLEX in terms of effectiveness and efficiency.

Same group of authors [14] used the similar model as in their previous paper [6] – VRPOD with time windows (VRPODTW), but they evaluated the impact of occasional drivers on the amount of CO_2 produced, as well as the total cost which consist of routing and fuel cost, cost of compensation to occasional drivers and cost of the occasional drivers when it does not make the delivery. The model was tested on the same instances as in [6] using CPLEX 12.5 software. When comparing the results of VRP using conventional vehicles and using occasional drivers, their study concluded significant benefits when using ODs instead of conventional vehicles, both in cost reduction as well as environmental impact.

VRPOD with time windows and transhipment nodes (VROPDTN) was formulated in [15]. In this variant of VRPODTW authors considered intermediate depots in the transportation network. Occasional drivers can choose if they will pick up the shipment in the central depot, or in the intermediate. Total cost that aimed to be minimized consists of conventional vehicles' cost and occasional drivers' compensation. Authors used VNS metaheuristics for solving small-size and large-size instances generated from Solomon benchmarks. The model was solved with CPLEX 12.7 software, then the VNS was used on same instances, and the results were compared. In both small-size and particularly large-size instances, VNS outperformed CPLEX.

Marcina and Guerriero [16] considered the green vehicle routing problem with occasional drivers. These authors developed a new mathematical formulation in which the objective function has seven parts: the recharging costs, the energy consumption costs, the total diesel cost, the routing costs (for

electric vehicles and internal combustion commercial vehicles), the cost of compensation of the occasional drivers for the delivery service and the cost of the occasional driver when it does not perform the delivery service. The authors made tests using the 30 instances proposed in the literature for the electric vehicle VRP with time windows (these instances are based on Solomon's instances for VRP with time windows). The authors concluded that occasional drivers influence significant reduction of emissions: 79 % for the instances with 5 customers, 52 % for the instances with 10 customers, and 73 % for the instances with 15 customers.
An environmentally friendly vehicle routing problem with regular and occasional drivers, taking into account their behavioral control characteristics was studied in [17]. These authors proposed a multi-criteria optimization model that has four objective functions. The first function, which is minimized, represented the total energy consumed during the realization of the routes. The second function represented the maximum speed, and it is maximized. The third objective function was the total energy consumption for all routes. This function was minimized. The fourth objective function, the total costs of a given vehicle routing plan, taking into account both regular and occasional drivers was also minimized. The authors tested the model on a small example taken from the literature.

4. CONCLUSION

The concept of crowd logistics is becoming increasingly popular. One of the most important optimization problems based on this concept is the vehicle routing problem with occasional drivers. This routing problem involves delivering part of the shipments through conventional means, using vehicles from a professional delivery company, while the other part is handled by hiring occasional drivers. The implementation of deliveries in this manner is gaining increasing attention because it can lead to various benefits, such as cost reduction, decreased fuel consumption, and reduced emissions of exhaust gases, etc.
In this paper, we provide an overview of the studies in which this problem was analysed. A total of 13 papers were analysed, ending in 2020. In future research, we will analyse papers that are not covered in this overview.

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APPLICATION OF PROBABILITY AND STOCHASTIC ANALYSIS TO TRAFFIC IMPROVEMENT

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Abstract: *Of great importance for improvement, traffic planning, traffic safety and traffic regulation are certain areas of mathematics such as applied probability and stochastic analysis, within which various binomial, Poisson, exponential, log normal, generalized logarithmic distributions, as well as stochastic processes are studied, and in within them Markov processes and chains. In this paper will be presented some further application in traffic improvement.*
Keywords: traffic improvment, applied probability, stochastic processes, Markovs chains.

1. INTRODUCTION

In technique and technology both deterministic and stochastic models are known. Deterministic problems, from our point of view, are considered as equations for expected values of random processes and phenomena. Problems which arise in the description of expected values consist in the fact that expected values need satisfy stability both in traditional presentation of continuous variation of solutions on given data and in stability or instability of scenaria of behaviour of random phenomena. In the present exposition for solutions of problems in the traditional presentation concerning stability, equations for dispersion are derived. These equations are obtained with the help of Focker-Planck-Kolmogorov equation and equations for random fields derived in paper [1,2,3]. Equations for differential entropy which permit analysis of stability of scenaria of behaviour of radnom phenomena are also given. Entropy posses an amazing property: with its help it is possible to predict occurence of this or that event in advance. Besides that, the theme of finding maximum of the entropy and results of investigation of behaviour of random phenomena which result from that maximum is also addressed here.

2. FOCKER-PLANCK-KOLMOGOROV EQUATION FOR PROBABILITY DENSITY

The basis for obtaining stochastic analogues of deterministic problems, corresponding to ordinary differential equations with technical thematics, is the Focker-Planck-Kolmogorov equation for probability density (denoted by PD). *P(t,C),* written without the term, responsible for spasmodicity. It has the following form:

$$\partial P(t,C)/\partial t = -\partial(A(t,C)P(t,C))/\partial C + 0,5B\partial^2 P(t,C)/\partial C^2 \quad (1)$$

where*A(t,C),*is the drift coefficient (function of sources (sinks)), *B* is the coefficient ofdiffusion of random Markov process. Let *t* stands for time and *C/T,* be the real characteristic of random process. In synergetics [1] there is a notion of the control parameter. Under its influence the whole random process adjusts, despite the action of other factors. Such a control character in this exposition of stochastic phenomena is the drift coefficient.

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Depending on the choice of functional dependence of this coefficient on expected values different interpretations of the described systems will be obtained. Some material constants appear in differential equations for expected values. These quantities often have quite distinguished random character, occasionally not depending on the basic characteristic of the process. Most often they satisfy the normal distribution law with different drift coefficients and determine the shift of scenaria of behaviour of a radnom object. Beside that, in space-time fields the particular role is played by boundary conditions, which independently on inside state of the object, may have independent time behaviour. This behaviour, which has several shifts of analytic form of the drift coefficient, will influence the change of scenaria of behaviour of the described space object. The expected value (mathematical expectation) we introduce in the following notation.

$$M^{(1)}(t) = \int_{-\infty}^{+\infty} CP(t,C)dC \tag{2}$$

The initial moment of the second order, we denote as:

$$M^{(2)}(t) = \int_{-\infty}^{+\infty} C^2 P(t,C)dC \tag{3}$$

We denote by

$$\sigma^2(t) = M^{(2)}(t) - (M^{(1)}(t))^2 \tag{4}$$

the dispersion. We introduce the differential entropy in the following way:

$$S(t) = \int_{-\infty}^{+\infty} P(t,C)\ln P(t,C)dC \tag{5}$$

The equation for expected value corresponding to the PD*P(t,C)*, in the classical representation is obtained from equation (1) as:

$$dM^{(1)}(t)/dt = \int_{-\infty}^{+\infty} A(t,C)P(t,C)dC \tag{6}$$

In this case, in order to find the expected value one has to solve tho problem for PD. In this exposition the drift coefficient is proposed to be given as

$$A(t,C) = Cf(M^{(1)}(t))/M^{(1)}(t) \tag{7}$$

Then the equation for expected value will fully correspond to the differential equation in deterministic formulation:

$$dM^{(1)}(t)/dt = f(M^{(1)}(t)) \tag{8}$$

The equation for dispersion is:

$$d\sigma^2(t)/dt = 2(\int_{-\infty}^{+\infty} CA(t,C)P(t,C)dC - \int_{-\infty}^{+\infty} CP(t,C)dC\int_{-\infty}^{+\infty} A(t,C)P(t,C)dC) + B \tag{9}$$

With the drift coefficient in the form (8), the equation for dispersions obtains the form convenient for investigation of stability of solutions of differential equations for expected values in deterministic formulation (8):

$$d\sigma^2(t)/dt = 2(f(M^{(1)}(t)/M^{(1)}(t))\sigma^2(t) + B \tag{10}$$

The equation for the change of differential entropy is:

$$dS/dt = \int_{-\infty}^{+\infty} (\partial A(t,C)/\partial CP(t,C))dC + 0,5B\int_{-\infty}^{+\infty} \ln P(t,C)(\partial^2 P(t,C)/\partial C^2)dC \tag{11}$$

Under the choice of the drift coefficient in the form (3), the equation for differential entropy is as follows:

$$dS/dt = f(M^{(1)}(t))/M^{(1)}(t) + 0,5B\int_{-\infty}^{+\infty} \ln P(t,C)(\partial^2 P(t,C)/\partial C^2)dC \tag{12}$$

If the moment of diffusion of the Markov process is equal to zero, $B = 0$, then equations (10) and (12) may be solved without finding PD, which is the essential advantage of the method for investigation of random phenomena proposed here.

Equation (6) with $B \approx 0$allows one to find minimal and maximal values of the dispersion, which is important in the search for recommendation for experiment planning and the analysis of experimental data. Equation (8) allows with $B \approx 0$ to determine moments of extremal values of $S(t)$, and also dependence of jumps of the derivation of differential entropy under a change of scenaria of evolution of a random phenomena.

In the case of the dependence of PD on two random variables$P(t,C,T)$, it satisfies multidimensional Focker-Planck-Kolmogorom equation:

$$\partial P(t,C,T)/\partial t = -\partial(A_C(t,C,T)P(t,C,T))/\partial C + \partial(A_T(t,C,T)P(t,C,T))/\partial T + \\ +0,5B_C\partial^2 P(t,C,T)/\partial C^2 + 0,5B_T\partial^2 P(t,C,T)/\partial T^2. \quad (13)$$

Expected values satisfy equations:

$$dM_C^{(1)}(t)/dt = \int_{-\infty}^{+\infty}\int_{-\infty}^{+\infty} A_C(t,C,T)P(t,C,T)dCdT \quad (14)$$

$$dM_T^{(1)}(t)/dt = \int_{-\infty}^{+\infty}\int_{-\infty}^{+\infty} A_T(t,C,T)P(t,C,T)dCdT \quad (15)$$

The dispersion is in this case described by equations:

$$d\sigma_C^{(2)}(t)/dt = 2(\int_{-\infty}^{+\infty}\int_{-\infty}^{+\infty} CA_C(t,C,T)P(t,C,T)dCdT - \\ -M_C^{(1)}\int_{-\infty}^{+\infty}\int_{-\infty}^{+\infty} A_C(t,C,T)P(t,C,T)dCdT) + B_C; \quad (16)$$

$$d\sigma_T^{(2)}(t)/dt = 2(\int_{-\infty}^{+\infty}\int_{-\infty}^{+\infty} TA_T(t,C,T)P(t,C,T)dCdT - \\ -M_T^{(1)}\int_{-\infty}^{+\infty}\int_{-\infty}^{+\infty} A_T(t,C,T)P(t,C,T)dCdT) + B_T; \quad (17)$$

$$d\sigma_{CT}^{(2)}(t)/dt = \int_{-\infty}^{+\infty}\int_{-\infty}^{+\infty}(TA_C(t,C,T)P(t,C,T) + CA_T(t,C,T)P(t,C,T))dCdT - \\ -(M_T^{(1)}dM_C^{(1)}/dt + M_T^{(1)}dM_C^{(1)}/dt). \quad (18)$$

For

$$A_C(t,C,T) = a_{11}C + a_{12}T \quad A_T(t,C,T) = a_{21}C + a_{22}T \quad (19)$$

the dispersion is determined by the following system of equations:

$$d(\sigma_C^2(t))/dt = 2a_{11}\sigma_C^2 + 2a_{12}\sigma_{CT}^2, + B_C \quad t > 0 \quad (20)$$

$$d(\sigma_T^2(t))/dt = 2a_{21}\sigma_{CT}^2 + 2a_{22}\sigma_T^2, + B_T;\ t > 0 \quad (21)$$

$$d(\sigma_{CT}^2(t))/dt = a_{21}M_C^{(2)} + a_{12}M_T^{(2)} + (a_{11} + a_{22})M_{CT}^{(2)} - \\ -(a_{21}(M_C^{(1)})^2 + a_{12}(M_T^{(1)})^2 + (a_{11} + a_{22})M_C^{(1)}M_T^{(1)}) = \\ = a_{21}\sigma_C^2 + a_{12}\sigma_T^2 + (a_{11} + a_{22})\sigma_{CT}^2;\ t > 0. \quad (22)$$

From these equations one may obtain classical stability conditions for the solution of systems of ordinary deterministic differential equations by Lyapunov, in the case.

$B_C=0$, $B_T=0$ and one can also predict instability for arbitrary coefficients on the right-hand side if $B_C \neq 0$, $B_T \neq 0$. The described results are given in [1]. Equation for the variation in time of differential entropy

$$S(t) = \int_{-\infty}^{+\infty}\int_{-\infty}^{+\infty} P(t,C,T)\ln P(t,C,T)dCdT \quad (23)$$

has the form:

$$dS/dt = \int_{-\infty}^{+\infty}\int_{-\infty}^{+\infty}[(\partial A_C(t,C,T)/\partial C + (\partial A_C(t,C,T)/\partial T]P(t,C,T)dCdT + \\ +0,5B_C\int_{-\infty}^{+\infty}\int_{-\infty}^{+\infty}[\ln P(t,C,T)\partial^2 P(t,C,T)/\partial C^2]dCdT + \\ +\int_{-\infty}^{+\infty}\int_{-\infty}^{+\infty}[\partial A_T(t,C,T)/\partial T + (\partial A_T(t,C,T)/\partial C]P(t,C,T)]dCdT + \\ +0,5B_T\int_{-\infty}^{+\infty}\int_{-\infty}^{+\infty}[\ln P(t,C,T)\partial^2 P(t,C,T)/\partial T^2]dCdT. \quad (24)$$

If$B_C=0$, $B_T=0$, then equation (20) (assuming (15)) obtains the following form:

$$dS/dt = a_{11} + a_{12} + a_{21} + a_{22}. \quad (25)$$

Depending on the sign of the sum ($a_{11}+a_{12}+a_{21}+a_{22}$) one obtains linear in time the increase of entropy, if $a_{11}+a_{12}+a_{21}+a_{22}>0$, or linear decrease if $a_{11}+a_{12}+a_{21}+a_{22}<0$, and for the entropy $a_{11}+a_{12}+a_{21}+a_{22}=0$ remains constant and equal to its initial value.

3. FOCKER-PLANCK-KOLMOGOROV EQUATION FOR STOCHASTIC FIELDS

Let us write equations for stochastic fields. The equation for PD, describing random field of concentration has the form:

$$\partial P(t,x,C)/\partial t - D\partial^2 P(t,x,C)/\partial x^2 = -\partial(A(t,x,C)P(t,x,C))/\partial C + \\ +0,5B\partial^2 P(t,x,C)/\partial C^2. \quad (26)$$

The equation for expected value:

$$M^{(1)}(t,x) = \int_{-\infty}^{+\infty} CP(t,x,C)dC \quad (27)$$

$$\partial M^{(1)}(t,x)/\partial t - D\partial^2 M^{(1)}(t,x)/\partial x^2 = \int_{-\infty}^{+\infty} A(t,x,C)P(t,x,C)dC \quad (28)$$

If the drift coefficient has the special form

$$A(t,x,C) = Cf(M^{(1)}(t,x))/M^{(1)}(t,x) \quad (29)$$

then the equaion for expected values obtains the classical form of a deterministic equation:

$$\partial M^{(1)}(t,x)/\partial t - D\partial^2 M^{(1)}(t,x)/\partial x^2 = f(M^{(1)}(t,x)) \quad (30)$$

The equation for dispersion:

$$\partial\sigma^2(t,x)/\partial t - D\partial^2\sigma^2(t,x)/\partial x^2 = 2D(\partial M^{(1)}(t,x)/\partial x)^2 + \\ +2[\int_{-\infty}^{+\infty} CA(t,x,C)P(t,x,C)dC - M^{(1)}(t,x)\int_{-\infty}^{+\infty} A(t,x,C)P(t,x,C)dC] + B \quad (31)$$

Under conditions (27) equation for dispersion is as follows:

$$\partial\sigma^2(t,x)/\partial t - D\partial^2\sigma^2(t,x)/\partial x^2 = 2D(\partial M^{(1)}(t,x)/\partial x)^2 + \\ +2[f(M^{(1)}(t,x)/M^{(1)}(t,x)]\sigma^2(t,x) + B. \quad (32)$$

The equation for differential entropy:

$$\partial S(t,x)/\partial t - D\partial^2 S(t,x)/\partial x^2 = \int_{-\infty}^{+\infty}\partial A(t,x,C)/\partial C P(t,x,C)dC + \\ +0,5B\int_{-\infty}^{+\infty}\ln P(t,x,C)\partial^2 P(t,x,C)/\partial C^2 dC - D\int_{-\infty}^{+\infty}(1/P(t,x,C))(\partial P(t,x,C)/\partial x)^2 dC. \quad (33)$$

Under conditions (23), the equation for entropy transforms into the form:

$$\partial S(t,x)/\partial t - D\partial^2 S(t,x)/\partial x^2 = [f(M^{(1)}(t,x)/M^{(1)}(t,x)] + \\ +0,5B\int_{-\infty}^{+\infty}\ln P(t,x,C)\partial^2 P(t,x,C)/\partial C^2 dC - D\int_{-\infty}^{+\infty}(1/P(t,x,C))(\partial P(t,x,C)/\partial x)^2 dC. \quad (34)$$

The equation for description of wave fields is:

$$\partial^2 P(t,x,C)/\partial t^2 - c^2\partial^2 P(t,x,C)/\partial x^2 = \\ = -\partial(A(t,x,C)P(t,x,C))/\partial C + 0,5B\partial^2 P(t,x,C)/\partial C^2 \quad (35)$$

The equation for expected values:

$$\partial^2 M^{(1)}(t,x)/\partial t^2 - c^2\partial^2 M^{(1)}(t,x)/\partial x^2 = \int_{-\infty}^{+\infty} A(t,x,C)P(t,x,C))dC \quad (36)$$

Under conditions (23), the equation obtains the well-known form of a deterministic equation for expected values:

$$\partial^2 M^{(1)}(t,x)/\partial t^2 - c^2\partial^2 M^{(1)}(t,x)/\partial x^2 = f(M^{(1)}(t,x)) \quad (37)$$

The equation for dispersion:

$$\partial^2\sigma^2(t,x)/\partial t^2 - c\partial^2\sigma^2(t,x)/\partial x^2 = 2[c(\partial M^{(1)}(t,x)/\partial x)^2 - (\partial M^{(1)}(t,x)/\partial t)^2] + \\ +2[\int_{-\infty}^{+\infty} CA(t,x,C)P(t,x,C)dC - M^{(1)}(t,x)\int_{-\infty}^{+\infty} A(t,x,C)P(t,x,C)dC] + B. \quad (38)$$

Taking into account formula (26) equation (34) may be rewritten as:

$$\partial^2\sigma^2(t,x)/\partial t^2 - c\partial^2\sigma^2(t,x)/\partial x^2 = 2[f(M^{(1)}(t,x))/M^{(1)}(t,x)]\sigma^2(t,x)] + \\ +2[c(\partial M^{(1)}(t,x)/\partial x)^2 - (\partial M^{(1)}(t,x)/\partial t)^2] + B. \quad (39)$$

4. STOHASTIC MODELING IN TRAFFIC IMPROVEMENT

Stochastic models of traffic flow are used in a variety of applications, e.g., traffic state estimation, travel time reliability, and traffic control. A main source of uncertainty in traffic dynamics is heterogeneity among drivers. This is captured using parametric uncertainty, resulting in stochastic microscopic models. These, in turn, are used to develop probabilistic traffic relations and stochastic models of traffic dynamics. Hence, the relevance of the compilation and consideration of practical aspects, as well as the mathematical solution of the problems of modeling the traffic flows of the metropolis, which will be considered in papers [4,5].

Classical mathematical models of continuous traffic flows considered Descartes's coordinates as real numbers. In probabilistic modes Descartes's coordinates will be considered as random variables. Let $C(X_1,X_2,X_3)$ be random vector which Descartes's coordinates X_1, X_2 and $X_3$are random variables. They determine probabilty of particle position in spatial motion.In probabilistic mathematical model of continuous traffic flows, path of spatial or planar motion can be described by equation (1), where t is time elapsed from start of motion. So, traffic flow can be considered as stohastic process, which probability density is given by equation (1). Its expected value is define by equation (8) and dispersion by (9) for one-dimensional case. For multi-dimensional case, expected value is given as solution of system of equations (14) and (15) and dispersion can be obtained as solution of system of equations (16), (17) and (18). Also, traffic flow can be considered as random field. In this case, its expected value can be obtained by (37) and dispersion can be obtained by(38).

5. CONCLUSION

In this paper some new formulations of problems of stochastic description of random and deterministic mathematical models given in [1] are presented. The basic assumption is the following: a solution of a deterministic problem is the expected value of its stochastic analogue. Topicality of the problem consists in the fact that deterministic problem does not allow to reveal neither the stability of a stochastic phenomena, nor a change in scenario of its development. Proposed equations allows one to investigate stability of solutions for expected values from the analysis of the dispersion. The use of differential entropy permits to find moments of change of a

scenario of evolution of random phenomena and reveal repercussions of the achievement of maximal entropy. Presented theory can be applied in analysis of some mathematical models of traffic improvement given in [4,5].

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ENVIRONMENT AND SUSTAINABLE DEVELOPMENT. MECHATRONICS. OCCUPATIONAL SAFETY AND HEALTH AND FIRE SAFETY. SMART MANAGEMENT SYSTEMS. GRAPHIC ENGINEERING. DESIGN. TRAFFIC ENGINEERING. BIOTECHNOLOGY AND HEALTHCARE. MECHANICAL ENGINEERING. ECOTOURISM AND RURAL DEVELOPMENT.

Student paper

IMPROVEMENT OF TRAFFIC SAFETY ON THE CHOSEN INTERSECTION IN THE TOWN OF PANCEVO

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Abstract: *Traffic safety management is important in order to reduce the number of injured participants in traffic accidents and thus reduce the total damage for the society or local government caused by traffic accidents. Participation in traffic requires competence, knowledge, skills and safe behaviour which depends on traffic culture of traffic participants. In this work, possible measures and suggestions concerning traffic safety are presented. According to total number and consequences of traffic accidents in the Republic of Serbia, it can be observed that the number of injured as well as the number of casualties in traffic accidents has the decreasing trend until 2020 and in majority of traffic accident there was merely material damage. 27% of all traffic accidents happen on intersections. Taking into consideration the huge number of incidents on intersections, possible improvements can be divided into two groups: infrastructural solutions and advanced solutions. The advantages of infrastructural solutions are based on the fact that traffic participants can observe the situation on an intersection better. On the example of the concrete intersection in the town of Pancevo, suggestions for the improvement of traffic safety are given.*
Key words: traffic safety management, traffic accident, intersection

1. INITIAL CONSIDERATIONS

It was proven in many researches that the traffic safety mostly depends on human factor, internal sources of behaviour and individual reaction of drivers in different situations on the roads. Participation in traffic requires competence, knowledge, skills and safe behaviour which depends on traffic culture.

Law regulating traffic safety on roads contains important news in the domain of possible traffic safety improvement in the country, in local governments, in municipalities and cities (towns). On local level it is necessary to make strategies concerning traffic safety, to write annual plans concerning traffic safety and to monitor traffic safety. Consequences of traffic expansion development are the increasing number of vehicles, roads, density of traffic flow etc.

Huge number of different vehicles use the same roads. Difference of vehicles participating in traffic is clearly observed on intersections which connect urban and rural areas.

In the context of huge number of incidents on intersections, there are two possible solutions of this problem: infrastructural solutions and advanced solutions. Infrastructural solutions are based on sensors located near intersections. Sensors detect approaching vehicles and in the case of possible accident, the system generates warning light signals which drivers can see. The advantages of infrastructural solutions are based on the fact that traffic participants can observe the situation on an intersection better.

The goal of the research is traffic analysis on intersections, especially on ones with traffic lights and to give suggestions for the improvement of traffic flow based on functional, economic and ecological aspect.

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2. TRAFFIC SAFETY ANALYSIS IN THE TOWN OF PANCEVO FROM THE YEAR 2018 TO THE YEAR 2022

Total number of traffic accidents during this period in the town of Pancevo was 1.713, which is 1% of total number of traffic accidents in the Republic of Serbia, while the total number of casualties is 1.722, which is approximately 2% of the total number of casualties in traffic accidents in the Republic of Serbia.
While analysing the basic parameters of traffic safety on the territory of the town of Pancevo during this period, it can be seen that in the year 2021 there was the largest number of both traffic accidents and casualties. The total number of traffic accidents in the year 2021 was 490, which is 1,4% of the total number of traffic accidents in the Republic of Serbia in the above-mentioned year, while the total number of casualties in the same year was 387, which is 1.9% of the total number of casualties in this year.

3. TRAFFIC SAFETY ANALYSIS ON THE CHOSEN INTERSECTION FROM THE YEAR 2018 TO THE YEAR 2022

The Miloša Obrenovića street connects the centre of Pancevo with Tesla settlement and continues onto the Bavaništanski road, which connects the town of Pancevo with Bavaniste. The Prvomajska street continues onto the Stevana Šupljikca street and those two streets are major part of the bypass, i.e., the section of the European road E-70 which passes through the town of Pancevo.
The road E-70 is the international road of class A and it begins in Spain and finishes in Georgia and is 5.114km long. Apart from Serbia, this road passes through France, Italy, Slovenia, Croatia, Romania, Bulgaria and Turkey.
On figure 1 there are spots of traffic accidents based on the consequences on the observed intersection the Prvomajska – the Stevana Šupljikca – the Bavaništanski road – the Miloša Obrenovića.

Figure 1. Spots of traffic accidents on the observed intersection from year 2018 to year 2022
Source: *http://bazabs.abs.gov.rs/smartPortal/saobNezgode*

Total number of traffic accidents on intersections in the town is 665, which is 39% of total number of traffic accidents in the town of Pancevo. Total number of traffic accidents on the observed intersection (26) is 4% of total number of traffic accidents on intersections in the town of Pancevo.
Total number of traffic accidents during the observed period on the observed intersection is 26, which is 18% of total number of traffic accidents on the streets that this intersection consists of.

Total number of casualties on the observed intersection is 28, which is 19% of total number of casualties in traffic accidents on the streets that this intersection consists of.
While analysing the types of traffic accidents on the observed intersection, it can be concluded that during the period of 5 years there were 14 traffic accidents with at least two vehicles – turning or crossing, 7 traffic accidents with at least two vehicles – without turning and 3 traffic accidents with one vehicle. Traffic accident in which some participants die is in the group of traffic accidents with at least two vehicles – turning or crossing.
The most common groups of influential factors that can cause traffic accidents on the observed intersection are: drivers' wrong execution of actions in traffic, drivers' reckless actions, drivers' mistakes due to bad psychophysical condition, carelessness, distraction and mistakes due to inadequate visibility, i.e. a complete experience of the road and traffic. The largest number of traffic accidents (9), which caused minor bodily injuries of some participants, were caused by drivers' wrong execution of actions in traffic. The largest number of traffic accidents (6), which caused material damage, were caused by drivers' reckless actions and these actions also caused the death of some participants in traffic accidents. While analysing the influential factors it can be concluded that the largest number of traffic accidents was caused by drivers' wrong execution of actions in traffic (14) and by drivers' reckless actions (13).
It can be concluded that the majority of traffic accidents happened on intersections regulated by traffic lights working properly and the number of such traffic accidents is 14. Traffic accident which caused the death of some traffic participants happened on intersection regulated by traffic lights at the moment when there was only yellow flashing light on, which happens very often and it is shown on figure 2.

Figure 2. Traffic lightswith yellow flashing light on the chosen intersection

Since the observed intersection is huge and accesses to it are not at the right angle there is the problem of poor visibility when accessing it from some streets. The poorest visibility, especially during night, observing from the stop line is in the Miloša Obrenovića street and it is shown on figure 3. From the above-mentioned stop line, there is also poor visibility from the Stevana Šupljikca and the Prvomajska streets. There is poor visibility from the Stevana Šupljikca street due to residential building and some greenery, while there is poor visibility from the Prvomajska street due to sharp angle compared to the stop line and due to advertising sign and tall protective fence.

Figure 3. Intersection access from the stop line in the Miloša Obrenovića street

4. MEASURES AND SUGGESTIONS

Traffic on the observed intersection is regulated by traffic lights, which allow alternating vehicle passing from the Stevana Šupljikca and the Prvomajska streets and at the same time from the Miloša Obrenovića street and the Bavaništanski road. In the case when traffic lights do not work or there are only yellow flashing lights, drivers rely on traffic signs.
Due to the huge number of vehicles on city roads there is the problem of traffic regulation. Roads and their surrounding areas as well as the road conditions directly influence drivers and their vehicles. Surrounding areas influence the consequences of traffic accidents while the road conditions influence traffic safety. The observed intersection, the Prvomajska – the Stevana Šupljikca – the Bavaništanski road – the Miloša Obrenovića, is one of the busiest intersections in the town of Pancevo. This intersection belongs to corridor E70 in Pancevo. Since this road connects many European countries, it is very important for the strengthening of trade, economy, material goods and as such directly influences people's lives.
The idea of this work is to implement some measures for the improvement of traffic safety on the observed intersection and its relieving as well as the improvement of traffic conditions.
Measure suggestions:

- Zebra crossings replace with footbridges and so lower the number of conflict points
- Lanes for opposite directions physically separate
- Place traffic lights controlled by artificial intelligence, technology which can prioritize and thus regulate traffic on intersection
- Place cameras which record speed limit of vehicles
- Upon completion of road works on the road Bubanj Potok – Vinča – Pančevo, redirect cargo traffic onto the above-mentioned road and so decongest the observed intersection
- Make roundabout at the place of the observed intersection

Cameras which record speed limit have advanced functions for traffic safety improvement. They offer the solution which can repress violation of traffic regulations, speeding and improper parking and stopping. Intelligent cameras have multiple advantages: increased security, detection of potential danger and warning the competent services, recording videos and data in real time, increased effectiveness for counting and classification of vehicle types. The main goals of cameras is to make it easier for competent services to fully understand every traffic situation.
Nowadays, roundabouts are used more often. Essential parts, number of lanes and the diameter of the circle directly influence the vehicle speed, traffic safety and reduce waste of time. At roundabout intersections there is no privileged direction, which means that neither direction has high speed. The main advantage of roundabout is there are no conflict points. The usage of roundabouts equals main and side direction as far as importance is concerned. Apart from reducing waste of time, roundabouts have higher throughput. On figure 4, there are current solution and suggested solution in the form of roundabout intersection.

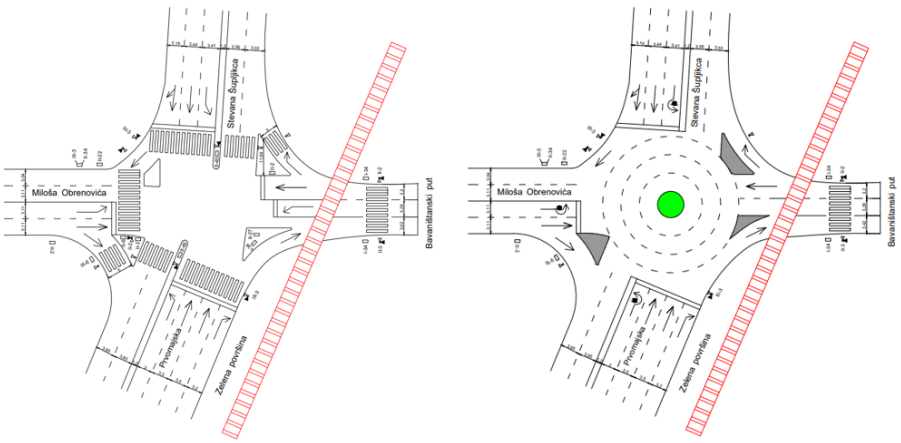

Figure 4. Current solution and suggested solution in the form of roundabout intersection

The way that roundabout intersections influence traffic safety improvement and their importance on intersections with huge number of traffic accidents, can be seen in professional literature used for this work [7, 8, 9, 10, 11].
Much more space is needed for roundabout intersections compared to classical intersections. Traffic regulation with multiple accesses is more effective when implementing roundabouts. Geometry of intersection with unfavourable angles of leg intersection makes such an intersection busy during morning and afternoon rush hour. Above-mentioned characteristics can be seen on the observed intersection. The suggestion of changing this intersection into roundabout intersection, in near future can make this intersection convenient and safe.
Knowledge as prerequisite for safe and secure driving a vehicle makes driving rational and quality, and the key word is prevention, i.e., investment into traffic safety.
Huge traffic density can lead to its slowing down, which can cause traffic participants to become nervous, increase in fuel consumption, longer travel time etc. The best tool is vehicle speed management, functioning of the road network and promotion, in media and in driving schools, of driver training with the goal to improve traffic safety on roads.
Some of many problems on the chosen intersection are as follows: in the situation of conditional turning of vehicles to the right, drivers must give way to pedestrians and vehicles, vehicles in direction the Bavaništanski road – the Miloša Obrenovića street when turning to the left must give way to vehicles from the opposite direction etc. The above-mentioned problems can lead to huge number of conflict points that influence the effective traffic flow through this intersection and are shown on figure 5.

Figure 5. Photo documentation of problems on the chosen intersection
Source: https://www.google.rs/maps/

5. CONCLUSION

The Republic of Serbia is one of the countries which, in its regulations, implements modern procedures for traffic safety improvement on roads. Law on road traffic safety prescribes implementation of independent projects for controlling traffic safety on roads mainly on state roads according to predetermined frequency, while for other roads it can be done if there are realistic possibilities. In practice, it means that controls will be rarely conducted although the practical researches imply that the risk of traffic accident is not on the negligible level.
Law on road traffic safety brings some innovations for traffic safety improvement, which is basically the research goal of this work. Taking into consideration the importance of factors: participant – vehicle – road – surrounding area, regardless the position and road rang, prevention is of the utmost importance on spots of higher risks.
Taking into consideration advantages and disadvantages, as well as desirable and undesirable situations on roundabout intersections, it is necessary to carefully plan their implementation. It is important to consider their influences on security, capacity, ecology and aesthetics. It is important to analyse and evaluate all previously mentioned influences. For project evaluation should be used

the method of gain – expenses. Gain considers security and functionality, while expenses consider building and maintenance.

Roundabout intersections are safer and provide higher traffic flow compared to classical intersections. They secure continuous driving and fit well with the surrounding area. Advantages for the chosen intersection are higher level of security, shorter waiting time at access points and lower maintenance costs. Ecologically, they are more acceptable since they lower energy consumption and harmful gases emissions. Quality of roundabout intersections improves over time and security level and traffic quality become higher.

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BIOTECHNOLOGY AND HEALTHCARE

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BIOLOGICAL CONTROL AS AN EVOLVING TECHNOLOGY IN PEST MANAGAMENT

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Abstract: *Biological control involves the use of populations of natural enemies to suppress pests populations to lower densities, either permanently or temporarly. Natural enemies are the fundamental resource of biological control, mainly represented by two major groups: parasitoids and parasit insects. When pests are to be controlled over large areas, the only long-term affective approach is introduction of natural enemies. There are two types of permanent biological control: classical and new association. When biological control is used to temporary suppress pests in production area, three approaches are available: conservation control, augmentation, and application of biopesticides. In recent decades, the increase use of biological control is due to its safety, species specific and permanent action on the target agriculture pests. Unlike the use of chemical pesticides, this method is environmental friendly, with no effects on human health. The aim of these paper is to review different major strategies of biological control of pests used in agriculture and nature ecosytems like farms, green houses, garden and forests.*
Keywords: Biological Control, Natural Enemies, Pest Populations

1. INTRODUCTION

Biological control has long been considered as a potential alternative to pesticidal strategies for pest management. Predators and parasitoids, as well as entomopathogenic nematodes and microbes, are main tolls for biological control, and have been in action for a long time in the history of agriculture [1]. Biological control agents of weeds include herbivores and plant pathogens. Predators are mainly free-living species that directly consume a large number of preys during their whole lifetime. Insect parasites (parasitoids) are smaller than their host and develop inside, or attach to the outside, of the host's body. Pathogenic microorganisms include bacteria, fungi, and viruses. They kill or debilitate their host and are relatively host-specific. Populations of some aphids, caterpillars, mites, and other invertebrates are sometimes drastically reduced by naturally occurring pathogens, usually under conditions such as prolonged high humidity or dense pest populations.

Biological control method has been actively practiced for more than 100 years and the history of biocontrol and its successes, has been extensively reviewed in literature. Interest in biological control has increased over recent decades for many reason [2]. First, insect pests continue to cause severe damage to crops globally, estimated to be at least $470 billion per year [3]. Second, the human population growth, combined with increasing per capita demands for protein, require that losses from pests and other causes (including human wastage) are addressed so that food availability is doubled in coming decades [4; 5]. Third, the availability of insecticides is threatened as a number of arthropod pests have developed resistance to one or more pesticides leaving growers to search for alternative

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management strategies [6]. Accordingly, agricultural intensification efforts should be based on ecological principles rather than greater reliance on non-renewable resources [7]. The primary factors affecting adoption of biological control are efficacy, predictability, and cost [8].
Biological control of pest dated back to 16th century in China. They were the first to use natural enemies to control insect pests in the third century, for the control of citrus insect pest such as *Tesseratoma papillos* Drury (Hemiptera: Tesseratomideae) using nests of the ant *Oecophylla smaragdina* Fabricius (Hymenoptera: Formicideae) in Canton [9].
In the second half of the 20th Century, following the Green Revolution biological control has resurfaced with renewed force in recent years, especially by the adoption of integrated pest management (IPM) programs. These programs were implemented as a consequence of the anappropriate use of agrochemicals, which led to a number of problems, such as insect and mite resistance to insecticides and acaricides, as well as environmental contamination [10].
The aim of these paper is to briefly describe the history of the major forms of biological control review different strategies of biological control of pests used in agiculture and nature ecosytems like farms, green houses, garden and forests.

2. STRATEGIES OF BIOLOGICAL CONTROL

There is a long history of seeking to increase the efficacy of biological pest control by predators and parasitoids, as well as entomopathogenic nematodes and microbes [1]. Ant colonies have been traded and the movement of ants between tree crop canopies facilitated by bamboo poles for 100s of years [11]. Biological control efforts against plants and insects have different histories, and since the 1800s, 'classical biological control' efforts to suppress exotic pests have involved importing their natural enemies; though this practice is increasingly under scrutiny to avoid effects of introduced agents on non-target, native species [12]. During the 1900's, insect biological control against environmental pests develop as an independent goal [11]. This practice continues to grow in popularity though the costs to farmers are often significantly higher than the use of insecticide applications.
Biological control can be approached by two means: permanent suppresion of pests and temporary [13]. When the goal is a permanent control which targets non-native invasive species over large areas, the only feasible method is classical biological control. If the target is a native pest (or an exotic species of unknown origin), and the natural enemies released against it come from a different species, the approach is called new association biological control. When biological control is used to temporary suppress pests in production area, three approaches are available: conservation control, augmentation, and application of biopesticides [13].

2.1. Classical biological control

Classical biocontrol is defined; as the intentional introduction of an exotic (non-native), usually co-evolved biological control agent for permanent establishment and long term pest control [8]. This is usually done by government authorities. In recent years, classical biological control has come under increasing scrutiny for its nontarget effects.
Many of the important arthropod pests of agriculture and natural areas are non-native invasive species [14]. For example, in the USA, 35% of the 700 most important insect pest are invasive species. Since 1888, natural enemy introductions have provided complete or partial control of more than 200 pest arthropod and 40 weeds [15,16]. Rapid suppresion of an invasive plant by an introduced insect is illustrated by the case of the floating fern *Azzola filiculoides* Lamarck (Salvinales, Salivinaceae) [17]. *Azolla filiculoides* (red waterfern) is a floating fern native to South America which has invaded aquatic ecosystems in South Africa. Thick mats of *A. filiculoides* on dams and slow-moving water bodies cause economic losses to water-users. Among those most seriously affected were farming (71%), recreational (24%), and municipal (5%) users. The frond-feeding weevil *Stenopelmus rufinasus* Gyllenhal (Coleoptera: Curculionideae) was released as a biological control agent at the

end of 1997. Within 3 years, the weevil had reduced the weed population to the point that it was no longer considered a problem in South Africa.
Introduced as a method classical biological control has major advantages over other forms of control because it is self-maintaning and less expensive over the long term. They are usually conducted by public institutions, using public resources to solve problems for the common good [13].

2.2. New association biological control

This term appiles if the target pest is a native species or an invasive species of unknown origin [13]. Natural enemies are collected from a different species that are related either taxonomically or ecologically to the pest. *Peristenus digoneutis* Loan (Hymenoptera: Braconidae) was introduced to the eastern USA for biological control of the tarnished plant bug, *Lygus lineolaris* Palisot de Beauvois (Hemiptera: Miridae), and has since spread through much of the northeast [18]. New association biocontrol differ from classical in two ways. First, the ecological justification (restoring disturbated ecosystems to pre-invasing conditions) for classic biological control is missing when native species are targetied. The second way is that, by definition, natural enemies are not located by finding the pest overseas and collecting its natural enemies. One has to select surrogates from another biogeographic region that are enough like the pest (based on taxonomy, ecology, morphology, etc.) to have natural enemies that would attack the pest [13].

2.3. Conservation biological control

The discipline of conservation biological control has evolved rapidly over the last two decades [1]. This type of control include modification of the environment or existing farming practices to protect and enhance the abundance and diversity of the natural enemy community in order to reduce the effect of pests. Ecosystem manipulation involves increasing the species diversity, and this approaches provide natural enemies with resources such as nectar, pollen, alternative prey and alternative hosts and operate to reduce pest densities through out the enhancement of natural enemies.
Research has been done on myriad arthropod pests, including species with high levels of insecticide resistance such as *Chilo suppressalis* Walker (Lepidoptera: Crambidae) and *Helicoverpa armigera* Hubner (Lepidoptera: Noctuidae) [19]. As an example of conservation biological control, alternative habitats for natural enemies are provided, in the form of ‘beetle-banks’ in Britain or ‘sown seed strips’ in Switzerland incereal crops [2]. These practices are highly successful and are among the few documented uptakes of a biocontrol option in temperate open-field arable agriculture [20].
Studies show that the conservation of natural enemy species richness sometimes weakens, or has no affect, on biological control. This approach is likely to be true for many native insect pests, but is not true for weeds, nor it is usually true for invasive insects unless a programe of classical biological control has imported effective specialized natural enemies. Conservation method depend on knowing how effective a particular practice will be under local conditions, and as so can be implemented on individual farms. This requires extensive local research in farmer’s fields.

2.4. Augmentation biological control

Augmentation is the periodic release of a natural enemy that does not occur in sufficient numbers to keep a pest below damaging levels. The practice of augmentation is based on the knowledge or assumption that in some situations there are not adequate numbers or species of natural enemies to provide optimal biological control. It can be used when natural enemies are missing (as in green housees), or arrive too late for new plantings (some row crops), or are too scarce to provide control (in large monocultures).
There are two general approaches to augmentation: inundative releases and inoculative releases [2]. Inundation, or mass release, involves releasing large numbers of natural enemies for immediate reduction of a pest population. It is a corrective measure; the expected outcome is immediate pest

control. In practice, releases are often repeated if pest populations were not all present in a susceptible stage during the previous application, if new pests disperse into the crop, or if the crop is long lived, increasing the length of time it could become infested [21]. Therefore, it may be used int he field and in greenhouse as seasonal release [22]. For example, *Eretmocerus eremicus* Rose&Zolnerowich (Hymenoptera: Aphelinideae) must be released weekly for continuous suppresion of whiteflies in greenhouse. The utilization of some microbial insecticides, such as those containing *Bacillus thuringiensis* Berliner (Bacilales, Bacilaceae), is also inundation. Inoculation on the other hand; involves releasing small numbers of natural enemies at prescribed intervals throughout the pest period, starting when the pest population is very low. The natural enemies are expected to reproduce themselves to provide more long-term control. However, the expected outcome of inoculative releases is to keep the pest at low numbers, and it is more of a preventive measure [2].

2.5. Biopesticides

Biopesticides are naturally occurring formulations made from the living organisams that control pests by non toxic mechanisms and in ecofriendly manner. The science of biopesticide is still considered to be young and evolving. Biopesticide is gaining interest because of its advantages associated with the environmental safety, target-specificity, efficacy, biodegradability and suitability in the integrated pest management programs. Global production of biopesticides has been estimated to be over 3,000 tons per year, which is increasing rapidly, and about 90% of the microbial biopesticides are derived from just one entomopathogenic bacterium *Bacillus thuringiensis* [23]. *Bacillus thuringiensis* is the most commonly used biopesticide globally. It is primarily a pathogen of lepidopterous pests like American bollworm in cotton and stem borers in rice. When ingested by pest larvae, this bacteria releases toxins which damage the mid gut of the pest, eventually killing it. Main sources for the production of this biopreparations are the strains of the subspecies *kurstaki*, *galeriae* and *dendrolimus*. Certain soil bacteria, algae, fungi, plants and insects possess the unique ability to produce hydrogen cyanide (HCN), which plays an important role in the biotic interactions of those organisms. In particular, cyanogenic bacteria have been found to inhibit the growth of various pathogenic fungi, weeds, insects, termites and nematodes. Thus, the use of HCN-producing bacteria as biopesticides offers an ecofriendly approach for sustainable agriculture.

3. CONCLUSION

Biological control of pest is the non-chemical way in which we use of pathogens, predator and parasitoid in purpose for killing pest, reducing their populations or eliminating them completely from our farms, garden and forest. It is environmentally friendly and increase productivity and safety of the consumers. Statistical data shows that, unfortunately, farmers have been slow to adopt biological control as part of their pest management practice. For example, biological control is practiced in just 5% of the estimated 741,290 acres of greenhouses worldwide. The primary factors affecting adoption of biological control are efficacy, predictability, and cost.

Classical biological control is a powerful tool for suppression of invasive species of plants and insects in natural and agricultural ecosystems. It will play an increasingly important role in restoration of ecosystems and biodiversity, because it provides a mechanisam to permanently suppress invaders over large landscapes without long-term resource commitments and for that reason it makes it sustainable. However, for biological control to be fully utilized, it is essential for the users to have insects available whenever they are required, in order to use them in inoculative (classical biological control), inundative (applied biological control), or seasonal inoculative releases (biological control in protected crops) to control the target pests.

Conservation method depend on knowing how effective a particular way of practice will be under local ecological conditions on the field, and as so it is appropriate for individual agroecosystems. Augmentation is limited principally by costs, agent availability and quality, and field effectivness of the reared organisams. Costs limit the use of reared natural enemies when the natual enemy is

inexpensive to rear, the crop has high cash value, or cheaper alternatives such as insectides are not available.

In recent years, microbial antagonists are used for the control of pest and diseases. Typical example abounds on the *Bacillus thuringiensis* which are toxic to many species of pest insects. However, while present in the market place for over 65 years, currently make up less then 1% of insecticide use.

As a conculsion there is a need to develop better and more widely applicable strategies that will allow the promise of conservation biological control to be realized more widely in global agriculture. Key to achieving this objective is to find a predator which may consume multiple species of prey in addition to plant foods (e.g., pollen).

Biopesticide is one of the promising alternatives to manage environmental pollutions. Since the environmental safety is a global concern, we need to create awareness among the farmers, manufacturers, government agencies, policy makers and the common men to switch-over to biopesticides for the pest management requirements.

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SMART FARMING AND LONG-TERM SUSTAINABILITY

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Abstract: *Agriculture has played a vital role throughout human history since ancient times, as it is essential for the survival of the human species. Many changes occurred during this period, from the domestication of animals and plants to the systematic use of crop rotation and other advances in agricultural practices. The last innovation a few decades ago was the increased use and production of pesticides, which drastically increased agricultural productivity, as diseases and pests were more effectively controlled. Agriculture today is considered to be experiencing a new evolution called Smart farming, which is based on information and communication technologies that include unmanned aerial vehicles (UAVs), unmanned ground vehicles (UGVs), image processing, machine learning, big data, cloud computing and wireless, sensor networks (VSN). With the world's population constantly growing and currently numbering more than 8 billion people, it is estimated that food production will need to double by 2050. Smart agriculture aims to increase productivity and improve the quality of the final product while reducing production costs by using the latest technologies and enable the sustainability of environmental resources through the optimal use of pesticides and chemical fertilizers.*
Keywords: smart farming, sustainability, environmental resources, agriculture

1. INTRODUCTION

Agriculture is essential to human survival as it provides food for the growing world population and play important role in economic development. Contrarily, agriculture is the primary cause of environmental degradation because it is thought to be a major contributor to climate change, freshwater scarcity, fish die-offs, soil fertility degradation, the environment and soil pollution, landscape changes, and loss of biodiversity and ecosystem at all levels [1,2,3,4,5]. The predominance of annual plants cultivated in monocultures is one of the traits of conventional agricultural production. These crops cause ecological degradation, soil erosion, and an increase in pests and weeds that have adapted to the crop [4]. Due to the development of resistance, which arises as a concurrent issue in monocultures, large quantities of various active ingredients of pesticides are needed to control them. The need for agricultural output has expanded dramatically in response to the growing global population, which has resulted in extensive pesticide use and the development of artificial fertilizers

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in conventional agriculture. The quality and fertility of the soil have decreased as a result of the usage of these chemical agents in agricultural fields. Several million people worldwide are going without food, and at the same time, the environmental resources are becoming more and more polluted. The challenges of preserving soil fertility, water scarcity in endangered regions of the world, pests and illnesses that harm crops and livestock, and increasingly strict criteria for food quality and safety can all be observed from a for mentioned information, demonstrating the need for an integrated approach. [4,6]. The current phrase in the agricultural industry is "smart farming," which aims to replace conventional methods with creative ones based on information and communication technologies (ICT) [7]. Smart agriculture is one of the new perspective technologies [8]. Technologies like Unmanned Aerial Vehicles (UAVs), Unmanned Ground Vehicles (UGVs), Image Processing, Machine Learning, Big Data, Cloud Computing, and Wireless Sensor Networks (WSNs), are expected to bring significant changes in conventional agriculture [7].

2. STATE OF CONVENTIONL AGRICULTURE AND SUSTAINABLE AGRICULTURE

Over the last several decades, the rapid growth in technological innovations have led to profound structural changes in the agricultural sector, including a transition from smallholder mixed farms toward large-scale specialized industrial production systems [2,9]. Agricultural sector faces many challenges to ensure possible improvements in production sustainability in ways that promote food security, poverty reduction and improved public health [2]. Agriculture is both affected by climate change and an important contributor to greenhouse gas (GHG) emissions. Total emissions on agricultural land in 2019 amounted to 10.7 billion tons of carbon dioxide equivalent (Gt CO_2eq) of GHG released into the atmosphere in 2019. [10]. Agriculture contributes nearly 11% of global greenhouse gas emissions [11]. One of the biggest problems facing crop production are plant diseases and pests. Historically, many plant diseases caused by various phytopathogenic microorganisms have led to catastrophic losses, such as the Irish famine (1845), the Great Bengal famine (1943), the southern maize leaf blight epidemic (1970), and coffee rust (1970). Until recently, only chemical pesticides were used to control harmful agents, largely due to their cost-effectiveness [12, 13]. Intensive use of pesticides caused surface and ground water pollution. Groundwater is much more serious problem because pesticides do not degrade there as rapidly as in other environments, ground-water is commonly used for irrigation and for drinking by man and domestic animals [14]. With an increasing human population under a decreasing per capita agricultural land globally, optimizing productivity while maintaining the preservation of soil health and the protection of environmental quality is a key challenge [11]. Sustainable agriculture, unlike conventional agricultural production, produces abundant food without depleting the earth's resources or polluting its environment. For the sustainable maintenance of agriculture, the dynamic nature of soil is of primary importance [15, 16, 17]. 95% of our food is produced by plants growing in soil (FAO, 2020). Soil content is regulated by numerous aspects such as various biotic and abiotic factors, soil moisture, nitrogen, phosphorus and potassium content, organic carbon and others. Wise soil management means increases organic matter [18].

3. SMART FARMING AND SUSTAINABILITY

Smart agriculture with Internet of Things and Wireless Sensor Network is a transformation from traditional farming to smart farming [19, 20, 21]. The global agricultural development trend known as "smart agriculture" uses IoT sensors and near- and remote sensing techniques to monitor crop conditions at various growth stages. In order to practice smart agriculture, a significant amount of crop health data must be collected and processed. The health of plants is influenced by a number of variables, including temperature and water content. With the help of vast amounts of data from various sources and different parts of the field, such as soil nutrients, the abundance of pests and weeds, the amount of chlorophyll in plants, and some weather conditions, smart agriculture enables a farmer to precisely know what parameters are needed for productive crops, where these parameters

are needed, and in what amounts at a specific moment in time. It is necessary to analyze all the data gathered in order to generate agronomic advice. For instance, the amount of chlorophyll content in plants, depending on their stage of development, indicates the nutrients required. The qualities of the soil where the plant is placed, along with the weather forecast, are integrated with this information. The amount of a specific fertilizer that should be applied to that plant the following day is calculated using all the data that has been gathered. To increase yields, farmers must receive agronomic information at the proper time and be sure to follow its suggestions [19]. According to Shafi et al. (2019) the main objective of smart agriculture is to produce surplus yield by optimizing the resources such as water, pesticides, fertilizers, etc., for resource optimization. Inputs for crop production can be managed by smart agriculture in an environmentally sustainable manner. Smart agriculture can target rates of fertilizer, seed, and chemicals for soil and other conditions by applying site-specific knowledge [22]. All of factors point to the fact that smart agriculture can help production agriculture become more environmentally friendly by using fertilizers and pesticides only when and where they are truly necessary. Environmental advantages of precision agriculture result from more focused input utilization that lowers losses from excess applications as well as from reductions in losses owing to nutrient imbalances, weeds, insect damage, reduction in pesticide resistance development [22, 23]. Unmanned aerial vehicle (UAV) aircrafts are used to spray pesticides in order to minimize the health issues that might arise when doing it manually, which is one method of implementing smart agriculture. UAVs can be utilized in places where labor and equipment are difficult to employ. They are equipped with the cameras and sensors for crop monitoring and sprayers for pesticide spraying. A UAV is an aircraft which can flight without a human pilot and controlled by the radio channel. A technical analysis of UAVs in smart agriculture is to analyze their applicability in agriculture operations like crop monitoring, crop height Estimations, pesticide Spraying, soil and field analysis. Their hardware implementations are solely based on important factors such as weight, flying range, payload, configuration, and costs [23]. A traditional agricultural environmental monitoring system supplies electricity and transmits data by cable. It is particularly challenging to obtain information about the agricultural environment in real time because to the challenging installation of power lines, high investment prices, etc. Systems for monitoring the agricultural environment using wireless sensor networks have been developed to increase crop output while reducing pollution and environmental deterioration. In this way, researchers can achieve real-time remote monitoring of agricultural land in the control room, according to temperature and air humidity, light intensity, soil moisture and soil pH and other agricultural information for making correct decisions. The monitoring system for the agricultural environment is made up of several dense wireless sensor nodes that are dispersed across the agricultural environment. Different sensors can be used on farmland depending on the needs, creating a self-organized network to track changes in values like temperature, humidity,CO_2 concentration, soil pH value, and light intensity. Remote monitoring terminal through GPRS processes and analyzes the collected data, and then the data will be displayed in the form of curves, graphs and report forms and also written into database, through which completes browse and inquire the current information [24]. In the area of smart agriculture, there is also the potential to investigate various deep learning (DL) models for spotting insects in pictures. Different DL-based object detection algorithms exist for identifying outdoor insect pests. To guarantee healthy crop growth, early pest insect identification is essential, because this lowers the likelihood of yield loss and enables the adoption of precise treatments that have positive environmental and economic effects [25]. Intensive development of the Internet of Things (IoT) technologies enabled different novel applications, including smart agriculture systems. IoT technologies serve as the technical foundation for smart agriculture networks. IoT includes the basic communication infrastructure and range of services, such as local or remote data acquisition, cloudbased intelligent information analysis and decision making, user interfacing, and agriculture operation automation. Such capabilities have the potential to change the agriculture sector, which is now one of the least efficient in our economic value chain. Currently, integration of wireless sensors and the IoT in smart agriculture can raise agriculture to levels which were previously unimaginable. IoT can help to improve the solutions of many traditional farming issues, like drought response, yield optimization, land suitability, irrigation,

and pest control. Soil mapping creates the possibility to sow different crop varieties in a specific field to better match soil properties such as seed suitability, time to sow, planting depth, as some are deep rooted and others less so. Additionally, combining the growth of several crops may result in more intelligent agricultural practices that make the greatest use of available resources [16, 27]. The accuracy of new IoT-based fertilizing methods helps to estimate the amount of nutrients needed while requiring minimum labor requirements. In order to make agriculture sustainable it is considered that in the future IoT will be involved in all operations, which includes water and energy use, crop transportation, alerts on the operation and maintenance of agricultural machinery, etc. Implementation of such a system in the field can help to improve the yield of the crops and overall production and enable the long-term sustainability of agricultural land and other environmental resources.

4. CONCLUSION

The goal of advancing agriculture is essential given the global trend toward new technology and their deployment. The majority of the research that has been conducted thus far shows that smart agriculture-based practices have a significant impact on sustainability and productivity. The goal of smart agriculture is to provide decision-support systems based on a variety of crop-related factors, such as soil nutrients, soil water content, wind speed, sunshine intensity, temperature, humidity, chlorophyll content, etc. Due to high costs, lack of internet access, and a lack of application knowledge among farmers, there are still restrictions on the conversion and adoption of smart agriculture today, but breaking beyond conventional methods and thinking, the use of wireless sensor networks in monitoring agricultural environments has the potential to significantly increase crop production's efficiency and dependability as well as protection environmental protection in the future.

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VARROA DESTRUCTOR, THE PARASITIC MITE OF *APIS MELLIFERA*: A REWIEW

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Abstract: *Honey bees are the primary commercial pollinators across the world. Long before written history was created, The western honey bee, Apis mellifera L. was a very valuable socio-economic resource for people. It has been carried throughout the world for hundreds of years for the purpose of producing honey and pollination. A. mellifera is a social insect that lives in a colony where the queen, workers and drones are interdependent and cannot survive alone, so the colony can be considered as one organism. The number of honey bees has been declining globally in recent decades. In addition to climatic factors that affect the biology and ecology of bees, the main reason for the reduction in the number of colonies is harmful agents, among which diseases, parasites and pesticides stand out. Perhaps the most harmful parasite mite that infects honey bees globally is Varroa destructor (Mesostigmata: Varroidae). Varroa is an invasive species that has spread globally since switching from its original host, the Asian honey bee (Apis cerana) (Hymenoptera: Apidae), to the Western honey bee (Apis mellifera) (Hymenoptera: Apidae). It now attacks honey bees on nearly every continent where apiculture is practiced and present the most important ectoparasite of Apis mellifera.*

Keywords: Varroa destructor, mite, honey bees, Apis mellifera, pollination.

1. INTRODUCTION

Honeybees are insects that come under order Hymenoptera and family Apidae. Based on morphometric, behavioural and biogeographical studies, 26 subspecies have been identified. *Apis mellifera* are found all over the world and their native range extends across Africa, Asia, and Europe. Distribution of *Apis dorsata* extends from Pakistan to Indonesia across the Indian subcontinent. The distribution of *Apis florea* is often limited to warm regions, ranging from Pakistan to Sri Lanka. *Apis cerana* was more commonly found in tropical and subtropical regions of Asia than in temperate regions. Because of their hidden nesting habits, only *A. cerana* and *A. mellifera* have been domesticated by man among all the *Apis* species [1, 2]. The western honey bee, *Apis mellifera*, has been globally transported for hundreds of years for honey production and pollination and has been of enormous socio-economic value to humans long before the beginning of written history. The oldest records of honey hunting date back to prehistoric cave paintings [3, 4, 5]. Based on the fossil record, the first signs of social bees appeared about the same time as some of the earliest flowering plants that needed insect pollination [3]. In addition to exhibiting sophisticated behavioral features like sociality, language, labor division, and remarkable capacities for learning and memory, honeybees also have a complex social structure. Honeybee females can grow into either workers or into morphologically different, reproductively active queens, a phenomenon known as polyphenism [1]. The honey bee *Apis mellifera* is a social insect which lives in a colony where the queen, workers and drones are interdependent and cannot survive alone. The colony can be considered as one organism (Figure 1). The colony has a one year developmental cycle which is dependent on some external factors such as season, geography, beekeeping practices, etc. [6]. The queen, the only reproductive person in each colony, is responsible alone for laying the eggs that hatch into workers (females) and

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drones (males). Despite being sterile, workers collaborate on all actions related to colony upkeep, defense, food foraging, and brood rearing. Although worker honey bees have the same physical characteristics, each individual is specialized in carrying out particular behavioral tasks within the colony [7].

Throughout history, honey bees have benefited man both for food and their ability to increase crop yield via pollination [8]. Next to pollination, honey production is the second biggest benefit humans get from bees. Honey is a complex nutritional sweetener composedmainly of carbohydrates and water, and it also contains small amounts of other compounds, such as organic acids, minerals, vitamins, enzymes, proteins, amino acids. Its is usually consumed in natura, and as a food ingredient but has been also employed in both human and veterinary medicine [9]. Nowadays, the benefits of plant pollination exceed all other economic benefits that modern beekeeping has through the production of honey, propolis, wax and more. A number of important horticultural crops depend increasingly on controlled honey bee colonies which help in pollination in modern agriculture.

Figure 1. Colony of bees
Source: own archive

2. MEET THE ENEMY: THE PARASITIC BEE MITE - *VARROA DESTRUCTOR*

The process of honey bee pollination is essential to ecosystem health and agricultural production optimization [10]. The honey bee, of all insect species, is most crucial to the pollination of agricultural crops. Only 15-20% of pollination is carried out by other mediators, such as bumblebees, solitary bees, butterflies, etc., compared to 80–85% by bees. With their activities, these insects affect not only the maintenance of plant communities but also entire ecosystems. In modern commercial beekeeping, bees face numerous enemies in the form of diseases and pests. This number has increased in recent decades. International transport, export or import of bees and/or their products increased the possibility of introducing different pathogens (parasites, bacteria, viruses and fungi) into bee colonies. Arguably the most destructive parasite mite attacking honey bees globally is hemophagous honey bee mite *Varroa destructor* (Mesostigmata: Varroidae). *Varroa* is an invasive species that has spread globally since switching from its original host, the Asian honey bee *(Apis cerana*) (Hymenoptera: Apidae), to the Western honey bee (*Apis mellifera*) (Hymenoptera: Apidae). *Varroa* was first reported in Africanized honeybees in Brazil in the early 1970s. It is presently regarded as the main danger to apiculture [11,12]. *Varroa destructor* is an obligatory parasite, spending its entire life in the bee's nest [13]. High levels of *Varroa* infestation, particularly in the absence of mite management techniques, can cause varroosis throughout the colony and ultimately colony loss. Because it can multiply within both worker and drone cells, allowing populations to grow quickly, *Varroa* has become an effective parasite of *A. mellifera* [14,10]. The *Varroa destructor* mite is the largest threat to apiculture worldwide and has been responsible for devastating losses of wild honeybee populations in Europe and North America [14]. *Varroa jacobsoni,* on the other hand, has comparatively little influence on the colonies of its native host, *A. cerana,* owing, at least in part, to the fact that the mite can only breed when a male brood is present. In contrast, *V. destructor* can reproduce on both male and female brood, which results in an extended reproductive season and increased numbers of *V.destructor* mites,

which parasitize both adult bees and their larvae in the hive [10]. *Varroa* mites enter brood cells inhabited by mature bee larvae prior to worker bees sealing comb cells with wax. Here, they will eventually feed on the hemolymph and fat bodies of host pupae [15]. Parasitism of honey bees by the *V. destructor* reduces the body weight and water content of young bees, there is a reduction in the size of the drones and their reproductive capacity, which directly affects the bee population, i.e. the entire colony. Additionally, *Varroa* affects foragers' ability to fly, locate, and navigate, which reduces their efficiency in gathering the resources necessary for colony development. Certain haplotypes of *V. destructor* parasitizing *A. mellifera* transmit various bee-related viruses. The quantity of viral infection rises in the spring and summer as the *Varroa* population grows within the colony. High levels of *Varroa* infestation can lead to colony-wide varroosis and eventually colony death, especially when no control measures are taken against the mites [12]. High *Varroa* parasitization impacts bees at the individual level, causing bees to exhibit lower weight, decreased learning capacity, and shorter lifespan (Figure 2).

Figure 2. Colony of *Varroa destructor* on the bottom of the hive
Source: own archive

3. VARROA'S EFFECTS COMBINED WITH ADDITIONAL COLONY STRESSES

Because of their crowded living conditions and the potential that closely related nestmates would have similar vulnerabilities against particular pathogens, social insects are particularly vulnerable to parasites and diseases. Among the social insects, parasites and diseases that affect honey bees are exceptionally varied, and disease-related problems have been linked to both decreased productivity and colony failure [16]. *Varroa* can interact with other biotic and abiotic stressors, including viruses, pesticides, other parasites and diseases, and environmental conditions. Exposure to pesticides, poor forage, mite parasites, and pathogens has resulted in high annual death of colonies in the USA, Europe, and other parts of the world [17]. Climate change means that honey bee colonies must endure longer durations of brood raising and foraging due to longer warm seasons. A longer brood time increases the number of *Varroa* reproductive cycles, perhaps leading to an increase in the mite population. In order for pathogens and pests to persist in a host population, they must be spread past one colony to another. Usually, inter-colony transmission happens when honeybee workers "drift"- that is, leave their home colony and join a foreign colony. Colonies with high *Varroa* infestation had a significantly enhanced acceptance of drifters, although they did not send out more drifting workers. Since *Varroa*-infested colonies show an enhanced attraction of drifting workers, and not only those infected with Varroa and its associated pathogens, infestation by Varroa may also facilitate the uptake of other pests and parasites [18]. Nosema infection reduces the effectiveness of bee defences against

the mite [19]. Nosemosis or Nosema disease is caused by two species of microsporidian parasites (a type of spore forming fungus) called *Nosema apis* and *Nosema ceranae*. Nosemosis is one of the most serious adult honey bee diseases and has high prevalence in honey bee colonies [17, 20]. Iportant bacterial pathogen (*Paenibacillus larvae* subsp. *larvae*) cause of the disease American foulbrood which is infectious disease of the larval stages of the honey bee Apis mellifera. The disease is also important from the point of view of international trade, so the import or export of bee colonies is allowed under certain, controlled conditions [16].
If mite populations develop undetected, untreated and infested honey bee colonies usually collapse within a year. Beekeepers check adult honey bees and their offspring for varroa mite infestations using a variety of techniques. These methods include counting mites on traps and on such colony contents as hive debris on the bottom boards, brood, as well as the bodies of captured worker bees. Collecting data foroptimally timing acaricide applications and effectively controling mites requires sampling such hive contents [15]. The "sugar shake" is a straightforward, non-destructive technique for gathering samples of varroa mites that are present on adult honey bees' bodies. This method consists only of dusting live bees' bodies with powdered sugar. *Varroa* mites will rapidly lose adhesion to the powdered sugar, which causes them to become permanently detached from their host bees' tarsal pads. The powdered sugar will quickly clog the tarsal pads of varroa mites. On this way, they lose adhesion and become permanently dislodged from host bees. For the purpose of controlling varroa mites in both conventional and organic honeybee colonies, organic acids that are mostly generated from plant components and essential oils are commonly utilized. Formic acid and oxalic acid are the most often used organic acids with strong acaricidal action [15,21]. Oxalic acid is applied via spraying and sublimation methods. It is a component of honey that occurs naturally, is safe for beekeepers to use, highly effective against the Varroa mite, and leaves no residue behind. However, other research indicates that mites have a high chance of becoming resistant to oxalic acid [22].

4. CONCLUSION

There has been a dramatic decline in the number of cultivated honey bees and wild bees in Europe during the last few decades. The reasons for the decline are varied and include habitat loss, pests and diseases, and excessive use of agrochemicals. At the same time, more crops are cultivated that require pollination. *Varroa destructor* is one of the biggest biological threats to the health of western bees (*Apis mellifera*) worldwide. The mite is a big problem for beekeeping and the search for new control methods is constantly in the focus of researchers and beekeepers. The most common applications in the control of *Varroa* are acaricides. However, acaricides can have harmful side effects on individual bees as well as entire colonies. Beekeepers routinely use chemical treatments to control this parasite, although overuse and mismanagement of these treatments have led to widespread resistance in *Varroa* populations. As a result, and to prevent the development of resistance to acaricides, they must be administered at the lowest effective dose. The application of toxic active products each season can be reduced by increased mite monitoring and the use of less persistent, low-residue acaricides. The need for a sustainable solution to the threat of the *Varroa* mite is essential for the economic viability of beekeeping and agriculture, as well as for bee health, conservation and ecosystem services. The special importance of healthy bee colonies refers to pollination as the primary benefit that humans and agriculture derive from bees. The constant education of agricultural producers, in terms of pointing out the importance of bees, and the preservation of the entire biodiversity is of exceptional importance.

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ENVIRONMENT AND SUSTAINABLE DEVELOPMENT. MECHATRONICS. OCCUPATIONAL SAFETY AND HEALTH AND FIRE SAFETY. SMART MANAGEMENT SYSTEMS. GRAPHIC ENGINEERING. DESIGN. TRAFFIC ENGINEERING. BIOTECHNOLOGY AND HEALTHCARE. MECHANICAL ENGINEERING. ECOTOURISM AND RURAL DEVELOPMENT.

RESEARCH ON THE PHOTOSYNTHESIS RATE IN THE SPECIES *SALVIA OFFICINALIS IN VITRO* AND *IN VIVO*

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Abstract: *Salvia Officinalis is an aromatic perennial plant, native to southern Europe and Asia Minor. It is cultivated as a culinary plant and as a plant of great medicinal importance, officially listed in the Pharmacopoeias of many countries around the world. Salvia Officinalis is a subshrub, originally from the Mediterranean region, with a height of 30-80 cm. The stem of this plant is erect, bushy, branched, at the base being lignified. It is covered with a grey-brown bark. The research focused on determining the photosynthetic rate in this species, using variants cultivated both in vivo and in vitro. The evaluation was carried out over a period of 49 days. For the variant cultured in vitro, we used the MS culture medium. The experimental results show significant differences between the experimental variants. Also, the processing of the results allowed us to establish the optimal technologies regarding the rate of photosynthesis both in the species cultivated in vitro and in vivo.*
Keywords: *Salvia Officinalis, in vitro*, in vivo, photosynthetic rate, medicinal plant

1. INTRODUCTION

The species is heat-loving, emerging above 10˚C, preferring hot summers and mild, short winters. On the other hand, Salvia is not picky about the type of soil, it can be found even on calcareous and sandy areas. Studies have shown that to establish the culture of Salvia, a well-cultivated land is needed. Plowing is done right after clearing the land of the previous plant, then harrowing is done in the direction of plowing [1]. Sowing is carried out in November or early spring. Care works consist of manual or mechanical weeding. In the spring, the work is carried out which consists in the removal of lignified stems, called rejuvenation work, which lead to the appearance of young shoots, with large leaves, helping to increase the harvest [2]. After the second year of cultivation, plant rejuvenation procedures are carried out in the spring, the stems are cut 8-10 cm compared to the soil. This procedure must be repeated after each year, at a distance of 10-12 cm [3]. Numerous studies have demonstrated the benefits of vitamins B1 and C, found in the composition of the leaves. The leaves of this species contain a volatile oil, represented by thuil, salven, terpenes, thujone and sabinol. We also find tannins, potassium salts, bitter principles, polyphenols, glycosides and resins. In Romania, the cultivation of *Salvia Officinalis* is a risky one, being restricted by the winter period when the temperatures are negative. In this case there is a high risk of freezing [4]. The nature of the active principles it contains and the complex chemical composition give this plant

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carminative, estrogenic, choleretic, and antiseptic properties. Studies have shown that *Salvia* has a hypoglycemic effect, a calming effect on the nervous system. Thanks to the phytoestrogenic compounds it contains, it helps balance the body of menopausal women and regulates menstruation [5]. Numerous studies have shown that this plant acts in conditions such as: hepatobiliary disorders, poor blood circulation, fights nervousness, hypertension, mental depression, hepatitis, jaundice, abdominal bloating, vascular diseases, poor blood circulation, prevents heart attack, disorders of the menstrual cycle, ovarian dysfunction, diabetes, headaches, fatigue, paralysis, asthma, chronic bronchitis, bactericidal action on Koch barium [6].
On the other hand, this plant is used as a raw material in the manufacture of detergents and fine soaps. *Sage* is included in the recipes of creams, shaving lotions and colognes. The essential oil is often used in perfumeries in combination with lavender, citrus and rose oils[7].
The photosynthesis process takes place at the level of the leaves, which is why, in this area of the plant, the substances necessary to initiate the cycle so necessary to maintain life must be transported. Carbon dioxide is captured through extremely small pores, which are called stomata [8]. Oxygen is released, at the end of the process, also through these holes. Water is absorbed through the roots and transported to the leaves through the vascular tissue system of the plant [9]. Sunlight rays are absorbed by chlorophylls - green pigments, located at the level of chloroplasts, which are the seat of photosynthesis in plants [10]. Following thorough research carried out over the last 50 years with the help of radioactively labeled carbon isotopes, it was possible to discover the mechanism thorough process by which plants synthesize organic compounds from mineral salts in the presence of aluminum and chlorophyll [11]. These researches revealed the fact that photosynthesis takes place in the form of a chain of successive reactions that require light conditions in the first stages (Robin Hill phase) and dark conditions in the following stages (F.F. Blackman phase) [12]. Devices to measure photosynthesis, based on chlorophyll fluorescence, have been in development since the early 1990s. EARS, of Delft, the Netherlands, was the first company to develop a portable instrument [13]. The plant is composed of cells, which contain a large number of green grains, the chloroplasts. In these chloroplasts there is a folded membrane, consisting of proteins and lipids, the thylakoid [14]. Embedded in the thylakoid there are clusters of several hundreds of chlorophyll-molecules, the so-called photosystems [15]. These provide the energy for the photosynthesis reaction. They function as antennae that capture light particles or photons. Photosystems absorb mainly blue and red light, while green light is scattered.

2. MATERIAL AND METHOD

Photosynthetic capacity was determined with the EARS Plant Photosynthesis Meter (PPM) which measures the photosynthetic light utilization of plants. The measurement is based on chlorophyll fluorescence, a very weak optical signal emitted by the plant, but which can be detected by the machine. Due to its light weight, the instrument is very suitable for use in the laboratory and in the field. In addition, long measurement series can be performed automatically. For this reason, PPM has a wide range of applications in research, education and practice. The plant material for "*in vitro"* and "*in vivo*" multiplication was represented by the seeds of the medicinal plant species *Salvia Officinalis.*

3. RESULTS AND DISCUSSIONS

The F test shows that both the in vivo or vitro culture mode and the time period have a very significant effect on the photosynthesis rate [$p<0.001$]. There are very significant differences between the ratings of each factor, and the interaction of the factors is insignificant (Table 1).

Table 1. Analysis of variance on the effect of culture mode and determination period on photosynthesis rate in *Salvia Officinalis*

The source of variation	GL	SP	S2	Sample F	
Total	17	1366.278			
Culture mode	1	180.500	23.8897		0.0004 ***
Determination period	2	1067.111	533.556	70.6176	0.000***
Culture mode × Determination period	2	28.000	14.000	1.8529	0.1989 ns
Error	12	90.667	7.556		

Coefficient of variation: 4.34%

According to the coefficient of variation, it follows that the rate of photosynthesis has a small variation, cv<10% [cv = 4.34%]. Regarding the effect of the culture mode on the rate of photosynthesis in Salvia Officinalis, it can be seen from the data in Table 2 that the rate of photosynthesis varied from 60.2% in the in vitro mode to 66.6% in the in vivo culture mode. The result obtained in the in vitro culture mode having a very significant negative statistical assurance.

Table 2. Experimental results on the influence of culture mode on photosynthesis rate in *Salvia Officinalis*

Culture mode	Mediate photosynthesis rate [%]	Difference from the witness	The meaning
Culture mode 1 – *vivo*	66.6	mt	
Culture mode 2 – *vitro*	60.2	-6.3	000

DL 5% = 2.82% DL 1% = 3.96 DL 0.1% = 5.60

Table 3. Experimental results on the influence of the determination period on the photosynthesis rate in *Salvia Officinalis*

Determination period (days)	Mediate photosynthesis rate [%]	Difference from the witness	The meaning
Period 1 - 21 days	54.8	mt	-
Period 2 - 35 days	61.8	7.0	***
Period 3 - 49 days	73.5	18.7	***

DL 5% = 3.45% DL 1% = 4.85 DL 0.1% = 6.85

From the point of view of the influence of the determination period on the photosynthesis rate, values between 54.8%-73.5% were obtained. Compared to the control, the photosynthesis rate registered very significant increases, an increase of 7.0 at 35 days and 18.7% at 49 days, respectively.

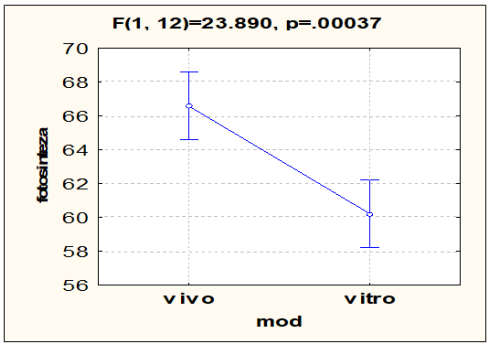

Figure 1. Influence of in vivo or *in vitro* culture mode on photosynthesis rate in *Salvia Officinalis*

The in vivo culture mode is clearly superior to the *in vitro* culture mode in terms of the rate of photosynthesis.

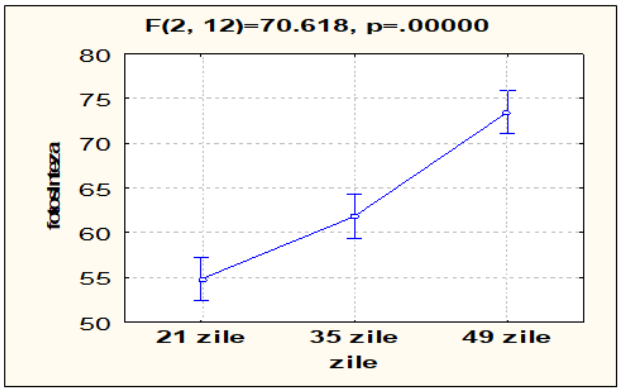

Figure 2. Influence of time on photosynthesis rate in *Salvia Officinalis*

The analysis of the photosynthesis rate over time highlights the fact that it is between 54.8 - 73.5%. At 49 days and at 35 days, the highest percentage of photosynthesis resulted, being far superior to the 21-day period.

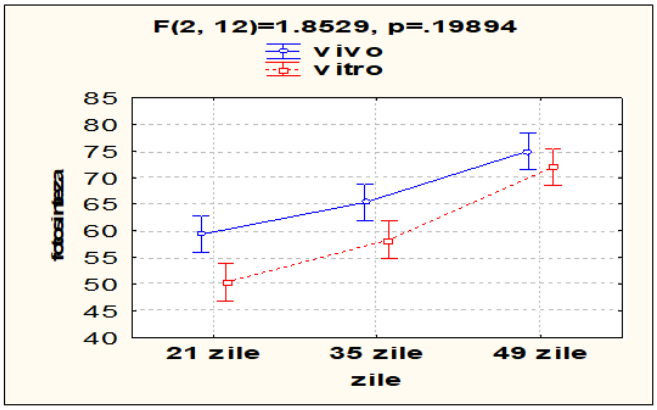

Figure 3. Influence of the interaction of culture mode and time period on photosynthesis in *Salvia Officinalis* species

Regardless of the time steps, the highest percentage of the photosynthesis rate was recorded in the in vivo culture mode. At 49 days, the values obtained on the two modes of in vivo and in vitro culture are similar, that is, they belong to the same homogeneity class.

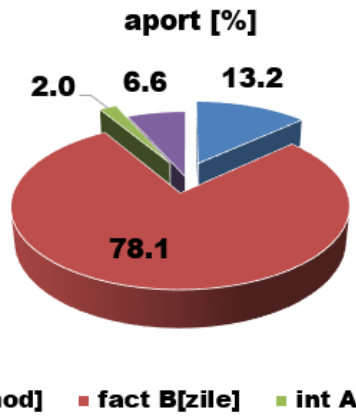

Figure 4. Contribution of culture mode factors, time period and their interaction to photosynthesis rate in *Salvia Officinalis*

4. CONCLUSIONS

In conclusion, the in vivo culture mode is superior to the *in vitro* culture in terms of the photosynthesis rate, a percentage of 66.6%, compared to 60.2%.
On the other hand, the best results were obtained during the period of determining the photosynthesis rate at 49 days, in a proportion of 73.5%, followed by the time period of 35 days with a percentage of 61.8%. Regarding the rate of photosynthesis, at the determination period of 21 days we had the lowest results, a percentage of 54.8%.
The culture method contributes to the photosynthesis rate in proportion of 13.2%, the factor represented by the number of days on which the determinations were made in proportion of 78.1%, and their interaction with 2.0%

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APPLICATION OF NEW TECHNOLOGIES FOR ADAPTATION TO CLIMATE CHANGES IN AGRICULTURAL PRODUCTION– A REVIEW

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Abstract: *Climate change seriously threatens food security worldwide, causing extreme weather conditions and reducing agricultural productivity. Increased temperatures and greenhouse gas emissions are the main drivers of these changes. While increased CO_2 concentration can enhance plant growth, elevated temperatures and other factors offset these benefits. Therefore, it is essential to consider adaptation measures, including the development of climate-tolerant crop varieties and innovations in agricultural practices to preserve food security in a changing climate. Smart agriculture involves the use of advanced technologies such as climate, soil, and plant monitoring sensors, IoT devices that enable the connectivity of various aspects of agricultural production, and data analytics for decision-making. These technologies enable farmers to better understand environmental changes and respond quickly to unpredictable climatic conditions.*
Keywords: climate, climate change, agriculture, adaptation strategies, biodiversity

1. INTRODUCTION

Global climate change has reached a serious threat level for global food security and the nutrition of the world's population. The effects of these changes are becoming increasingly apparent, jeopardizing the sustainability of agriculture and food supply stability. The main factor responsible for this situation is the increased emissions of greenhouse gases, leading to global warming and the greenhouse effect. Rising surface temperatures on Earth have a range of serious consequences, including extreme weather events like droughts, floods, and storms, as well as altered precipitation patterns. These climate factors continually reduce the productivity of various agricultural crops, resulting in lower yields and reduced food quality. Increased temperatures also shorten the growing seasons, directly impacting crop yields. Global temperatures are expected to continue rising, leading to more frequent and prolonged heatwaves, further negatively affecting agricultural production [1,2,3,4].

Changes in temperatures and precipitation patterns have a significant impact on planting, crop yields, and phenological characteristics. Climate change and its unpredictable variability present real threats to agriculture and global food security. The increased concentration of CO_2, a significant greenhouse gas, has a complex impact on agriculture. On the one hand, it can accelerate plant growth and increase productivity through enhanced photosynthesis. However, these benefits are offset by increased temperatures, which lead to higher plant respiration, increased

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evapotranspiration (loss of water through plants), increased pest occurrences, changes in weed flora, and shortened crop durations. All these changes make agriculture more vulnerable to climate impacts. In light of these challenges, it is clear that concrete steps need to be taken to mitigate the negative effects of climate change on agriculture and food security [5, 6].

A key approach in this context is the development of heat-tolerant crop varieties and the implementation of innovations in existing agricultural practices. These adaptation strategies play a crucial role in reducing the harmful consequences of climate change on global food security and are essential steps towards preserving food supply stability in a changing climate. The agricultural sector faces serious challenges in the context of the need to adapt to climate change. With the expected growth of the world's population to nine billion by 2050, there is a need to ensure an adequate food supply and other basic needs. However, limited arable land for expansion and increasingly frequent extreme weather events due to climate change pose significant threats to agriculture. Various technologies and practices have been developed worldwide to facilitate agriculture's adaptation to climate change. These include improved weather forecasting, water conservation, drip irrigation, sustainable soil management, livestock improvement, and changes in crop varieties and planting systems. Some of these approaches require financial investments, while others require changes in practices and increased awareness among farmers. Technological strategies for adapting to climate change in agriculture are based on agroecological principles and encompass diverse scientific technologies from climatology, biology, and agronomy. They also focus on social and institutional capacity-building processes for adaptation. These technologies include climate change planning, sustainable water and soil management, sustainable crop and livestock management, sustainable agriculture systems, capacity building, and the involvement of relevant stakeholders. Instead of technologies that tend to homogenize the natural environment and agricultural production, those that promote diversity and environmental conservation are preferred. Most of these technologies are already known and applied, but they are adapted based on specific conditions and needs caused by climate change. Agroecology as a multidisciplinary approach, explores the sustainability of agricultural systems and promotes biodiversity conservation. This approach provides a useful framework for selecting and implementing technological solutions in agriculture, considering a comprehensive assessment of factors that affect their efficiency and ecological integration. Making informed decisions about appropriate technological solutions requires taking into account specific local contexts, including social and cultural norms, to achieve the optimal impact on system sustainability. When it comes to adapting agriculture to climate change, it is especially important to emphasize the preservation of water resources and the promotion of sustainable irrigation methods. Introducing improved plant genetic varieties, precise monitoring of weather conditions, and the application of precision agriculture play a crucial role in addressing the challenges brought about by climate instability. Through collaboration between farmers, researchers, and authorities, an integrated approach can be developed to ensure the resilience of agriculture to climate change and contribute to global food security. Adapting to climate change in agriculture requires a systematic approach that encompasses various technological and social aspects to achieve sustainable solutions [7].

Impact translates from climate to the environment, to the productive sphere, to economic and social dimensions, bringing a range of additional risks on availability of food, on access to food and utilization of food, as well as on the stability of these characteristics, for both farm and non-farm households [7].

2. THE IMPACT OF CLIMATE CHANGE ON AGRICULTURE AND ADAPTATION STRATEGIES

Climate change has a significant and profound impact on the agriculture sector worldwide. Increasing global temperatures, altered precipitation patterns, and more frequent extreme weather events pose serious challenges to food producers. Maintaining the sustainability of agriculture and global food security requires the implementation of diverse adaptation strategies. These strategies need to be quantified using modeling approaches to better understand and predict the potential

effects of climate change on agriculture. To address these challenges, farmers and scientists are collaborating to develop adaptation strategies. This includes adjusting planting dates to maximize crop potential and reduce losses due to unfavorable weather conditions [5]. Optimal plant densities are also being researched, as higher plant density can offset yield losses. Genetic selection and technology play a crucial role in adapting agriculture to climate change. Developing crop varieties that are tolerant of higher temperatures, drought, and unpredictable rainfall becomes imperative. Scientists are focusing on selecting genotypes that better withstand stress and developing genetically engineered varieties that are more resilient to climate change. Innovations in agriculture are also of vital importance. Precision agriculture, the use of satellite monitoring, and automated irrigation systems can significantly optimize resource utilization and reduce food production losses. Given the changing climate conditions that lead to reduced water availability for agriculture, preserving water resources is imperative. Efficient irrigation systems and water recycling become key to sustainable food production. Furthermore, precise nutrient management can enhance crop resilience through improved fertilizer efficiency and reduced greenhouse gas emissions. Farmer education plays a crucial role in successfully addressing climate change. Farmers need training on the latest techniques and practices to better cope with changes and manage their resources more efficiently. At the policy and regulatory level, governments and international organizations must recognize the urgency of the issue and adopt policies that support sustainable agriculture and the reduction of greenhouse gas emissions. Addressing climate change in agriculture requires a comprehensive approach and collaboration across different sectors. Preserving the future of agriculture and global food security demands thoughtful and effective measures to safeguard our planet and ensure an adequate food supply for future generations.

3. PRECISION AGRICULTURE AND ITS ROLE IN CLIMATE CHANGE ADAPTATION

Precision agriculture plays a crucial role in adapting to climate change. With changing climate conditions, farmers face increasing challenges in preserving crop productivity and sustainability. This modern agricultural practice utilizes advanced technology, including GPS, sensors, drones, and satellites, to enable precise resource management such as water, fertilizers, and pesticides. This approach reduces resource overuse and economic costs, which becomes increasingly important in the context of growing climate change unpredictability. Several key ways in which precision agriculture can help in adapting to climate change include: GPS (Global Positioning System, sensors, drones, satellites, crop adaptability, early warning of damage, sustainable practices, precision agriculture [8].

The combination of these technologies allows farmers to better understand and respond to climate change, increasing agriculture's resilience to extreme weather conditions, droughts, floods, heatwaves, and other challenges brought by climate change.

4. BIODIVERSE AGRICULTURE, OR "ECOLOGICALLY INTENSIVE AGRICULTURE"

Biodiverse agriculture, also known as "ecologically intensive agriculture," is a key aspect of modern agriculture focused on the sustainable preservation of biodiversity within agricultural ecosystems. Like natural ecosystems, agricultural ecosystems depend on the diversity of plant and animal species to achieve sustainable productivity, fertility, and resilience to external changes and disruptions. The concept of biodiverse agriculture relies on a high level of biological diversity within agricultural systems to achieve sustainable productivity and resilience, while also contributing to environmental protection and reducing the need for chemical agents. This approach plays a crucial role in addressing current climate changes as it promotes ecosystem services and reduces the need for chemical agents. However, while this concept is of fundamental importance, its complexity has not yet been fully understood, making its regulation challenging. In the context of ensuring global food supply, careful consideration should be given to protecting valuable ecosystems and their biodiversity. In the food production sector, priority should be given to the

restoration and preservation of ecosystems, requiring long-term planning and fundamental changes in economic, production, and development strategies. It is also necessary to restructure food systems to achieve a neutral or positive impact on the environment while ensuring healthy nutrition and food security. Low-impact strategies must become a priority.

Agroecology, as an approach that promotes sustainable agricultural production and biodiversity conservation, provides a useful framework for selecting technology adapted to local needs. In making informed decisions about the appropriate technological options, it is essential to consider local contexts, including social and cultural norms. To support the decision-making process, the application of a community-based adaptation (CBA) framework is proposed, involving various stakeholders and enabling participatory planning, monitoring, and implementation of adaptation activities. Additionally, setting criteria for prioritizing adaptation technologies, taking into account ecological sustainability, access to climate change information, water, carbon, and nutrient cycles, economic aspects, cultural diversity, scaling, and institutional integration. Adaptation in agriculture requires a comprehensive approach, encompassing technical and social aspects to preserve productivity while protecting the environment. An impact assessment of climate change provides a scientific basis for the development of adaptation strategies that can mitigate the negative effects of climate change on agricultural crops. Biodiversity, including genetic diversity, species diversity, and ecosystem interactions, enhances ecosystem resilience to changing conditions and environmental stresses. Genetically diverse populations and species richness have a higher potential for adapting to climate change. Therefore, the use of native and locally adapted plants and animals is promoted, as well as crop and livestock variety selection.

5. AGRICULTURE ADAPTED TO CLIMATE CHANGE

In order to effectively address the challenges of climate change in the context of agriculture, it is necessary for farmers to adopt an approach that involves the development or transformation of their agricultural systems. This approach involves replacing old procedures and practices with new agricultural methods and techniques that are in line with the requirements of climate change [9,10]. Agriculture adapted to climate change (ACC) can be described as a comprehensive approach to agricultural management aimed at achieving sustainable growth in agricultural productivity and income, addressing food security and climate change issues, directing agricultural development to achieve climate change mitigation and adaptation goals, and efficiently managing agricultural growth [11,12,13,14,15]. ACC encompasses a wide range of adaptive measures and practices aimed at reducing the impact of climate change, sustainably increasing agricultural productivity (in the context of food, fibers, and fuels production), reducing greenhouse gas emissions, increasing agricultural resilience to climate change, and promoting national food security and development goals [12,13,16,17]. ACC doesn't only address ecological aspects but also takes into account social and economic aspects to achieve comprehensive benefits and reduce compromises, including institutional, political, and technological practices [15]. ACC activities involve a combination of traditional agricultural practices that have evolved over time and innovative agricultural technologies that are widely recognized and promoted. This includes approaches such as agroforestry, conservation agriculture, biodiversity-based agriculture, water management, and sustainable land management practices or technologies [15,18,19]. At the farm level, the implementation of ACC measures depends on the socio-economic environment influenced by institutional patterns, resource availability, and climatic conditions. Using different methods allows farmers to synergize ACC practices and technologies, increasing farm productivity while addressing interconnected challenges [13,19,20]. While it is desirable to achieve all the set ACC goals, in the real world of agriculture, compromises between productivity, sustainability, and climate change mitigation will be necessary. Today, the concept of ACC plays a crucial role for many organizations dealing with the intersection of climate adaptation and agriculture. ACC provides guidance for identifying successful models of agricultural production among different approaches. Any agricultural technology that surpasses conventional practices can contribute to achieving ACC goals

and be recognized as climate-sustainable [21]. Currently, existing directions for ACC development include (i) the application of advanced internet technologies to ensure information security in agriculture; (ii) the improvement of crop structures and management methods; (iii) the provision of "Internet + weather" services; (iv) the improvement of the quality of agricultural services; and (v) the development and application of agricultural weather disaster insurance [12]. These concepts and strategies will enhance environmental protection, support sustainable agricultural progress, and reduce the impact of climate change.

Climate change represents a significant and serious threat to global food security and agricultural sustainability. Rising temperatures, altered precipitation patterns, and increased greenhouse gas concentrations significantly affect plant productivity, reducing yields and food quality. These effects are becoming increasingly evident and are expected to continue in the future. To preserve global food security, urgent measures to adapt to climate change are necessary. This includes developing crop varieties tolerant to high temperatures and implementing innovations in agricultural practices to mitigate the negative effects of climate change on food production. It is also important to work on reducing greenhouse gas emissions to slow down global warming and mitigate the climate impacts on agriculture. Sustaining the world food supply system requires a multidisciplinary approach involving farmers, researchers, government and international organizations to develop strategies and solutions to address this serious threat and ensure an adequate and safe food supply for the growing global population [22, 23].

6. CONCLUSION

Climate change poses a serious threat to the agriculture sector and global food security. Rising temperatures and increased CO_2 concentrations in the atmosphere can have complex effects on plant growth and productivity while simultaneously increasing the number of pests and weeds. Additionally, the microbial population in the soil can also be affected by climate change, which can impact the availability of nutrients for plants. Climate-smart agriculture is becoming crucial for adapting to these new conditions, but it requires innovations and changes in agricultural practices. It's also important to understand the economic consequences of climate change in agriculture, including the costs of adaptation and reduced yields. To address these challenges, serious global steps are needed to reduce greenhouse gas emissions and slow down temperature rise. Additionally, local and regional initiatives for adapting to climate change in agriculture are becoming increasingly important to preserve food security and sustainable agricultural production.

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INFORMATION SYSTEMS IN ORGANIC AGRICULTURE – A REVIEW

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Abstract: *Organic agriculture is becoming an increasingly significant component of the global food system, with a focus on environmental sustainability and product quality. Information systems and technologies play a crucial role in supporting organic production, environmental conservation, and the production of safe and healthy safe food. The application of precision agriculture, utilizing cutting-edge technological systems, enables pest and disease monitoring and management, efficient water and energy management, digital product identification, the use of Geographic Information Systems (GIS) for crop planning, and blockchain technology for supply chain transparency. Through these applications, information systems and technologies significantly contribute to reducing the negative environmental impacts of agriculture, increasing productivity, and ensuring healthy safe food with greater nutritional benefits in organic farming. This symbiosis of science and technology in organic agriculture helps create more sustainable agricultural systems that can meet the needs of current and future generations.*
Keywords: organic agriculture, information systems, environmental sustainability, healthy food

1. INTRODUCTION

The dynamics of global population growth and the need to ensure a larger quantity of high-quality food, combined with the imperative of preserving the environment and resources, are key factors shaping the development of technologies in the field of organic agriculture. Organic agriculture is a holistic production management system, which promotes and enhances agro-ecosystem health, including biodiversity, biological cycles, and soil biological activity [1-10]. Faced with the challenges of the modern era, the agricultural sector must address a dual task: increasing productivity and ensuring long-term sustainability. It is evident that Information Technology (IT) plays a pivotal role in enhancing productivity in organic agriculture, with the ultimate goal of benefiting agricultural producers [11-15]. Specifically, the application of precision agriculture, using cutting-edge satellite-guided and automated technology systems, along with Geographic Information Systems (GIS), significantly contributes to yield improvement. Simultaneously, these technological advances promote efficient resource utilization, thereby reducing negative environmental impacts. In this light, the integration of new technologies into organic agriculture becomes essential for enhancing the production of safe and healthy safe food and represents the potential for sustainable sector development.

Contemporary trends in information technology development offer organic agriculture a unique opportunity to improve its operations, increase production efficiency, and minimize the negative impact on the environment. Given the specific requirements for producing environmentally friendly

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products to meet the global demand for organic agricultural products, the main direction of its development lies in the introduction of innovative methods and technologies into the production process.

Despite global challenges in the agricultural sector, the prospects for organic production development through digitization are promising. The use of information systems in organic agriculture is driven by the need to increase its efficiency and manageability, improve product quality, and align with the requirements of organic agriculture standards in the green economy. They enable the automation of many routine processes and informed decision-making [16].

2. APPLICATION OF INFORMATION TECHNOLOGY FOR EFFICIENT RESOURCE AND PROCESS MANAGEMENT IN ORGANIC AGRICULTURE

Organic agriculture represents a specific branch of agricultural production that requires a special management system to ensure sustainable and environmentally-friendly production. The implementation of Enterprise Resource Planning (ERP) and Customer Relationship Management (CRM) systems can significantly enhance the efficiency of managing all aspects of organic agriculture, including the management of material and financial resources. One of the key systems for managing organic agriculture is FarmERP. This system encompasses a range of functions crucial for organic farms, including yield tracking and analysis for various crops. These systems allow farmers to gain a better understanding of yield dynamics and make informed decisions. Additionally, FarmERP includes crop planning systems, taking into account crop rotation and their mutual location, which is crucial for preserving soil health. Furthermore, the system provides soil condition monitoring and offers agronomic recommendations for the care of different crops, considering optimal sowing times and agronomic operations. FarmERP also includes cost tracking systems, essential for monitoring the costs of major material resources such as seeds, fertilizers, and fuel. FarmLogs is another important cost management tool in organic agriculture. This system allows tracking all costs associated with organic production, including fertilizers, seeds, labor, fuel, and other factors. It also enables monitoring of soil conditions, such as pH values, moisture, and nutrient levels. Based on this data, FarmLogs provides recommendations based on successful agronomic practices, taking into account natural, climate, and weather conditions, as well as crop characteristics. ERP systems like SAP ERP provide a comprehensive solution for automating business processes in organic production. These systems enable the planning of agricultural tasks and resources, efficient management of business operations, and the optimization of the overall business of organic farms. Additionally, the information system FarmOS supports farmers in managing organic production. This system includes crop and crop rotation planning, weather monitoring, financial accounting, and nutrient management. FarmOS also allows tracking mineral and organic fertilizers, organizing pest control, and provides documentation necessary for compliance with organic agriculture standards. The implementation of ERP and CRM systems, such as FarmERP, FarmLogs, SAP ERP, FarmOS, and others, plays a crucial role in optimizing organic agriculture management. These systems provide better control over all aspects of production, help reduce costs, improve product quality, and contribute to the sustainability of organic agriculture [17-19].

3. ADVANCED INFORMATION SYSTEMS FOR ENSURING COMPLIANCE WITH ORGANIC AGRICULTURE STANDARDS

In the modern context, the use of information systems has become a key component in achieving compliance with stringent organic agriculture standards. These standards encompass various aspects, including the production, labeling, and certification of organic products, as well as requirements for ecological and socially sustainable agricultural practices. In this context, digital solutions play a crucial role in facilitating the compliance process for farmers and providing them with tools to monitor and document all relevant aspects. Information systems enable farmers to

track all stages of organic product production, starting from agricultural activities such as the use of fertilizers, pesticides, and cultivation techniques that comply with organic standards. They allow for efficient monitoring of the flow of raw materials and products throughout the supply chain, contributing to transparency and the reliability of the organic chain. One of the key aspects of information systems for compliance with organic agriculture standards is simplifying the certification process. These systems enable farmers to collect, organize, and store all the necessary information and documentation required for certification. This includes data on inputs used, tracking production processes, and records of previous annual production cycles. All this information streamlines the certification process and facilitates effective communication with certification bodies. Additionally, information systems provide farmers with tools to monitor compliance with environmental and social standards [20-24].

4. IMPLEMENTATION OF SCIENTIFIC INFORMATION SYSTEMS FOR MONITORING AND MANAGING RISKS IN ORGANIC AGRICULTURE

Scientific-level information systems provide essential tools for monitoring and managing risks in the context of organic agriculture. These systems enable farmers to effectively track variables such as climate change, plant and animal diseases, as well as soil and water quality. Through this comprehensive data analysis, farmers can identify potential risks and take appropriate measures to minimize crop losses and enhance product quality. Information systems for risk monitoring and management in organic agriculture can include various components, including meteorological stations to monitor weather conditions, automated irrigation systems to reduce moisture-related risks, disease control information systems, and market analytics tools to optimize resources and reduce market risks. Integrating these information systems into a unified platform allows farmers to efficiently collect, analyze, and predict risks, enabling them to make strategic decisions to improve the sustainability and stability of organic agriculture [25, 26].

5. INFORMATION SYSTEMS ENABLING STATISTICAL DATA MANAGEMENT AND BIG DATA ANALYSIS

This process encompasses all relevant aspects of agricultural production and is based on the application of precision agriculture systems, including the use of GPS technology, field sensors, technology-equipped machinery, storage, and satellite imagery. Integrated systems for monitoring the health and movement of animals, as well as physiological parameters, are also included. This comprehensive set of data includes a significant amount of unstructured information that is crucial for making informed decisions and optimizing agricultural processes. An example of such a system is AgSquared, a software platform that is entirely based on cloud technologies. This platform enables collaboration among various stakeholders in the agro-industry, including managers, agronomists, tractor operators, and farm workers. This approach provides constant access to key information, allowing for improvements in productivity, profitability, sustainability, and efficiency at any time and in any location within the agricultural sector. [27].

6. LAND MONITORING INFORMATION SYSTEMS

Land monitoring information systems are crucial in modern agriculture. They enable precise monitoring of soil fertility and quality, helping farmers choose suitable crops and apply optimal cultivation methods. The use of digital technologies enhances the productivity and sustainability of agricultural systems while preserving the natural balance. These systems allow for precise control of nutrients in the soil, reducing the use of fertilizers. They also improve product quality and reduce the risk of diseases and drought. Digital land monitoring systems provide rapid information on soil health, aiding in crop protection. These systems also support organic agriculture and the preservation of the natural balance by measuring various soil parameters [27].

7. INFORMATION SYSTEMS FOR PLANT CONDITION MONITORING

Organic agriculture requires the monitoring and control of plant conditions to achieve healthy growth and a good yield. Information systems play a crucial role in this process. The system for monitoring and controlling soil moisture uses sensors to measure moisture and provides irrigation recommendations. Additionally, a system for monitoring soil nutrients is important for the sustainable use of nutrients. These systems monitor the content of nitrogen, phosphorus, potassium, and other elements, recommending doses of organic fertilizers. Information systems are also used for early detection of pests and diseases through sensors, including infrared cameras or pest detectors. This allows for rapid interventions without the need for pesticides. Data collected from these systems are processed and sent to farmers, enabling them to optimize processes and improve productivity in organic agriculture. Overall, information systems enable the early detection of problems in organic agriculture, thereby improving yields and product quality [28].

8. INFORMATION SYSTEMS FOR ANIMAL CONDITION MONITORING

In organic agriculture, information systems for monitoring animal conditions play a crucial role. These systems encompass various technological solutions for precise monitoring and management of animal health and movement. One of the key technologies is the RFID identification system, which uses microchips embedded in animals. These microchips enable tracking animal movement and essential health parameters such as body temperature and pulse. Such monitoring allows farmers to effectively track each animal, which is essential for reproduction and rapid response to health issues. In addition, there are systems for monitoring animal health status, which serve to prevent diseases and the spread of infections among animals. These systems use databases of diseases and data analysis tools. Furthermore, feed control systems play an important role in ensuring proper animal nutrition while adhering to organic agriculture standards. These systems monitor and manage food and additives usage. There are also systems for monitoring physiological parameters such as hormone levels, pheromones, and body temperature. These data are crucial for determining the optimal breeding times and the overall health of animals in organic agriculture. All of these information systems enable farmers to efficiently manage farms, reduce negative environmental impacts, and adhere to organic agriculture standards [29].

9. COMMUNICATION INFORMATION SYSTEMS

Organic agriculture is a certified system, well controlled by authorities, so it would a strategy for gathering and analyses of data could be of great value to reinforce the implementation of organic agriculture as a health indicator, in any country or region, where organic agriculture certification already exists. Information systems play a crucial role in improving communication among various stakeholders in organic agriculture, including farmers, consumers, and other interested parties. These systems contribute to building more reliable and transparent relationships among participants in the organic market. By using information systems, farmers are facilitated in tracking changing market demands and consumer needs, allowing for production adaptation. Additionally, information systems provide consumers with access to essential information about the origin and quality of products, which fosters greater trust in organic products. Transparency in the supply chain becomes crucial for consumers and is achieved through the use of modern information technologies. Information systems enhance communication and collaboration among all stakeholders in the organic market, ensuring better sustainability and product quality, while also promoting transparency and trust in organic agriculture [30].

10. CONCLUSION

The integration of information technology (IT) into organic agriculture brings about profound transformations and a range of key elements that shape this change. On one hand, there is the potential for significant improvement in the production of organic food and environmental preservation. On the other hand, there are certain challenges that require careful consideration. The advantages of this integration include increased productivity, reduced negative environmental impacts, the production of high-quality food, and better farm management. These factors contribute to increased profitability and long-term sustainability of organic agriculture. The challenges that accompany this change include high initial costs for implementing IT systems, the need for farmer training, regular system maintenance, and data privacy and security concerns. These challenges can be barriers, especially for smaller farms and rural areas. In essence, the integration of IT into organic agriculture has the potential to significantly enhance this branch of agriculture, but it requires careful planning and management to maximize the benefits and minimize the drawbacks. This process represents a critical point for the long-term development of organic agriculture in line with the requirements of modern society and environmental preservation.

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RAISING THE VINEYARD - PRUNING AND AGRO-TECHNICAL MEASURES: A REVIEW

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Abstract: *The successful raising of a vineyard implies the knowledge and use of knowledge from all areas of viticultural science and technique, but also knowledge from other areas, from climatology, economics to the market. The choice of variety for establishing a vineyard depends on a large number of factors such as: climatic conditions, soil conditions, market requirements, but also the wishes of investors. Before planting a vineyard, it is necessary to carry out extensive soil preparations: soil fertility improvement, plowing the land and soil disinsection. The period of establishing a vineyard lasts at least three years. In this period special agrotechnical measures are carried out with the aim of caring for young shoots and forming the planned cultivation form. Regular pruning is the most important ampelotechnical measure that contributes to the establishment of a favorable relationship between the growth and development of individual organs of the vine, as well as between the yield and grape quality. Important agrotechnical measures for vineyard maintenance include and soil maintenance, fertilization, irrigation, protection against diseases and pests and harvest of grapes. As vineyards are raised for a longer period of exploitation, the goal of this work is to look at all the factors that affect production and, accordingly, to carefully plan each segment of vineyard raising and maintenance.*
Keywords: Viticulture, Cultivation System, Management Method

1. INTRODUCTION

Thanks to the long history and tradition, favorable agro-ecological conditions and soil characterized by good physical and chemical properties, viticulture has always been an important branch of agriculture in Serbia. According to the most recent regionalization, wine-growing Serbia is divided into 3 regions that represent geographical units and 22 regions [1]. During its development, the viticulture and wine industry went through crisis and difficult, but also glorious periods. According to the data of the Republic Institute of Statistics, of the over 100,000 ha of vineyards that Serbia had in the eighties of the 20th century, now Serbia has 20,466 ha under vines and annually produces around 30 million liters of wine. Although there is a significant decrease in the area under vineyards in comparison to the mentioned period, it is positive that new plantings are being raised with certified, clonal selection planting material and that there is a trend of increasing the number of wines with protected geographical origin. Of the total production area, grape varieties for wine production with geographical origin are grown on only 2065 ha [2]. As far as the assortment is concerned, foreign international varieties such as: Cabernet Sauvignon, Chardonnay, Sauvignon Blanc, Pinot Noir, Muscat Hamburg, Italian Riesling dominate. However, in recent years, the trend of growing international varieties is decreasing, while the growing of unique and autochthonous Serbian varieties such as: Prokupac, Tamjanika, Grašac, Seduša is increasingly important [3]. As vineyards are raised for a longer period of exploitation (economic profitability 25 years), the goal of this work is to look

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at all the factors that affect production and accordingly carefully plan each segment of vineyard raising and maintenance.

2. RAISING THE VINEYARD

2.1 Environmental conditions

The successful raising of a vineyard implies knowing and using knowledge from all areas of viticulture science and technology, but also knowledge from other areas, from climatology, economics to the market [4]. Weather conditions and soil type are important factors in preparing the plot for planting. The economic importance of wine production in a certain territory is one of the most effective motives for protecting the typicality of wine [5, 6]. The vine has certain requirements in terms of climate, and a good knowledge of the climatic conditions of the locality where it is intended to be grown is necessary. Light, heat, humidity (rain, fog, dew, snow, etc.) and winds, as the main factors of climate, each in their own way affect the success of growing vines. The vine has high heat requirements. It is successfully cultivated in regions where the average annual temperature is from 9°C to 13-14°C. During the dormant period, well-ripened shoots tolerate the cold well, but the differences between varieties are very large. Each phase in the life of the grapevine takes place in certain thermal conditions, that is, when the average daily temperatures reach a certain level. Thus, in our country, the initiation of juices starts at 8-10 °C, the initiation of buds at 10-12 °C, flowering at about 18 °C, and the ripening of grapes at about 20-30 °C. Temperatures lower than 0 °C negatively affect the vine plant, depending on its age during the growing season. Active buds die already at -3 °C, shoots at -1 °C, leaves and bunches at -3 °C, winter buds at -20 °C, and old vine at -30 °C [7]. However, too high temperatures can have a negative impact on the cultivation of vines, especially in recent decades due to global warming. In the wine industry, various technological solutions are being developed to mitigate the negative effects of current global warming in order to obtain wines with a lower alcohol content [8].

The vine is a plant of the sun, but it also uses diffused light very well. Well-lit vines are healthier, grapes on them ripen faster, berries are more resistant, accumulate more sugar. The better use of light is influenced by the choice of row direction, cultivation form, pruning, green operations and other phytotechnical measures [1]. The vine is considered to be relatively drought tolerant. The amount of precipitation of 550-700 mm is generally sufficient for the normal growth of the vines. Where temperatures are higher and precipitation is lower, vineyards can be grown successfully only through the use of irrigation [1]. There are a lot of vineyards in the plains in the world, but the vine is primarily a plant of sloping terrain. Top quality wines are most often obtained from grapes from vineyards on sloping sites [4]. Exposure plays a significant role in the ripening of grapes. In the northern hemisphere, the most favorable are southern, southwestern and southeastern exposures.

Soil is one of the most important factors of wine quality. Healthy soils form the basis of sustainable viticulture, where soil characteristics directly affect the quantity and quality of wine [9]. Terroir can be defined as the interaction of all the characteristics of the ecosystem in a given place that influence the phenotype of the crop, including vines (grape varieties and rootstock), climate and soil [10]. Winegrowers in geographically defined production areas attach special importance to the preservation of soil quality, adding to thus adding value to the wine [9]. Hard and cold soils are not suitable for growing vines, because vines do poorly on them and produce grapes and wine of poor quality. For normal development and regular fruiting, the vine requires a humus content of about 3% in the root zone, a phosphorus content of 15-30 mg 100 g^{-1} of soil, potassium in the range of 20-60 mg 100 g^{-1}, and magnesium 10-20 mg 100 g^{-1} of soil [11].

The choice of variety for establishing a vineyard depends on a large number of factors such as: climatic conditions, soil conditions, market requirements, but also the wishes of investors. In addition to the selection of the grape variety, great attention should be paid to the selection of the rootstock. Considering our ecological conditions and soil characteristics, the varieties should be grafted on*Berlandieri X Riparia* [7].

2.2 Raising the vineyard

Before planting a vineyard, it is necessary to carry out extensive soil preparations. High-quality soil preparation involves more complex operations in terms of improving the mechanical and chemical properties of the soil [1]. Adequate fertilization, precisely calculated, should match the cultivated crop as much as possible. Deep plowing is done after spreading fertilizers in autumn at least three months before planting [12]. The correct arrangement of the land area is very important for the rational organization of production in viticulture. These include: determination of plots and roads, planting distance, row direction and planting schedule. The arrangement of the land area depends on: the biological requirements of the vines, the size, position and relief of the surface for the vineyard, as well as on the mechanization that will be used during the exploitation of the vineyard [7]. The distance between planting vines is determined by the biological requirements of the vines, the existing machinery and the specific cultivation form. In practice, planting with a distance of 2.7-3.0 x 0.8-1.0 m for individual or 2.7-3.0 x 1.6 m for planting coppice in pairs is most often used. It is considered that the ideal direction of the rows in the vineyard is north-south, but this direction is deviated from: if the plot is narrow and long, if the plot is on sloping ground and in regions where dominant winds blow. The length of the rows in the vineyard should be 100-120 m, maximum up to 200 m.
In our climate, vines are usually planted from autumn (end of November) to spring (mid-April). The best way of planting is planting with a water planter - hydrobur. A very effective method of raising vineyards, which is increasingly used today, is mechanical planting with the help of laser or GPS guidance. The planting depth is 35-40 cm, where the junction should be 3-4 cm above the ground. Only first-class vine grafts or scarified cuttings can be used for growing vineyards. Before planting, it is necessary to check the correctness of the grafts and use only first-class grafts. In recent times, the top parts are paraffinized, as a measure of protection against drying out. The root of the cuttings should be shortened to a length of 8-12 cm for the classic method of planting, or to 2-3 cm for planting with a hydrobur. One of the strongest shoots is cut to 1-2 visible winter buds, while all other shoots are removed. After planting, it is necessary to additionally close the holes with earth in order to reduce the drying of the moisture around the seedling.
A prerequisite for the successful formation of a breeding form is a properly placed support. When marking the planting places in the vineyard, it is necessary to mark the places for the poles. The best solution would be to place the posts before planting or immediately after planting. The stakes must be installed in the spring of the second year, usually after the beginning of the growing season. After that, the wire is placed.

3. AGRO-TECHNICAL MEASURES

3.1 Agro-technical measures in a young vineyard

The period of establishing a vineyard lasts at least three years. In this period special agrotechnical measures are carried out with the aim of caring for young shoots and forming the planned cultivation form of the sedge. The design of the cultivation form of the grapevine depends on a number of factors: agroecological, agrotechnical, organizational and technical, assortment, orientation in the production of grapes and wine, product marketability, socio-economic conditions. The designed cultivation form should ensure: the appropriate vegetative and reproductive potential of the variety, the planned yield of grapes and the planned quality of grapes [4]. In our agro-ecological conditions, the following cultivation forms are most often applied: for varieties that require short pruning - the Roajat cordunica, and for varieties that require long pruning - the Karlovci cultivation form.
In the first year, all shoots on seedlings are nurtured. It is important to strengthen the seedling as much as possible and all agrotechnical measures should be directed in that direction. These include weed control, protection against fungal diseases and water supply. In years with a normal distribution of precipitation, 1-2 waterings are needed, and in dry years even more. It is known that the above-ground and underground parts of the tree are in direct correlation. A strong increase in the number of shoots

with healthy leaves testifies to the good development of the root system [1]. In order to further encourage the development of deep veins, which are the most important for the vine, it is necessary to remove surface veins twice during the growing season, the first time in July and the second in August. Until the end of the growing season, it is necessary to do several shallow land cultivation, usually 4-6. In the following years (second, third and beyond), soil cultivation is carried out in a similar way. The use of herbicides in vineyard plantings younger than 3 years is not recommended, except for the use of some selective herbicides that are used during the growing season [4].
In the second year, the strongest shoot is selected on the stem, which is pruned to one condir with two hooks, and all other shoots are removed. During the growing season, only two shoots are nurtured, while the other shoots are repeatedly removed. Shoots are tied every 20 cm to the side of the tree so that they are as straight as possible. One of the two nurtured shoots will produce a tree. Shoot in the zone of the future tree should be removed while they are still young.
Pruning in the spring of the third year is done in such a way that one of the two nurtured shoots is removed, and the other is pruned long depending on the selected growing form. During the growing season, all green shoots are removed from the part of the shoot from which the tree is formed. The shoots that develop above the tree form a photosynthetically active green wall, and their cutting is done 30-40 cm above the last wire.
In the fourth year, the formation of the selected breeding form continues or ends. Shoots emerging from the tree are removed this year and every year thereafter. From the fourth year, the vineyard is considered to be in full fruit bearing.
During the period of formation of the growing form, the young shoots are attacked by many pests, especially owls, wireworms and green beetles. If these pests appear during this period, protection of shoots and leaves with appropriate insecticides is undertaken. Considering that the shoots grow during the entire growing season, the susceptibility of plants to diseases is very high. This particularly applies to the spread of downy mildew (*Plasmopara viticola*) and powdery mildew (*Uncinula necator*). Shoots and leaves should be protected from these diseases with appropriate fungicides during the entire growing season.
Young vine plants are particularly sensitive to low temperatures. That is why their protection is also recommended in regions where vines rarely suffer from winter frosts. In the fall of the first and second year, the basal parts of the shoots must be covered; in later years it depends on climatic conditions [4].

3.2 Agro-technical measures in full fertility

Regular pruning (pruning at maturity) is the most important ampelotechnical measure that contributes to the establishment of a favorable relationship between the growth and development of individual organs of the vine. Pruning establishes an optimal relationship between the height of the yield and the quality of the grapes and makes it possible to maintain the desired cultivation form. Full-grown pruning is done by leaving short or long root elements on the growing form of the tree in accordance with the requirements of the variety and growing form. When pruning at maturity, in order to protect against infection by tree diseases, it is preferable to make as few wounds as possible and coat the cuts with some fungicide.
Green operations in the vineyard include all measures performed on seedlings during the growing season, namely: removal of excess shoots, shortening of shoots, shortening and removal shoots of the second order, ringing of vines, thinning of inflorescences, bunches and berries and defoliation (removal of leaves).
The removal of excess herbaceous shoots is carried out at the beginning of the growing season while the shoots are still small (several cm in length). Performs several times during the growing season. During the growing season, the shoots are directed upwards and passed between the double wires. When they outgrow the last (highest) level of the wires and before they begin to bend down, it is necessary to cross them 30-40 cm above the last level of the wires, which ensures a sufficient number of leaves on the shoots. Performs 2-4 times during the growing season. Shortening and removing the

shoots of the second row prevents crowding of the trellis. During the growing season, all zappers in the cluster zone are removed, and above that zone they are shortened to 2-4 leaves [1]. Girdling or ringing is a special measure in the production of table grapes in order to obtain larger berries and earlier ripening of grapes. It is performed with special scissors by removing the bark and phloem in the form of a 2-5 mm wide ring. This measure accelerates the growth and ripening of the berries in bunches and is carried out no later than two weeks after the flowering of the vine. Thinning of inflorescences, bunches and berries belongs to special measures in the production of table grapes. For table varieties, it is recommended to remove every third inflorescence on the shoot. Defoliation implies the removal of leaves from the shoots and is applied in cold and wet years at the time of grape ripening. This ensures better ripening of the grapes and aeration of the trellises in order to reduce the risk of rot attack on the grapes.

Tillage is a necessary agrotechnical measure in the vineyard, which regulates the water-air regime, destroys weeds and pests, and introduces mineral and organic fertilizers. According to the time of execution, processing can be autumn-winter, spring and summer. Autumn-winter processing is carried out immediately after the grape harvest at a depth of 20-30 cm, while at the same time the vine trunk can be covered in areas where there is a risk of freezing. Spring processing is carried out immediately after pruning at a depth of 15-20 cm in order to preserve moisture and shred the surface layer of the soil. Summer processing is carried out during the growing season at a depth of 5-10 cm in order to fight against weeds and preserve moisture. It is carried out several times a year with a tiller, disc harrow, cultivator and other attachment machines.

Fertilization is a regular agrotechnical measure that compensates for the amount of nutrients. If ameliorative fertilization is done correctly, every year the vineyard should be fertilized with 500-700 kg ha^{-1} of mineral fertilizer (formulation example: 8:16:24, or 0:10:30) [1]. Manure is applied in cycles of 3 to 5 years with a rate of 40,000 - 50,000 kg ha^{-1}.

During the entire growing season, the vines have a great need for water, but they are greatest during the period of intense shoot growth and development of green berries, that is, from mid-June to the end of August [12]. All wine-growing regions in Serbia generally have sufficient rainfall, but in some years their distribution is irregular [11]. There are various ways of irrigation, but in practice drip irrigation is the most widely used. This method has the greatest savings in water consumption compared to other irrigation methods. The watering norm is determined based on the type of soil, the height and distribution of precipitation, the phenophase of vine development, etc. and ranges from 40-80 liters of water per 1 m^{-2} [1].

Grape harvesting is the final and very important organizational and technical part of grape production technology. As a rule, grapes are harvested when they reach full maturity, because that is when the varietal properties are most strongly expressed [4]. In addition to harvesting at full maturity, grapes can also be harvested at physiological or technological maturity, which depends on the structure of the assortment and the production purpose of the grapes (for fresh consumption, for processing into premium, quality or ordinary wines, for processing into juices and jams or for drying). The criterion for determining the ripeness of table grapes and the ripeness of wine grapes is different. In the case of table grapes, in addition to the appropriate content of sugar and acids, it must also have a beautiful external appearance and a pleasant taste and smell. Harvesting of table grapes is done on several occasions (screening harvest), considering that with table varieties, not all bunches ripen at the same time. With table varieties, the external appearance of the grapes (shape and size of the berries, color, ash and compactness of the bunch) and taste are particularly important. To determine the ripeness of wine grapes, it is important to determine the content of sugar and total acids in the grapes. Wine grapes are harvested by variety, taking into account that grapes with white and colored berries are harvested separately. Grapes are harvested once only from the main shoots and only healthy grapes that have not been damaged by gray mold (*Botrytis*).

4. CONCLUSION

Serbia has 20,466 ha under vines and annually produces around 30 million liters of wine. As far as the assortment is concerned, international high-quality varieties predominate. However, in recent years, the cultivation of unique and autochthonous Serbian varieties such as: Prokupac, Tamjanika, Grašac, Seduša has become increasingly important. The choice of variety for establishing a vineyard depends on a large number of factors such as: climatic conditions, soil conditions, market requirements, but also the wishes of investors. The period of establishing a vineyard lasts at least three years. In this period, special agrotechnical measures are carried out with the aim of caring for young shoots and forming the projected growing form of the sedge. Regular agrotechnical measures in the full yield of the vineyard include: pruning, soil maintenance, irrigation, fertilization, protection against diseases and pests, and grape harvesting. As vineyards are raised for a longer period of exploitation, it is necessary to carefully look at all the factors that affect production and, accordingly, carefully plan each segment of vineyard raising and maintenance.

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CROP MODELLING: A NEW TOOLS FOR CROP PRODUCTION

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Abstract: *In an era of intense need for high yields, quality and safe food, the application of models in agricultural production can serve for successful and precise simulations and forecasts of crop yields. Crop models and decision tools are increasingly used to improve production efficiency and contributes to understanding of the real world because it helps to integrate the relevant processes of the studied system and to bridge areas and levels of knowledge. The combination of advanced technology and agriculture to improve the production of crop yield is becoming more interesting recently. For the implementation of such models for simulation crop production, it is necessary to define of problem, have correct and long-term data and create design and assesment of model.*
Keywords: Modelling, Agriculture, Crop production, Crop yield prediction

1. INTRODUCTION

In the past, farmers could estimate the weather and determine when the planting, agrotechnical measures and harvesting seasons in the field would begin using conventional methods and were relied on their long-terms experiences. Today, it is complicated to predict the weather using such a method because of global warming, which makes it difficult for farmers to predict the weather. For that reasons, in recent years, an era of intense need for high yields, quality and safe food, models have been increasingly used in plant production.
The models enable society to tackle a wide range of challenges: soil and water conservation, greenhouse effect mitigation, carbon conservation, sustainable agriculture and safe food and can serve for successful and precise simulations and forecasts of crop yields. Results of research suggest that it is a matter of urgency to model crop rotations in order to evaluate the resilience of cropping systems and their contribution to ecosystem services under changing climate conditions [1]. Modeling arose from the human need to understand the way systems function and determine their dynamic responses. It is a process of abstraction of a real system, which is obtained on the basis of a person's overall experience and way of thinking about the system he is considering [2]. Simulation models integrate knowledge from different disciplines and provide researchers with capabilities for conducting computer experiments to supplement actual experiments [3]. We reviewed the literature to understand the development of the model as a modern tool for accurate simulations and forecasting of crop yields.

2. DATA SET FOR CROP MODELING

Crop models and decision tools are increasingly used in agricultural field to improve production efficiency. The combination of advance technology (GIS, GPS, IoT, drones) and agriculture to improve the production of crop yield is becoming more interesting recently. Due to the rapid development of new higher technology, crop models and predictive tools are expected to become a key element of smart agriculture [4]. First, the farmer will mark the location of their agriculture area

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in polygons shape. Then the remote sensing device will take periodic land pictures and save it as time-series data. The monitoring process uses sensors to find out real-time of the condition of the agricultural area. The collected data will be stored in a database and it will be processed and used as input in decision making od model and its assessment (Figure 1) [5]. Setting the aims of a model generally takes much time, especial in long-term and multidisciplinary researches and was estimated to occupy 5% to 50% of the total time spent in large-scale predictive modelling efforts [6].

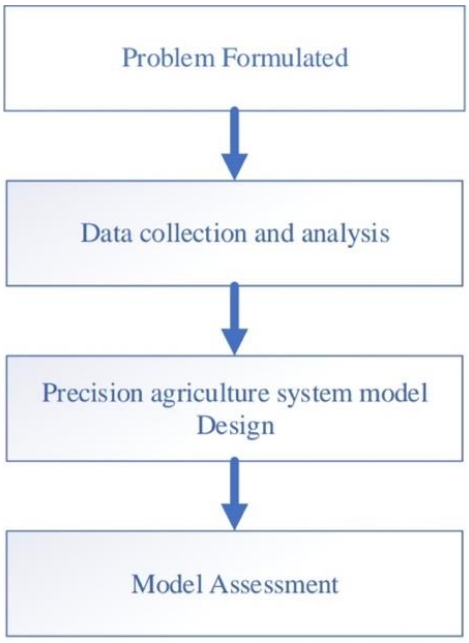

Figure 1. Research metodolgy
Source: [5]

Until today, a lot of approaches and modelling techniques have been in existence and the most crop models which were based as an linear relationship between variables and crop production. linear method such as linear regression is insufficient to show the interactions of the factors and crop yield. Although the collection of multi-year series of data and their unification into a single database is much more complex than with one-year trials, it is recommended to take into account long-term data as many factors as possible [7]. For the implementation of such models, it is necessary to have correct and continuous data, and when processing the results, it must be assessed whether the data of all years can be included in a unic combined analysis or it they need to be transformed, adjusted and divided into more or less homogeneous groups [8]. Today, it considered that Neural networks have replaced and removed the shortcomings of linear regression and become a new technology which provides assorted solutions for the complex problems in agriculture researches [9].

3. VALIDATION AND CALIBRATION OF MODEL

Back in 1977 Penning de Vries described the terms „*Evaluation*“, „*Validation*“ and „Verification“ „Evaluation“ Is the broadest term to describe the action of judging the value of a model and may be used for comparison of model output with real world data and for judgement of practical utility. „Validation“ is used as evaluation with emphasis on usefulness and relevance of the model, whilst „verification“ is used for evaluation with emphasis on truthfulness [6]. Model calibration is the process of adjusting influential model parameters and inputs within their reasonable ranges. The aim of calibration is that the model results are realistic with available observed data. During model validation, the accuracy of the model predictions is evalu- ated by comparison to additional and independent observed data. For some model support, a quality control program has been developed to reads model out-put and compares it with observed data to perform simple checks and it will sucesful used as a tool to start before they conduct calibration and validation [11].

4. ADVANSES IN CROP MODELIG

The first complex model to simulate the effects of soil erosion on soil productivity was *The Environmental Policy Integrated Climate (EPIC) model* developed in the early 1980s [12]. EPIC model was used to evaluate soil erosion impacts, and over time, modified to address numerous other environmental problems [11]. Later, the Agricultural Policy Environmental eXtender (APEX) model was developed an results of extensive biophysical/environmental/hydrological model and has a GIS (geographic information system) interface tool [13]. Similar to EPIC, APEX is a flexible and dynamic tool that can be used to estimate the impacts of land management, conservation practices, or climate on a wide range of environmental indicators; soil carbon sequestration; pesticide aplication; nutrient cycling and other APEX enhancements include a groundwater (shallow aquifer) submodel, spatial rainfall generator, landscape representation of conservation or best management practices, feedlot manure management, and simulation of different grazing density and manure deposition scenarios [14]. Models are updated daily and formating dana changed, but the approach is still the same. The DSSAT crop modeling can help to understand the interaction between genotype, environment and management, providing opportunities for data analytics for strategic and actionable decisions. The DSSAT are used to provide ultimate portability and as a result, a user can easily simulate crop growth, development, and yield for different crops for the same field while making only minor changes to the input files that are crop specific, such as variety selection, planting date, or plant density (Figure 2) [15].

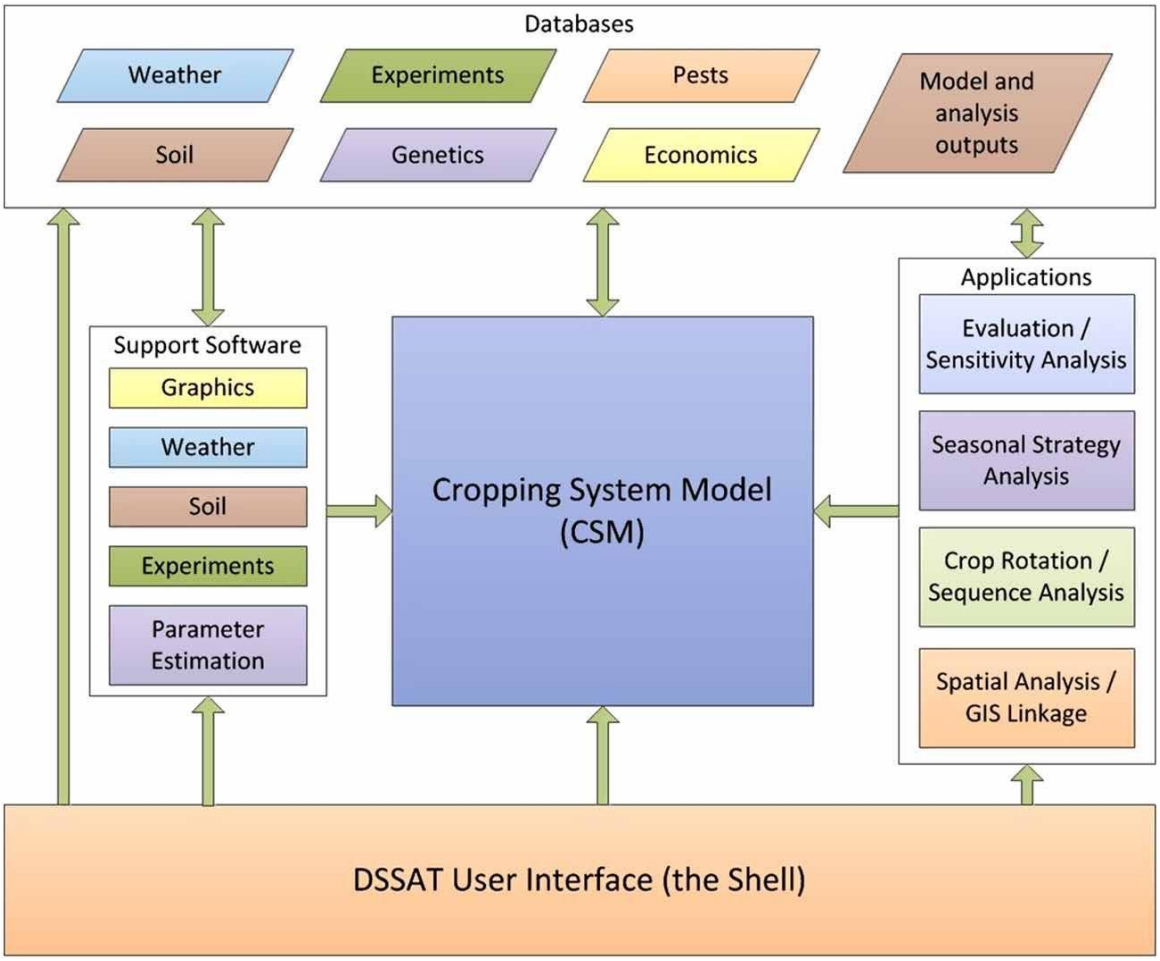

Figure 2. The DSSAT crop modeling ecosystem.
Source: [15]

The aim of the modelinig is to determine the crop yield a by considering dataset with some features which are important or related to crop production such as temperature, moisture, rainfall, humidity etc., and land factors like soil pH, soil type and production of the crop in previous years [16].

5. CONCLUSSION

The current agricultural production system is challenged with weather and climate extremes and variability and economic risks. There is pressure to grow more and healthy food. Development of models seems to have peaked in the last few years models has evolved and are now used by researchers world-wide and have become a successful tool for precise simulations and forecasts of crop yields. A major drawback is that most research still includes only a few of the many factors that affect crop yields in farmers fields but such kind of models cannot simulate real and relevant yields. To implement the model, it is necessary to have correct and continuous data and design and evaluation of the model, craate Model design and knowledge of adequate validation and calibration of the model.

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BASIC CONCEPTS OF ANN MODEL AND ITS APPLICATION IN AGRICULTURAL RESEARCH

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Abstract: *Modelling in the era of intensive agricultural production has become of crucial importance because in this way the occurrence of a factor or problem is simulated and thus enables timely reaction and problem solving. It is necessary to know and choose the right model, to know its advantages and disadvantages, to constantly improve and innovate it. One of the generally accepted models in agricultural research is Artificial Neural Network (ANN) i.e. Model of neural networks. In a real sense, ANN are one of the best solutions in s dynamic population of weed species in arable soil. Today, it considered that Neural networks have replaced and removed the shortcomings of linear regression and become a new technology which provides assorted solutions for the complex problems in agriculture researches. ANN have replaced recent methods and techniques in many applications, are often used in combination with other methods, and are often the only tool to solve tasks and search for solutions.*
Keywords: Artificial Neural Network (ANN), agriculture research, modeling

1. INTRODUCTION

Even 50 years ago it was concluded that many models are scientifically interesting, others are utilised to predict and their results are applied in other fields, and some models are largely used for instructive purposes. But all models have some value in each of these fields and contributes to understanding of the real world [1]. The agricultural system is extremely complex because it handles situations involving massive amounts of data that are caused by various sources. A lot of techniques and approaches have been used to identify any interactions between factors that that affecting yields with the crop performances [2]. Agricultural research takes into account a wide range of variables, such as crop and cultivar, temperature, rainfall, and light intensity, as well as postharvest handling and storage, fertilizer applications, and cultural techniques, land factors like soil pH, soil type and production of the crop in previous years [2,3]. But, collecting multi-year series of data and combining them into a single database is much more complex than with one-year trials [4]., it is recommended to take into account long-term data as many factors as possible [5]. One of the generally accepted models which can support a long-term data series is Artificial Neural Network (ANN). The paper presented the basic concepts of Artificial neural networks, and the aim was to review research and achievements in the application of ANN models.

2. ARTIFICIAL NEURAL NETWORK

Although Artificial neural networks have been around for quite some time: for the first time introduced in 1943 by neurophysiologist Warren McCulloch and mathematician Walter Pitts. The early successes of artificial neural networks led to the widespread belief that we would soon be talking to truly intelligent machines. In the early 1950s, the greatest influence on the development of neural

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networks was the work of Marvin Minsky, who constructed the Snark neurocomputer (1951). However, this computer did not achieve significant results, and computer Mark is considered the first real neurocomputer by Frank Rosenblatt and Charles Whiteman. In the 1960s, it became clear that it would not be easy, financial support was diverted for development and diverted to other parties. In the early 1980s, new architectures were found and better training techniques were developed, which reawakened occupation connectionism - study of neural networks [6].
ANN are biologically inspired computer programs designed to simulate the way in which the human brain processes information. They are digital representations of human brains, and just like people, ANNs learn (or are trained) by experience with suitable learning exemplars, not by programming. In order to learn, neural networks look for patterns and connections in the data. An average brain contains 100 billion neurons, each of which has 1000–10 000 connections with other neurons. On the other hand, Artificial neural networks rarely have more than a few hundred or a few thousand PE (artificial neurons or processing elements), so in complexity are thus still far beyond the creative capacity of the human brain (Figure 1.) [7].

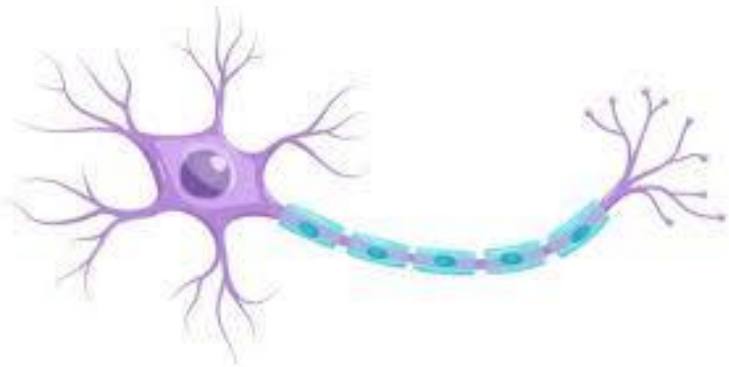

Figure 1. Neuron cell
Source: https://biologydictionary.net/cell-body/ [8]

3. ARCHITECTURE OF ARTIFICIAL NEURAL NETWORK

ANNs model have replaced recent methods and techniques in many applications, are often used in combination with other methods, and are often the only tool to solve tasks and search for solutions. For the application of the model in practice, a large database (at least from 2-10 years) is necessary in order to perform a relevant simulation for a given problem, i.e. to obtain reliable answers to questions within a certain problem in agricultural production [9]. It has the ability to help solve difficulties based on a large series of long-term data, striving for long-term solutions. ANN is suitable for data series where simplification is unacceptable, which often happens in long-term research [10]. The second important use case of ANNs in wireless networksis data analytics.To implement such models, it is necessary to have correct and continuous data, and when processing the results, it must be assessed whether all data can be included in a single combined analysis or it need to be transformed, adjusted and divided into more or less homogeneous groups. Becouse that, experiments of this type are classified as long-term ecological research (Long Term Ecological Research - LTER) [11]. Artificial neural networks consist of a large number of neurons. which are grouped into layers through which the network is connected to the environment. The first layer is input in which data is presented to the network, and each data input corresponds to an input variable. In the output layer, network outputs are calculated. Between the first and last layer are hidden layers (Figure 2.) For the successful application of ANN, it is necessary to collect as much data as possible. The type of data depends on the task that the network will perform. Data preparation includes normalization and scaling to avoid the negative effect of dominant values. The first step in building ANN is planning, then designing, training, testing and exploiting [12, 13].

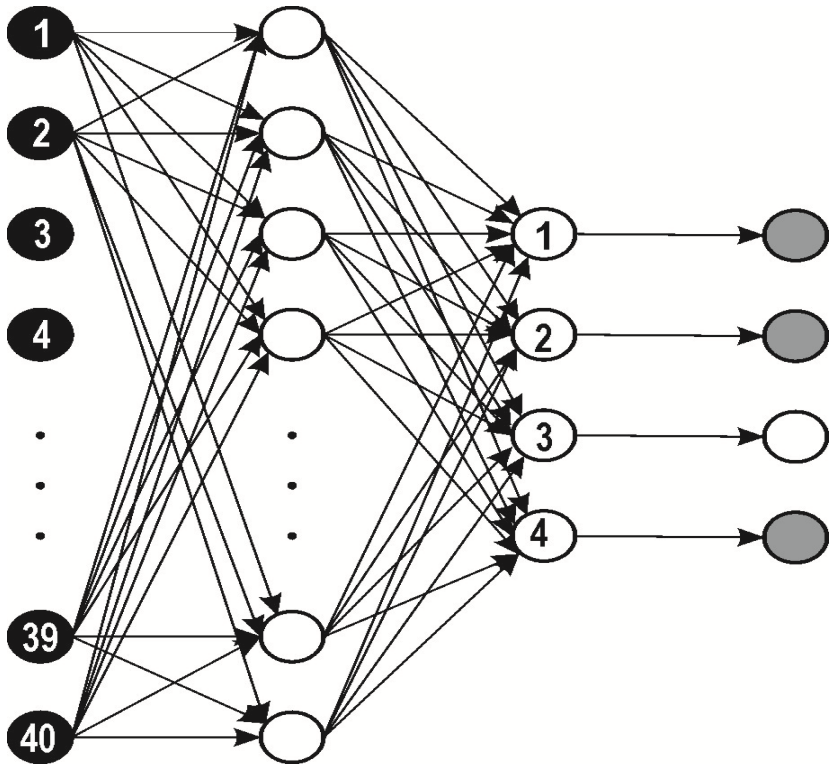

Figure 2. Architecture of artificial neural network
Source: [13]

4. APPLICATION OF THE ANN MODEL

Artificial neural networks has a general application in many evaluation areas: cost estimation, robotics, fault diagnosis, process management, quality control, etc. Presently, ANN has become a well-liked method to most authors because of its ability of prediction, forecasting and classification in biological science fields and medicine. Since there are a lot of factors which influence crop production, the use of ANN in predicting crop yield is very ussual. ANN is often used to predicted Soil and Soil-Plant Hydrology, in sensing technologies, biomass Factor, controlled environment [2]. ANN model performed extremely well in agriculture research for predicting dynamic population of weed species in arable soil [14]. Based on the ANN model and long-term data analyzis crop management, it was concluded that the greatest effect on the size of the total weed seed bank in soil with a share of 64.17% was the interaction of crop rotation + fertilization, followed by the triple interaction crop rotation+fertilization+sampling depth with a share of 30.52% and with the smallest share of only 5% interaction crop rotation+sampling depth [15]. Thus, the model clearly shows that the soil weed seed bank depend on several factors, that is, their interaction, namely the cropping rotation, fertilizer, depth of soil sampling and slightly less than the sampling time [16]. Also, with ANN model, it is possible to predict the yield, because it is determined by weather conditions, pest control and harvest plans. Today, the yield can be predicted with an accuracy of 86% [17]. by sensing various parameter of soil and also parameter related to atmosphere: type of soil, PH, nitrogen, phosphate, potassium, organic carbon, calcium, magnesium, sulphur, manganese, copper, iron, depth, temperature, rainfall, humidity [18].
Research of Alizamir and Sobhanardakani (2017) presents a new method for predicting heavy metal concentrations (As, Cu, Pb, and Zn) in the groundwater resources based on ANN and ICA (Imperialist competitive algorithm) [19]. This research is also agreed by the authors who believe that heavy metal concentrations in the environment can be more reliably predicted using strong statistical algorithms based on a set of physical and chemical characteristics, and ANNs are one of the successful computer modeling methods in modeling and predicting environmental characteristics [20, 21]. (Figure 3).

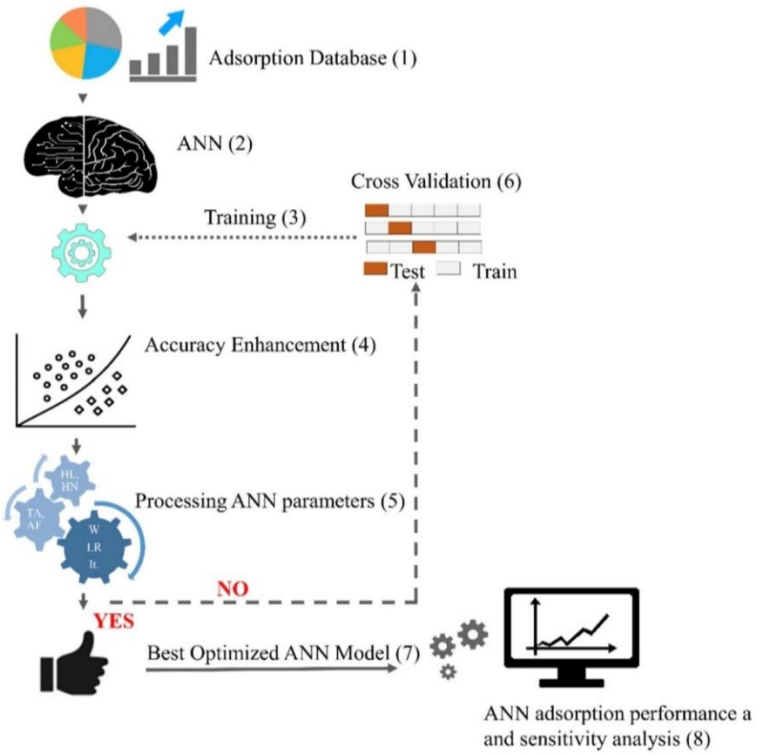

Figure 3. ANN-framework for predicting metal adsorption
Source: [21]

5. CONCLUSSION

Modeling is of crucial importance for designing and evaluating integrated agriculture, and for this it is necessary to choose the most adequate model. The combination of artificial intelligent and agriculture is and will become a more interesting area of research in the near future. A conclusion has been made that ANN has better explained yield variability rather than other methods. Undeniably, the application of ANN to precision agriculture plays a crucial role in future evaluation of the concept of precision agriculture as a sustainable means of meeting world's food demands. However, further research about the ANN impacts towards crop yield production must be conducted to ensure sustainability of future food needs. More researches towards dynamic modelling of precision farming in agriculture using neural networks are needed in the future.

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APPLICATIONS OF MOLECULAR MARKERS IN ANIMAL GENETICS AND BREEDING: A REVIEW

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Abstract: *Molecular markers play an important role in genetics and animal breeding because they enable the maximization of the selection process for those traits that are not easily observable, have low heritability or cannot be quantified. The application of methods based on DNA polymorphism in animal breeding has multiple advantages over the previous, conventional methods, bearing in mind the specificity, accuracy and simple possibility of application. The most commonly used types of molecular markers in genetics and animal breeding are: RFLP (Restriction fragment length polymorphism), RAPD (Randomly amplified polymorphic DNA), AFLP (Amplified fragment length polymorphism), SNP (Single nucleotide polymorphism) markers and microsatellites. They have found application in the genetic diversity conservation, parentage testing, sex determination, identification of disease carriers, the process of transgenesis, as well as Marker-Assisted Selection - MAS. This paper provides a brief review of the aforementioned molecular markers, their advantages and disadvantages, as well as their applications in genetics and animal breeding.*
Keywords: Farm animals, DNA polymorphism, Selection, MAS

1. INTRODUCTION

The main goal of a breeders is to select an animal with superior genetic potential to be the parent of the next generation. Traditional breeding methods are based on selecting animals based on their phenotype. The external characteristics of animals on the basis of which selection is made are called morphological or phenotypic markers, such as body shape, coat color, udder shape, skin structure or anatomical characteristics. The oldest are markers in breeding and they are used in practice whenever possible. However, very often they can lead to a bad assessment when it comes to the genetics of domestic animals because they are based on the subjective judgment of the breeder [1]. Also, most morphological markers are limited by gender, age-dependent and significantly influenced by the external environment [2]. With the development of methods of analytical biochemistry and molecular biology, newer markers have been developed - molecular markers. They made it possible to obtain indicators of the specificity of the organism at the molecular level, that is, at the level of protein and nucleic acid molecules. They are divided into: genetic and biochemical markers. Genetic markers (GM) are any genetic characteristic of an organism that helps to identify it [3]. In a narrower sense, they are genes or sequences of DNA molecules with a known location on a chromosome that are associated with a specific gene or trait. GM can be a short DNA sequence that includes changes in a small number of nucleotides, such as Single Nucleotide Polymorphism - SNP, or a long one, such as mini and microsatellites [1]. Biochemical markers are compounds such as proteins (isozymes), hormones, antibodies. However, their application is limited because they show a low degree of polymorphism and are not genetic material, but are products of gene expression, so they are significantly influenced by environmental factors. Genetic markers are based on nucleotide sequence mutations within an individual's genome and are the most reliable markers available. They are not affected by environmental factors and generally do not have pleiotropic effects on Quantitative Trait Loci – QTL [2]. Genetic markers

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have been increasingly used in genetics and animal breeding studies in recent years. Thus, the term Smart Breeding is used to describe breeding strategies supported by molecular markers. The development of molecular markers has enabled selection according to genotype, not phenotype, which makes them a powerful tool in animal breeding. Genetic markers can be used to measure the genetic response to selection in the breeding of farm animals. Genetic response to selection is a change in allele frequency at a specific place in the genome as a result of selection for a given quantitative trait. The improvement of the genetic characteristics of farm animals is traditionally done by artificial insemination. Animals with changes that better suited production conditions were selected for further breeding. This process led to changes in the allele frequencies of the genes that were observed. Recently, molecular markers are used in the mapping of QTLs on commercial animal farms, the main goal of which is to improve the efficiency of artificial selection in the so-called Marker-Assisted Selection - MAS, i.e. selection with the help of markers. The efficiency of artificial selection in animal husbandry would be greatly improved with the use of MAS and subsequent mating of selected lines. In order to achieve this, it is necessary to initially analyze the genotypes at hundreds of marked places, as well as monitor the phenotypic characteristics of hundreds and even thousands of individuals, with the fact that the number of analyzed markers would be significantly reduced in the next generation. With the availability of a dense map of markers and the appropriate cost of genotyping, genetic selection methods based on molecular markers can provide faster gains than would be expected using selection methods based on phenotype and pedigree [4]. The paper provides a brief review of some of the most commonly used molecular markers as well as some aspects of their application in animal genetics and breeding.

2. CLASSIFICATION OF MOLECULAR MARKERS

Molecular markers used to identify DNA polymorphisms in animal breeding are classified into three main groups based on the method used for their identification: 1) Molecular markers based on the hybridization method; the most commonly used type of this group of markers is Restriction Fragment Length Polymorphism (RFLP); 2) DNA markers based on Polymerase Chain Reaction – PCR, include: Random Amplified Length Polymorphic (RAPD) markers, Simple Sequence Repeats (SSR) markers or microsatellites and Amplified Fragment Length Polymorphisms (AFLP) markers; 3) DNA markers based on DNA chip and sequencing such as Single Nucleotide Polymorphism (SNP) marker [5]. Below is a brief description and application of the mentioned molecular markers.

- **Restriction Fragment Length Polymorphism - RFLP**: Differences in the size of DNA fragments that resulted from the degradation of DNA molecules by restriction enzymes are designated as restriction fragment length polymorphism (RFLP). These were the first molecular markers used in the construction of genetic maps. There may be many RFLP loci in two genotypes, cultivars or breeds. RFLP occurs both due to the occurrence of point mutations within the recognition sequences for restriction enzymes, usually by single nucleotide substitutions that remove the restriction site, and when duplication, insertion or deletion of a sequence occurs in the region between two restriction sites. Also, they can arise due to inversions, translocations and transpositions in the areas of restriction sites [3]. They are used to determine gene mutations as well as to find the place of the gene on the chromosome that is responsible for the occurrence of a certain disease [6]. RFLP markers were the first molecular markers used for genetic typing, better known as genetic fingerprinting profiling or testing [1]. Most RFLP markers are co-dominant (both alleles in heterozygous samples are detectable) and highly locus-specific. Also, their advantage is that they are highly reproducible, and the same combination of probe and enzyme applied to the same samples gives identical results in different laboratories. The disadvantages of this method are: the need for a large amount of isolated and pure DNA, it is time-consuming and technically demanding [3].
- **Randomly Amplified Polymorphic DNA - RAPD**: The PCR-based RAPD technique has been one of the most widely used techniques for DNA marker development in the last decade. The principle of the RAPD technique implies that one short (about 10 nucleotides in length),

oligonucleotide primer that binds to many different loci on the DNA molecule, is used to amplify random sequences from a complex DNA template [3]. This means that the amplified fragment of the DNA molecule obtained by PCR depends on the length and size of both the primer and the target genome. The main advantage of the RAPD technique is that it does not require prior sequencing of DNA molecules and provides a quick and efficient survey of DNA sequence polymorphisms at a very large number of loci [1]. The RAPD technique was used to assess genetic differences within or between taxa of interest by assessing the presence or absence of each DNA sequence modification product at each locus. However, the main disadvantage of RAPD technique is that RAPD primers are very sensitive to PCR conditions which can lead to poor reproducibility compared to other methods [5].

- Amplified Fragment Length Polymorphism - AFLP: AFLP technique is based on selective amplification of restriction DNA fragments (80-500 base pairs) obtained after degradation of genomic DNA by restriction endonucleases. The technique was originally known as Selective Restriction Fragment Amplification - SRFA [3]. AFLP markers have found the most widespread use in analyzes of genetic variability below the species level. This technique is used for identification of genetic polymorphisms, assessment and characterization of animal genetic resources, measurement of relatedness among different breeds as well as for construction of genetic maps and identification of genes of major species of farm animals [5,1]. The AFLP technique has wide taxonomic variability and can be used to examine any organism without prior knowledge of the organism's genomic makeup. The importance of the AFLP technique is also reflected in the fact that no prior information about the sequence is needed in order to construct the primers. However, the technique is expensive, technically demanding and requires a large amount of DNA molecules per reaction [2].

- Microsatellites: They represent a type of repetitive DNA, i.e. series of repeatable sequences arranged in tandems. They consist of a piece of DNA with a length of 1 to 6 base pairs that has been repeated several times in tandem. Microsatellites are also known as SSR (Simple Sequence Repeats) or STR (Short Tandem Repeats) markers, as they are the most commonly used. SSR/STR locus polymorphism is caused by variations in the number of tandem repeats [3]. They are classified as mono, di, tri, tetra, penta and hexa-nucleotide repeats, with di, tri and tetra-nucleotides being the most common choices in various molecular genetics studies. They are repeated (usually 5-20 times) in the genome with a minimum repeat length of 12 base-pairs. [1]. Due to their high abundance in the genome, extremely high degree of polymorphism and easy detection, they are very useful for various purposes: identification of animals, evaluation of animal genetic resources, determination of parentage, research of diseases, determination of genetic variability within and between races, determination of substructure of populations, reconstruction of phylogenetic relationships between populations as well as in studies on the process of domestication of animals and the migration of races. Also, they are used for mapping QTLs for production and functional traits of farm animals as well as in MAS [2]. The main disadvantages of this technique are that it is very expensive, complicated and time-consuming. Also, heterozygotes can be misclassified as homozygotes when null-alleles occur as a result of a mutation in the primer annealing sites [5].

- Single-Nucleotide Polymorphism – SNP: These are third-generation markers that were developed after RFLP and SSR techniques [7]. These are polymorphisms caused by point mutations, i.e. mutation of one nucleotide at a specific locus in the DNA sequence. These polymorphisms occur due to substitutions of individual nucleotides in the genome (transitions or transversions) or due to their insertions or deletions. Transitions are the most common (about 2/3) among all types of SNP mutations [1,3]. These are bi-allelic markers that indicate a specific polymorphism in only two alleles of the population. The majority of SNPs, generally two out of three, involve the substitution of cytosine (C) with thymine (T). Many SNP mutations do not affect the functioning of the cell, but are believed to predispose an organism to the development of a certain disease and affect how it will react to a certain drug [2]. They are used to assess genetic variability between different species and breeds of animals, as well as in genetic disease studies for different livestock species. The role of SNPs in farm animals has been very important in the study

of population structure, genetic differentiation, origin and evolution. The most important disadvantage of these markers is the low level of information obtained compared to highly polymorphic microsatellites, but this can be compensated for by using a larger number of markers [1,2].

3. APPLICATIONS OF MOLECULAR MARKERS IN ANIMAL GENETICS AND BREEDING

1) Genetic diversity conservation – The conservation of genetic diversity is important because it encourages a high level of heterozygosity in the population. Also, in order for animal populations to be able to face future changes in the environment, the existence of genetic variability is necessary. The existence of genetic diversity is necessary to ensure a long-term response to natural or artificial selection, for traits of economic or cultural importance. The primary goal of studying genetic diversity is to understand the degree of differentiation of populations within species. Population-specific genetic markers (alleles) can be generated using a number of methods for the detection of polymorphic loci. Genetic characterization of populations, races and species enables the assessment of genetic variability [8]. According to Gwakis [9] the most commonly used molecular markers for studying genetic variability at the DNA level molecules are RFLP, RAPD, AFLP, micro and minisatellites.

2) Determination of parentage: Molecular markers are used as a useful tool for determining genetic relatedness between individuals and testing parentage in segregated populations [5,8]. The concept is based on the principle of exclusion. The presence of a genetic locus on the alleles in the offspring that is not found in either of the putative parents effectively rules out a particular parental pair as the offspring's biological parents. Parentage testing using molecular markers gives a much higher probability of exclusion (> 90%), than testing with blood groups (70-90%) or some other biochemical markers (40-60%) [2]. Highly polymorphic DNA finger printing markers have been shown to be very useful for this purpose [8].

3) Sex determination of offspring: Molecular markers can be used to determine the sex of pre-implantation embryos. DNA sequences specific to the Y chromosome, such as the SRY, ZFY and TSPY genes, are used as probes. The TSPY gene was shown to be a very good male-specific marker due to the existence of a large number of gene copies [5]. Also, using PCR-based sexing methods has the advantage of being performed in less than five hours with almost 100% accuracy. They are less invasive than cytogenetic methods and can be applied in the early stages of embryo development [8].

4) Identification of disease carrier: Infectious diseases are responsible for large economic losses in animal husbandry. Most serious incurable diseases are not the result of infection by organisms that cause infectious diseases, but rather of defective genomes of certain individual animals. Certain allelic changes in the host's genome lead to its greater susceptibility or resistance to a particular disease [10]. Thus, Kingsbury [11] reported that a specific RFPL marker in the prion protein gene is responsible for variation in host response to bovine spongio-form encephalopathy (BSE) and its incubation time. DNA polymorphism that occurs within genes helps to understand the molecular mechanism and genetic control of several genetic and metabolic disorders and enables the identification of heterozygous individuals who are carriers of diseases/disorders, i.e. defective recessive alleles, but do not differ phenotypically from normal individuals. For this purpose, PCR-RFLP assay as well as microsatellite markers were used [8].

5) Transgenesis: This is a procedure in which a part, one or more genes of one organism is incorporated into the genome of another organism. According to research by Mitra et al. [10] the starting point in this process is the identification of genes of interest. For this purpose, molecular markers can serve as reference points for mapping relevant genes, which would be the first step towards their manipulation. Also, they can be used to identify animals carrying transgenes in order to reproduce them.

6) Marker-Assisted Selection (MAS): It represents the identification and use of molecular markers that are linked to genes that control traits of interest. MAS is a form of indirect selection and the most widely used molecular marker. It is irreplaceable when, in traditional breeding methods, there is no possibility of selection for important traits that are not observable or cannot be quantified. In order to get from markers to MAS, the following is needed: high-density DNA marker maps, which means many markers whose location is known, and which are spread over relatively short intervals in the genome; then, defining genes that are assumed to determine traits of interest, and testing statistical relationships between markers and traits of interest. When the defined marker is located next to, or even in the gene of interest, the next step is possible, i.e. MAS desirable traits. Desirable traits can be controlled by a single gene, such as major genes, or they are complex quantitative traits, controlled by a larger number of minor genes (QTL) and significantly influenced by environmental factors. Much of the research program is focused on the construction of maps for molecular markers and the discovery of QTLs that are required for the potential application of MAS. High linkage disequilibrium, a large population a large number of markers per chromosome, genomes containing a large number of chromosomes high heterozygote frequencies at the relevant genes and markers that are located close to quantitative trait loci (QTLs) with large effects are expected have higher response to MAS [5]. MAS can be used to detect genes responsible for certain genetic disorders, disease resistance and product quality. The use of MAS improves the longevity of animals, feather pecking, resistance to stress as well as the desired characteristic behavior [12].

4. CONCLUSION

Advances in the field of molecular biology and molecular technologies have enabled the discovery of a large number of genetic polymorphisms at the DNA sequence level, which are used as molecular markers to determine the genetic basis for the observed phenotypic variability, with the aim of improving animal breeding programs. The application of molecular markers in animal breeding programs has many advantages over conventional mehods in terms of their accuracy and specificity. They have found a wide range of applications in animal genetics: estimation of genetic distance, determination of twin zygosity and freemartinism, gene mapping, parentage testing, sex determination of pre-implantation embryos, identification of disease carriers, transgenesis and others. Overall, the improvement of farm animal species is largely achieved by the application of molecular markers. The choice of markers for different applications depends on certain factors: the degree of polymorphism, the possibility of automation of the method, the radioisotopes used, the reproducibility and the cost of the technique. Although a large number a different markers are used for different applications, it is considered that SSR markers (microsatellites) are the most common choice among available markers for various genetic studies, due to multiple alleles, cost-effectiveness and transferability.

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PRECISION AGRICULTURE TECHNOLOGIES AND METHODOLOGIES USED TO CROP YIELD PREDICTION – A REVIEW

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Abstract: *Pre-harvest forecasting of crop yields is essential for planning and making various decisions about the timing of harvest, processing, storage, transportation and marketing of agricultural products. Early forecasting of crop yields plays an important role in reducing hunger worldwide by assessing the availability of food for a growing world population. Traditional methods of crop yield estimation are a time-consuming, subjective and expensive process. Remote sensing as a basic element of the concept of precision agriculture provides accurate agricultural statistics one month before harvest along with the spatial distribution of different crops. Remote sensing data provide important spatio-temporal and meteorological information as well as information on the status of crops at different stages of growth. Therefore, this paper provides a brief review of basic remote sensing tools and technologies, as well as how remote sensing data can be used to crop yields prediction.*
Keywords: Remote sensing, Sensors, Vegetation indices

1. INTRODUCTION

Achieving maximum crop yield with minimum investment is the ultimate goal of farmers in their search for economically efficient agricultural production. Early detection of problems related to crop yield can go a long way in reducing loss and achieving target yield and profit. Monitoring crop growth and yield in agricultural fields is an essential procedure for food security and predicting economic returns. Some studies [1] have shown that traditional crop yield estimation methods can lead to poor estimation. In addition, these methods depend on rigorous data collection in the field, which is an expensive and time-consuming process. In the era of digital technologies, traditional agricultural management methods have been supplemented by new sensor and drive technologies and improved information and communication technologies. Based on the concept of "produce more with less", precision agriculture, also known as smart agriculture, has been used for more than 25 years to optimize the use of agricultural inputs, such as fertilizers and herbicides, thereby maximizing profits, while reducing negative environmental impacts by regulating spatial variability [2]. Crop yield prediction using precision agriculture methods can help to model the spatial distribution of site-specific yields and to investigate the factors affecting yield under different seasonal influences [3]. According to the definition of ISPA - International Society for Precision Agriculture, precision agriculture is a management strategy that collects, processes and analyzes temporal, spatial and individual data and combines them with other information, in order to support management decisions according to the estimated variability, and with the aim of better efficiency in the

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use of resources as increasing productivity, quality, profitability and sustainability of agricultural production [4]. Detection is the basic element of the concept of precision agriculture. Remote sensing is described as a set of techniques that use space to monitor Earth's resources ranging from high altitudes such as satellite technologies to low altitudes such as observation from the ground for greater precision and accuracy [5]. The spectrum of electromagnetic waves (visible and infrared light, RADAR and microwaves) is used as the basis for remote sensing in order to assess its interaction with the features of the Earth [6]. Remote sensing uses a range of devices such as different types of sensors, drones, aircraft and unmanned aerial vehicles as well as cameras mounted on satellites in orbit. Sensors in fields and crops provide detailed data on soil characteristics, climate, fertilizer needs, water availability and pest infestation. Also, aerial footage captured by drones or unmanned aerial vehicles (UAVs) that can patrol fields can alert farmers to crop maturing or potential problems, as well as deviations from expected growth rates or quality. Satellites used for the purpose of precision agriculture facilitate the detection of relevant changes on the ground using satellite images [7]. This paper provides a brief review of basic precision agriculture technologies and methodologies that can be used to crop yields prediction.

2. REMOTE SENSING IN CROP YIELD PREDICTION

Remote Sensing (RS) has become one of the most important technologies in agriculture that contributes to the improvement of management practices because it provides data on the status of crops at different stages of growth. Remote sensing technology involves the collection and analysis of crop data using an instrument placed in the atmosphere or a satellite, without any physical contact [8]. It is the process of monitoring and recognizing places on Earth by measuring emitted and reflected radiation with the help of sensors [9]. Remote sensing data has several applications in agriculture, one of which is crop yield prediction.

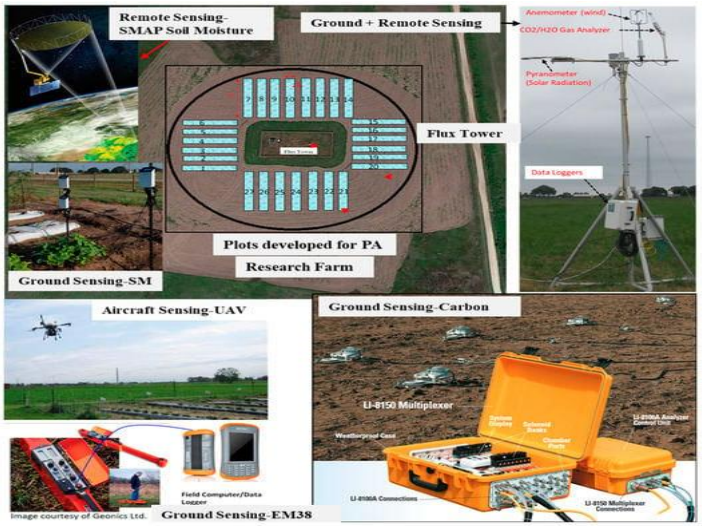

Figure 1. A typical layout for the remote, aircraft, and ground sensing systems deployed for prediction crop yield in precision agriculture. SMAP = Soil Moisture Active Passive; PA = Precision Agriculture; SM = Soil Moisture; UAV = Unmanned Aerial Vehicle; EM = Electromagnetic. (UAV photo credit—Dr. Ripendra Awal, PVAMU, Prairie View, TX, USA)
Source: [10]

Remote sensing systems used for this purpose can be classified based on sensor platform or sensor type. Sensors are usually placed on satellites, antennas or on platforms on the ground (Figure 1). Also, more recently, antenna platforms are being used that include aircraft as well as unmanned aerial vehicles.

Ground platforms can be grouped into three categories: hand-held, field-mounted and those mounted on tractors or other agricultural machinery. Sensors used for remote sensing differ based on the spatial, spectral, radiometric and temporal resolution they offer. The spatial resolution of the sensor is defined by the size of the pixel that represents the surface of the ground, while the temporal resolution is related to the sensor platform, not the sensor itself. The time resolution for a satellite is the time it takes to complete an orbit and revisit the same observation area. Spectral resolution is indicated by the number of captured bands in a certain part of the electromagnetic spectrum [10]. Biomass and crop yield estimation usually requires the application of sensors with a higher spatial resolution [11]. Aerial platforms such as unmanned aerial vehicles generally provide higher spatial resolution images compared to satellites. As Joshi et al. [12] report, approximately 81% of crop mapping and yield forecasting studies used satellite sensors and 12% used unmanned aerial vehicles. However, drones are much more often used in yield prediction studies than crop mapping. For the purpose of crop yield prediction, both RADAR (Radio detection and ranging) and LIDAR (Light Detection and Ranging) sensors are used to obtain remote sensing data. Data obtained by RADAR systems have been used by many researchers to estimate aboveground production and crop biomass [13,14]. Debnath et al. [15] in their research, in addition to numerous applications, among other things, used LIDAR sensors to estimate biomass and crop yield.

Climate, soil properties, soil nutrients, crop nutrients, crop volume and biomass, water content, diseases, weeds, insects as well as crop variety have an impact on crop yield and agricultural production. All the mentioned factors influence the spectral characteristics of the crop, which can be evaluated through various sensors. Therefore, remote sensing offers a timely and cost-effective method for monitoring and assessing crop vitality, production and yield. The assessment of crop production using remote sensing techniques was carried out using different approaches. The earliest approach was based on the delineation of the area of a specific crop from the acquired satellite image combined with human experience for the expected yield of different local varieties of the given crop. This high accuracy of land cover classification depends on the type of satellite images used in the survey and the size of the farm under the crop. Another approach is to estimate the biophysical and biochemical parameters of the crop obtained using multiple sensors. These parameters, which are closely related to crop vitality, affect the spectroscopic characteristics of the crop, which can be measured using various remote sensing sensors. This approach is very effective; however, it sometimes requires a lengthy data collection process, which may not always be available. A third approach is to estimate crop yield through direct empirical statistical models between crop spectral characteristics measured by ground-based, airborne LIDAR and RADAR sensors as well as satellite remote sensors and observed yield. Using direct statistical empirical models with very few inputs can be the most practical and efficient method for predicting returns. The input factors for these models can be spectral factors collected by remote sensing sensors and the measured factors represent biochemical or biophysical parameters of the crop. Some of the statistical models used for this purpose are: multiple linear regression (MLR), stepwise multiple regression (SMR), generalized linear model (GLM), generalized boosted model (GBM), kernel-based regularized least squares (KRLS) [16].

3. VEGETATION INDICES IN CROP YIELD PREDICTION

One of the most important reasons for using remote sensing to obtain crop information is the calculation of vegetation indices (VI). The measured light reflected by plants in the visible, ultraviolet, and infrared parts of the spectrum is commonly used to calculate VIs that provide useful information about the conditions under which plants grow. VIs are calculated through mathematical expressions that combine the measured absorption and reflection of solar energy in many spectral bands, as a certain value would be obtained which helps to estimate crop growth, vitality, biomass, yield and chlorophyll content [10]. Each VI represents a number that quantifies plant biomass and/or vigor for each pixel in the remote

sensing image. Indices are calculated using several spectral bands that are sensitive to plant biomass and vigor. Some used VIs for crop yield prediction are: Normalized Difference Vegetation Index - NDVI, Enhanced Vegetation Index - EVI, Soil-Adjusted Vegetation Index - SAVI, Modified Soil Adjusted Vegetation Index - MSAVI [17]. The mentioned vegetation indices, their abbreviations and the equations by which they are calculated are shown in Table 1 [10]. Most VIs use information that include reflected light in the red and near-infrared part of the spectrum. A satellite with a multispectral sensor covers the visible and infrared part of the electromagnetic spectrum, which provides information for obtaining numerous VI [18]. One of the most commonly used indices for monitoring and evaluating crop yields is NDVI, which represents the ratio between the near-infrared (NIR) and the visible red part (RED) of the spectrum that plants reflect. Its values range from -1 to +1. Higher values of this index indicate that the plants are healthier, have stronger vigor and greater vigor, i.e. biomass, which will later directly affect the higher yield of the plants. EVI is similar to the NDVI index, however it minimizes the effects of soil background and atmospheric influences and uses the blue part of the spectrum to improve sensitivity to plant reflectance. It is used to determine plant health as well as water stress, especially in crops with high canopy density, where NDVI masks small variations. SAVI is a modified NDVI index, and it is used when monitoring the state of vegetation with less vigor or in the initial stages of growth when it is necessary to remove the influence of soil reflection (color and soil moisture). It is most suitable for analyzing vegetation that covers 15% or less of the total land area. MSAVI index comes to the fore when the soil is almost bare, immediately after the crop has sprouted. While other indices in the initial stages of the crop do not detect plants, this one has the function of recognizing small ones. With its help, it is possible to notice oases in the field where crop development is weaker, and the reason may be poorly done sowing, stressful conditions such as drought, extreme temperatures and precipitation. For this reason, it helps farmers in making decisions so that they can ultimately expect more and better yields [17].

Table 1. Some recently used vegetation indices for remote sensing applications in crop yield prediction
Source: [10]

Index name (abbreviation)	Definition/Equation
Normalized Difference Vegetation Index (NDVI)	$\frac{R_{NIR} - R_{red}}{R_{NIR} + R_{red}}$
Enhanced Vegetation Index (EVI)	$\frac{2.5(R_{NIR} - R_{red})}{(R_{NIR} + 6R_{red} - 7.5R_{Blue} + 1)}$
Soil-Adjusted Vegetation Index (SAVI)	$\frac{(R_{NIR} - R_{red})(1 + L)}{R_{NIR} + R_{red} + L}$
Modified Soil Adjusted Vegetation Index (MSAVI)	$\frac{2R_{NIR} + 1 - \sqrt{(2R_{NIR} + 1)^2 - 8(R_{NIR} - R_{red})}}{2}$

* NIR – near-infrared light, red – visible red light, Blue – visible blue light, L – soil conditioning index

Regardless of the variations, all designed VIs are sensitive to biochemical and biophysical parameters such as leaf chemical composition, fraction of absorbed photosynthetically active radiation, biomass and leaf area index (LAI). Remote sensing data have just been used to estimate LAI and biomass for different crops. LAI and crop biomass are considered to be two essential indicators of growth and development, and LAI is used as an input in many models to predict crop growth and yield [19]. Crop biophysical parameters obtained by remote sensing, or vegetation indices, have a strong correlation with observed crop yield and biomass, indicating their potential for application in crop yield estimation [20]. Crop yield estimation based on remotely sensed data is generally carried out in two ways. First, biophysical

parameters like LAI are used in models to predict crop yield and biomass. Second, statistical or empirical relationships are developed between remotely sensed crop parameters/indices (e.g. LAI, NDVI) and observed crop yield and biomass in a representative field. The developed statistical regression model or empirical relationship can then be used to map crop yields to the target crop field. Crop modeling is a data-intensive approach such as model input parameters, meteorological data and observed yield and biomass data. Maresma et al. [21] used a regression model-based approach to estimate the relationship between maize yield and biomass and measured spectral indices. They determined that Red-Based Indices - RBI, NDVI and Wide Dynamic Range Vegetation Index - WDRVI have the highest correlation with grain yield. A study by Fernandes et al. [22] in the prediction of corn yield showed that NDVI and Green Normalized Difference Vegetation - GNDVI had good results in terms of field variability, while Haghverdi et al. [23] found that crop yield prediction using Red-Edge Based Normalized Vegetation Index - NDVIre is more effective compared to NDVI and GNDVI.

4. CONCLUSION

Climate, soil characteristics, soil nutrients, crop nutrients, crop volume and biomass, water content, diseases, weeds, insects and crop variety are factors that affect crop yield. All the mentioned factors influence the spectral characteristics of the crops that can be evaluated by different remote sensing techniques. Therefore, remote sensing offers a timely and cost-effective method for monitoring crop conditions and estimating crop yields. Data obtained by remote sensing are used to calculate vegetation indices that are used to derive vegetation phenology and estimate various biophysical and biochemical parameters that are closely related to crop vitality and on the basis of which it is possible to estimate crop yield. Also, one of the approaches for crop yield estimation is through direct empirical statistical models between crop spectral characteristics measured by different remote sensors and the observed yield. Using direct statistical empirical models with very few inputs may be the most practical and efficient method for predicting crop yields. The input factors for these models can be spectral factors collected through various remote sensing sensors, and the measured factors represent biochemical or biophysical parameters of the crop.

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IMPLEMENTATION OF ROBOTIC TECHNOLOGIES ON APPLE PRUNING: A REVIEW

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Abstract: *Pruning, as the main activity during the winter dormancy of fruit trees, plays an important role in preserving the health of seedlings, high yields and obtaining high-quality fruits. Automation and robotics are widely used in many agricultural operations, however, pruning operations are usually done manually. Manual pruning is one of the most labor-intensive operations, accounting for about 20% of total labor costs and largely dependent on skilled labor. In recent years, qualified labor is in increasing shortage, and the high cost of labor is becoming a big problem for fruit production. That is why scientists around the world are paying more and more attention to robotic pruning, which represents a long-term solution to the problem of labor shortages and high costs. However, there are numerous challenges to the successful adoption of robotic pruning technologies. Robotic technology using sensors requires robust systems for perception and manipulation in changing and complex environmental conditions, as well as a precise and efficient tree branch pruning system. This paper is a review of a previous research in this field and shows the potential possibilities for automatic pruning apple with modern tree architectures, adapted to machines for automated branch pruning.*
Keywords: Apple Pruning, Mechanical Pruning, Automated Pruning

1. INTRODUCTION

Fruit production in the Republic of Serbia is to a large extent based on the use of seasonal labor. Many critical activities in the orchard are not only labor intensive, but also very sensitive to climatic conditions [1]. The lack of qualified labor represents a great risk for performing seasonal tasks in orchards [2,3]. In the future, it is critical to minimize dependence on seasonal labor for the long-term sustainability of this industry [4].
Dormant pruning of fruit trees refers to the removal of damaged parts of trees, especially unproductive shoots and branches, and is essential for maintaining overall tree health, controlling plant size, increasing fruit quality and marketable yield [1]. In most orchards, this operations is performed manually using scissors and a saws, which is a very labor-intensive operation and potentially unsafe (a cut, falls and etc.). After harvesting, pruning is the second largest labor cost in fruit tree production, accounting for 20% of total costs in full years of production (is not included the fixed investment breakdown for each year, such as land, trellis, irrigation setup and others) [5]. Researchers have been working on the mechanization of fruit tree pruning for several decades. Due to high costs and the decreasing availability of skilled labor mechanical or automated pruning is proposed [1]. Early research works in pruning focused on mass mechanical indiscriminate pruning in which the cutting

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tool was passed over the wood in orchards while maintaining a certain distance from the center of the tree crown [6, 7, 8]. This type of pruning usually requires subsequent manual pruning [9]. Fence protective has been tried in the past as a supplement or replacement for selective manual pruning [1]. Ferree and Lakso [10] evaluated hedging for dormant pruning of vigorous semi-dwarf apple trees, and reported negative consequences of low within-canopy light levels and poor fruit color. These conditions resulted from a proliferation of new shoots arising from the numerous non-selective heading cuts made by the hedger [1]. Summer hedging with dormant selective hand pruning, conversely, was shown to be beneficial in creating higher light levels in the lower canopy [11].
Robotic pruning, which is selective pruning with precision cuts, typically cuts the branch with an end effector consisting of a blade and an anvil that uses a scissor motion [12]. Before cutting, the challenge is to detect the target branches and identify the predetermined cutting point. The location, orientation and dimension of the branch are the key information to perform accurate pruning, which results in a complex set of maneuvers and slows down the pruning process, so the pruning efficiency is very low [1].
Tree architecture is of paramount importance to the success of machine and automated pruning. A new orchard architecture suitable for mechanization with better machine accessibility of fruit or branches is also necessary. Different pruning strategies would be applied to the training system to meet the target apple tree system [1].
The aim of this paper is to review the contemporary architectures of apple trees and their compliance with the development of an automated pruning strategy.

2. TREE ARCHITECTURE AND AUTOMATED PRUNING.

2.1 Tree training systems

Apple orchards are evolving towards simpler, narrower, more affordable and more productive systems that are easier to mechanize and automate. Modern intensive orchard systems could provide easier detection and access to tree tops and fruits, resulting in greater potential for the application of mechanical and robotic technologies [13]. These architectures represent different training systems that create very narrow two-dimensional canopies where most branches and fruits are visible and accessible to machines [8]. These systems could increase profitability by improving yields and/or reducing labor costs.
One simplified architecture that is more amenable to mechanization than conventional orchard systems is the high-spindle wall system. In this architecture, trees are planted at smaller distances within the row of plants (1000-1300 trees ha^{-1}), and compared to classical architectures and branches, more secondary and tertiary branches are not allowed to grow [8]. A tall spindle means a conical crown where weak skeletal branches are arranged in a spiral and are getting shorter near the top. Between them there may be weak twigs and short fruitful twigs. This system for tree training is applied to fruit species grafted on weakly lush rootstocks (M.9 and M.27 for apple), as well as to apple spur types on medium lush rootstocks MM-160 and M.26. Pruning removes those branches that have an irregular position in the crown and that are too lush [14].
A super spindle is determined by its plant density. With a distance between rows of less than 3 m and a distance of trees in a row of less than 0.8 m, which gives a density of more than 4,000 trees per hectare [15]. The formation of the super spindle is similar to that of the tall spindle, except that the tree is narrower (the width at the base is up to 1 m) and during formation, the green is forced, i.e. summer pruning. Isolation of the top sapling is done in a timely manner, as well as the removal or shortening of saplings that are at a sharp angle. High-quality planting material (highly grafted and branched seedlings) and consistent architecture enable high reproductive potential and very early fertility, which in the case of apples can be up to 30 t ha^{-1} in the second year of planting.
Bi-axis is used for lusher combinations of cultivar-rootstocks, which due to their lushness do not give good results in the form of a slender spindle. The formation and maintenance is the same as with the slender spindle, with the difference that in this case two spindles are formed on one trunk. The

planting distance is 3.5 *m* x 1.8 - 2.0 *m*, which amounts to 1,500 trees per hectare, or 3,000 individual spindles. The height of the tree does not exceed 3 *m*, with the fact that each spindle is supported by a special armature, during formation, and later. Good results were obtained with more lush cultivars on weak- lush rootstocks, as well as with varieties that must have good fruit coloration [16].
The V-trellis growing system implies trees planted in one row on a support (support) inclined by 15° from the vertical. The trees are arranged alternately at a mutual angle of 30 degrees, which is why the leaf mass of the whole tree, and especially the base, is more exposed to sunlight. The formation of the cultivation form is quite similar to that of the standard spindle. The increase in the density of the assembly by planting fruit trees in the V-system is accompanied by an increase in the yield without a decrease in the quality of the fruits [14].
The Solaxe architecture partially adopts the concept of long pruning as in the case of a tall spindle, in less lush variety/rootstock combinations. With this compromise solution, it is possible to combine long pruning in the case of spindly forms and pruning of the parent tree support in solax. In the years of fruiting, a high yield and easier access to pruning are expected, as well as the possibility of converting the slender spindle into this growing form, in order to better adapt to the cultivar specifics. The planting distance depends on the lushness of the chosen cultivar/rootstocks combination and ranges from 3.5-4.0 *m* x 1.0-1.25-1.5-1.75 *m* (1,600-3,800 trees ha^{-1}) [16].

2.2 Mechanical pruning

Mechanical pruning is mainly performed in modern orchards with modern cultivation systems and large ones using mainly machines for pruning and shaping trees [17]. According to the mode of operation, the most commonly used pruning devices include reciprocating milling cutters and discs [18, 19, 20]. *Poni et al*. introduced a curtain pruner to cut upright branches, which improved pruning efficiency [21]. *Spinelli et al*. in Italy he designed a machine for pruning olives, which mainly consisted of a pruning device and a mechanism for crushing and recycling residual branches. This machine can crush and recycle residual branches during olive pruning, but it can only trim one side of the tree [22]. *Liu et al*. designed a wide-band combined pruning machine for new orchards [23] which consists of frame structure, cutting device, transmission system and hydraulic system. The cutting height range of the machine was 500–4000 *mm*, the maximum cutting diameter was 60 *mm*, the missed pruning rate was 7.3%, and the qualified pruning rate was 90.9%. The quality of the cut and the shape of the cut met the requirements for agronomic application. In 2021, *Li et al.* designed a horticultural plant pruning machine [24], whose pruning device consists of multiple cutting tools moving back and forth. It takes about 8.89 *s* to prune one horticultural plant with this machine. For tree crops, indiscriminate mechanical pruning has been investigated for various crops, such as cherry [25], citrus [26] and olive [27]. Mechanical pruning has shown some level of promise for citrus and olives. For example, medium-low vigor olive trees can be successfully controlled by mechanical pruning without compromising their yield [28]. Non-selective pruning systems are limited in their ability to provide pruning quality for some other fruit trees, such as cherry, peach and apple [29], which can lead to excessive shoot growth, leading to reduced fruit quality and yield. [30]. Therefore, mechanical pruning for fruit trees is mainly used for summer pruning with the removal of some outer shoots to increase light interception to the fruits [31].

2.3 Automated pruning

Automated pruning has not been introduced in current practice due to several important challenges. The first challenge is the complex canopy/tree structure environment. Another challenge is moving robotic parts quickly, efficiently and delicately [1]. These challenges have prevented pruning robots from achieving widespread adoption – there are no commercially available robotic tree pruning systems. In recent years, many scientists around the world have been developing and improving individual segments of automated pruning technology. In a review paper, *He and Schupp* [1] pay attention to modern apple canopy architecture for automation, defining two different pruning rules

for automated pruning and providing a summary of the sensor technologies involved in automating the pruning operation. However, the article did not include some key technological components (machine vision algorithms, manipulation and path planning) of the robotic pruning system [32]. A recent review by *Tinoco et al.* [33] focused on robotic manipulators for tree pruning and harvesting, mainly highlighting five harvesting manipulators and two pruning manipulators as case studies. In the last few years, research has been focused on the development of algorithms for automated pruning of dormant trees, in order to train the trees into the desired architecture [34, 35]. To develop a robotic pruning system, several components such as sensing or perception, mechanical manipulation, and path planning must be integrated for successful operation [32]. Path planning, pruning cut sequence, manipulation control and obstacle avoidance are also essential to the successful operation of a robotic pruning system. Machine vision systems have been developed to reconstruct tree branches for pruning, mechanical components for pruning have been investigated including manipulators [35, 36, 37] as well as end effectors [38, 39].

Figure 1. a) Mechanical pruning
Source:a) https://shorturl.at/rtST0

b) Pruning robot prototype
Source: b) https://shorturl.at/gozCM

3. CONCLUSION

Modern intensive orchard systems are various training system architectures that produce very small, two-dimensional canopies where the majority of the branches and fruits are visible and reachable to machines. By increasing yields, decreasing labor costs, and increasing the possibilities for the use o mechanical and robotic technology, these systems could boost profitability.
Mechanical pruning is mostly done in modern orchards, mainly by pruning and shaping machines. Non-selective pruning systems are limited in their ability to provide pruning quality which can lead to excessive shoot growth and reduced fruit quality and yield. Therefore, mechanical pruning is mainly used for summer pruning with the removal of outer shoots to increase the brightness of the fruits.
Due to a number of significant obstacles, including the complicated environment of the canopy/tree structure and the slow movement of robotic parts, automatic pruning has not yet been realized. The efficient functioning of a robotic pruning system depends on path planning, cutting sequence, manipulation control, obstacle avoidance, machine vision systems and manipulators as end effectors. Further research should be directed towards the development of these systems.

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PRECISION AGRICULTURE IN VEGETABLE FARMING

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Abstract: *Precision agriculture in vegetable farming is a transformative approach that integrates modern technology to enhance productivity, sustainability, and precision in farming practices. By utilizing various technologies such as GPS, sensors, drones, and data analytics, farmers can make informed decisions tailored to specific crops and fields. One key aspect of precision agriculture is data-driven decision-making. Farmers collect data on soil health, moisture levels, temperature, and crop growth using sensors and other monitoring devices. This data is then analyzed to determine the precise requirements of each crop, allowing farmers to tailor irrigation, fertilization, and pest control for optimal growth and yield. GPS technology assists in precise mapping and monitoring of fields, enabling farmers to manage and plan their operations more efficiently. Drones equipped with cameras and sensors can provide high-resolution images, helping identify issues like diseases, nutrient deficiencies, or pest infestations early on, enabling timely interventions. Automation plays a crucial role in precision agriculture as well. Automated machinery and equipment can perform tasks such as planting, spraying, and harvesting with precision and consistency. This not only saves labor but also ensures that tasks are carried out accurately, minimizing waste and maximizing yield. In this paper will describe the systems and equipment that can be used in growing vegetables.*
Keywords: vegetable farming, smart systems, precision agriculture

1. INTRODUCTION

'Precision Farming' or'Precision Agriculture' aims at increasing productivity, decreasing production costs and minimising the environmental impact on farming. In other words precision agriculture can be defined as a comprehensive system designed to choose risky agricultural production through the application of crop information, advanced technology and management practices. Precision agriculture is also known as precision farming, precision horticulture, site-specific farming, site-specific management, site-specific crop management, variable rate application, etc [1]. Information, technology and management are the keys to success in this production system [2]This approach considers a management system for farms that aims to increase yield or sustainability. PA can assist farmers, because it permits precise and optimized use of inputs adapted to the apparent plant status, consequently leading to reduced costs and environmental impact. Because the practise provides record trail, enhanced traceability of farm activities can be obtained that consumers and administration increasingly require [3].The steps can be divided into data collection and localisation, data analysis, management decisions on applications, evaluation of management decisions; and then a new cycle starts. Each year, data are stored in a database and are used as historical data for future

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decisionmaking [4]. Modern PA has a rather short history. Its application started over the last twenty-five years, when global positioning systems (GPS) and yield monitors were made available in field crops. Harvesting was mechanised and sensors were placed on harvesting machines to measure the spatial distribution of yield continuously. Applications started in cereals using impact or γ-ray grain flow sensors. When first yield monitors were developed and yield maps were created, it was shown that yield and soil properties varied highly within the field. This fact marked the development of modern PA [5]. However, applications in fruit and vegetables did not start until the 1990's and were published even later. This delay may be attributed, at least in part, to lack of appropriate technology [6]to record yield or quality data of the crop in an automated way. For this paper, will be describe the methods used in PA, as well as the benefits of this type of production in growing vegetables.

2. ELEMENTS OF PRECISION FARMING

2.1.The information

Information includes data on crop characteristics like stage of crop, crop health, nutrient requirement; detailed soil layer with physical and chemical properties, depth, texture, nutrient status, salinity and toxicity, soil temperature, productivity potential; microclimate data (season and daily) about the canopy temperature, wind direction and speed, humidity; surface and sub-surface drainage conditions; irrigation facilities, water availability and other planning inputs of interest [7].

2.2.The technological tools

Global Positioning System is one of the cutting edge technologies of this information- age for vegetable farming. Which asks the basic question "where is". It is computer based and the key components in this technology are satellites.

Geographical information system (GIS): A geographic information system (GIS) is a computer based system for storing very large amounts of data (collected based on spatial location), retrieving, manipulating, and displaying them for easy interpretation. The term "geographic" should be interpreted to mean "space" or "spatial". For crop production, some of the data of importance are soils, land use, vegetation, fertility, hydrology, and rainfall averages. Spatial analysis is concerned with analysing data involved with changes with space on location within an area. GIS has the capability of linking multiple sets of data (in layers) to study relationships among various attributes and creating new relationships.

Yield monitors: Yield monitors are crop yield measuring devices installed on harvesting equipment. The yield data from the monitor is recorded and stored at regular intervals along with positional data received from the GPS unit. GIS software takes the yield data and produces yield maps.

Variable Rate Technology: Consists of farm field equipment with the ability to precisely control the rate of application of crop inputs and tillage operations. Typical VRT system components include a computer controller, GPS receiver, and GIS map database. The computer controller will record the actual input being applied as the equipment crosses the field.

Remote Sensing: The art and science of obtaining information from a distance, i.e. obtaining information about objects or phenomena without being in physical contact with them. The science of remote sensing provides the instruments and theory to understand how objects and phenomena can be detected. The art of remote sensing is in the development and uses analysis techniques to generate useful information [8].Application of Remote Sensing in Precision Agriculture include:

Soil and drainage maps Soil maps. The grid sampling technique takes separate soil samples from uniform sized grids laid out over the field. Smaller grids are required which then requires many more soil samples to be taken for a larger number of grids. Drainage maps: colour infrared (CIR) aerial photographs have been shown to be an effective tool in locating unknown subsurface tile lines. The CIR photographs show different tones of grey depending on soil type and moisture. By filtering out spectral reflectance differences due to soil type, soil moisture content in dry soils that have a higher reflectance can be identified from lower reflectance wet soils. The resulting image shows where the tile lines are located and whether they are working properly [9].

Monitor crop health. Remote sensing data and images provide farmers with the ability to monitor the health and condition of crops. Multispectral remote sensing can detect reflected light that is not visible to the naked eye. The chlorophyll in the plant leaf reflects green light while absorbing most of the blue and red light waves emitted from the sun. Stressed plants reflect various wave lengths of light that are different from healthy plants. Healthy plants reflect more infrared energy from the spongy mesophyll plant leaf tissue than stressed plants. By being able to detect areas of plant stress before it becomes visible, farmers will have additional time to analyse the problem area and apply a treatment.

Water stress. The use of remote sensors to directly measure soil moisture has had very limited success. Synthetic Aperture Radar (SAR) sensors are sensitive to soil moisture and they have been used to directly measure soil moisture. SAR data requires extensive use of processing to remove surface induced noise such as soil surface roughness, vegetation and topography. A crop evapotranspiration rate decrease is an indicator of crop water stress or other crop problems such as plant disease or insect infestation. Remote sensing images have been combined with a crop water stress index (CWSI) model to measure field variations [10].

Weed management. Aerial remote sensing has not yet proved to be very useful in monitoring and locating dispersed weed populations. Some difficulties encountered are that weeds often will be dispersed throughout a crop that is spectrally similar, and very large scale high resolution images will be needed for detection and identification. The use of machine vision technology systems to detect and identify weeds places remote sensors directly on the sprayer equipment. Being close to the crop allows for very high spatial resolutions. Machine vision systems have the ability to be used in the field with the real time capabilities that are necessary to control sprayer equipment [11].

Insect detection. Aerial or satellite remote sensing has not been successfully used to identify and locate insects directly. Indirect detection of insects through the detection of plant stress has generally not been used in annual crops. The economic injury level for treatment is usually exceeded by the time plant stress is detected by remote sensing. Entomologists prefer to do direct in field scouting in order to detect insects in time for chemical treatments to be effective and economical.

Nutrient stress. Plant nitrogen stress areas can be located in the field using high resolution colour infrared aerial images. The reflectance of near infrared, visible red and visible green, wavelengths have a high correlation to the amount of applied nitrogen in the field. Canopy reflectance of red provides a good estimate of actual crop yields[12].

Yield forecasting. Plant tissue absorbs much of the red light and is very reflective of energy in near infrared (NIR) wavebands. The ratio of these two bands is referred to as the vegetation index (VI). The difference of red and NIR measurements divided by their sum is normalised difference VI (NDVI). For crops such as grain sorghum, production yields, leaf area index (LAI), crop height and biomass have been correlated with NDVI data obtained from multispectral images [13]. In order to get reasonably accurate yield predictions this data must be combined with input from weather models during the growing season [10].

2.3.Decision support (management)

Just having information about variability within the field does not solve any problems unless there is some kind of decision support system (DSS) in order to make VRT recommendations. Russo and Dantinne (1997) have suggested the following steps for a DSS:

1. Identify environmental and biological states and processes in the field that can be monitored and manipulated for the betterment of crop production.
2. Choose sensors and supporting equipment to record data on these states and processes.
3. Collect, store and communicate the field recorded data.
4. Process and manipulate the data into useful information and knowledge.
5. Present the information and knowledge in a form that can be interpreted to make decisions. Choose an action associated with a decision to change the identified state or process in a way that makes it more favourable to profitable crop production[14].

3. METHODS FOR IMPLEMENTING A PRECISION FARMING STRATEGY

1. **Map-based technologies**- This is currently the most widely used method. It may involve a GIS-based method of pre-sampling and mapping of the field. The computer generated maps are then converted into a form that can be used by the variable rate applicator. The applicator's controller then calculates the desired amount of an agronomic input to apply at each moment in time as the equipment traverses the field. The farmer knows how much of the agronomic input is needed before starting the application. A DGPS (Differential Global Positioning System) must be used to constantly evaluate the location in the field with a coordinate on the map and the desired application rate for that coordinate.

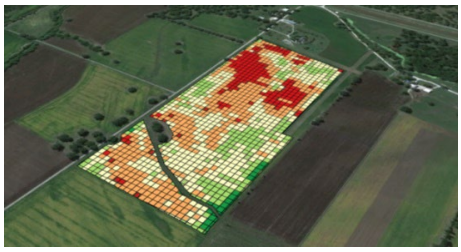

Figure 1. Mapping as a path to success in precision agriculture
Source: [15]

2. **Sensor-based technologies** – This method offers realtime sensing and variable rate control. The strategies provide on –the - go sensing of field characteristics, thereby eliminating the need for a positioning system. The sensors must be mounted strategically (e.g. at the front of the tractor) to allow the variable rate applicator's controller adequate time to adjust the rate of the agronomic input accordingly, before it passes the sensed location [7].

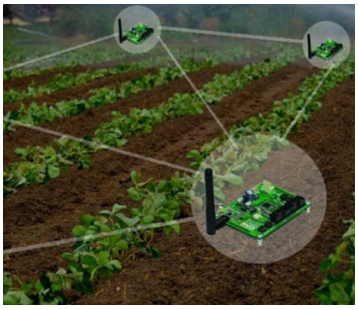

Figure 1. Examlple of the sensor based technology in agriculture
Source: [16]

4. CONCLUSION

Precision agriculture in vegetable farming has significant potential. Through technologies like sensors, GPS, and data analytics, farmers can optimize resource use, monitor crop health, and enhance overall efficency. PA enables targeted application of water, fertilizers, and pesticides, promoting sustainable practices and addressing specific needs of individualplants or areas within a field. Positive effect are increased efficency, enhanced yields, environmental sustainability, cost saving, this system can lead to reduced operational costs and increased profitability, data-driven decision making, because real-time data and analytics empower farmers to make informed decisions, allowing for proactive menagment of crops and addressing issues promptly. Negative sides are high initial costs, technological dependence, skill and knowledge gaps, data security concerns and environmental concerns. Balancing the positive and negative aspects of precision agriculture is crucial for its successful and susainable integration into vegetable farming practices. Addressing challenges and ensuring responsible use can maximize the benefits while minimizing potential drawbaks.

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THE AGRICULTURAL SMART SYSTEMS

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Abstract: *Precision agriculture has gained substantial attention due to the ever-growing world population demands for food and water. Due to the limited availability of both resources, farmers need a solution that changes the way they operate. The use of state-of-the-art technologies, such as the Internet of Things, transform traditional cultivation practices, like irrigation, to modern solutions of precision agriculture. Internet of Things (IoT)-based automation of agricultural events can change the agriculture sector from being static and manual to dynamic and smart, leading to enhanced production with reduced human efforts. Precision Agriculture (PA) along with Wireless Sensor Network (WSN) are the main drivers of automation in the agriculture domain. PA uses specific sensors and software to ensure that the crops receive exactly what they need to optimize productivity and sustainability. PA includes retrieving real data about the conditions of soil, crops and weather from the sensors deployed in the fields. High-resolution images of crops are obtained from satellite or air-borne platforms (manned or unmanned), which are further processed to extract information used to provide future decisions. In this paper will describe the basics of precision agriculture, as well as the systems that are applied.*
Keywords: smart agriculture, precision agriculture, IoT, PA, WSN

1. INTRODUCTION

Precision agriculture can be defined as a comprehensive system designed to optimise agricultural production through the application of crop information, advanced technology and management practices. To be a truly comprehensive system, it must begin during the planning stages of the crop and continue through the post harvest-processing phase of production. Information, technology and management are the keys to success in this production system [1]. The steps can be divided into data collection and localisation, data analysis, management decisions on applications, evaluation of management decisions; and then a new cycle starts. Each year, data are stored in a database and are used as historical data for future decisionmaking [2]. Modern PA has started over the last twenty-five years, when global positioning systems (GPS) and yield monitors were made available in field crops. Harvesting was mechanised and sensors were placed on harvesting machines to measure the spatial distribution of yield continuously.

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The technological tools often include:
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Water stress. The use of remote sensors to directly measure soil moisture has had very limited success. Synthetic Aperture Radar (SAR) sensors are sensitive to soil moisture and they have been used to directly measure soil moisture. SAR data requires extensive use of processing to remove surface induced noise such as soil surface roughness, vegetation and topography. A crop evapotranspiration rate decrease is an indicator of crop water stress or other crop problems such as plant disease or insect infestation. Remote sensing images have been combined with a crop water stress index (CWSI) model to measure field variations [8].

Weed management. The use of machine vision technology systems to detect and identify weeds places remote sensors directly on the sprayer equipment. Being close to the crop allows for very high spatial resolutions [9].

Insect detection. Aerial or satellite remote sensing has not been successfully used to identify and locate insects directly. Indirect detection of insects through the detection of plant stress has generally not been used in annual crops.

Nutrient stress. Plant nitrogen stress areas can be located in the field using high resolution colour infrared aerial images. The reflectance of near infrared, visible red and visible green, wavelengths have a high correlation to the amount of applied nitrogen in the field [10].

Yield forecasting. Plant tissue absorbs much of the red light and is very reflective of energy in near infrared (NIR) wavebands. The ratio of these two bands is referred to as the vegetation index (VI). The difference of red and NIR measurements divided by their sum is normalised difference VI (NDVI). For crops such as grain sorghum, production yields, leaf area index (LAI), crop height and biomass have been correlated with NDVI data obtained from multispectral images.

Decision support (management). Just having information about variability within the field does not solve any problems unless there is some kind of decision support system (DSS) in order to make VRT recommendations[11].

3. IoT BASED SMART AGRICULTURE

Every node is integration with different sensors and devices and they are interconnected to one central server via wireless communication modules. The server sends and receives information from user end using internet connectivity. There are two modes of operation of the system; auto mode and manual mode. In auto mode system takes its own decisions and controls the installed devices whereas in manual mode user can control the operations of system using android app or PC commands.

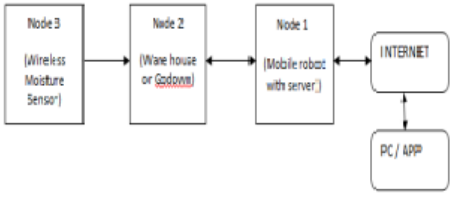

Figure 1. System overview
Source: [12]

3.1. Node 1- mobile robot with server

GPS based mobile robot which can be controlled remotely using computer. The Remote controlled robot have various sensors and devices like camera, obstacle sensor, siren, cutter, sprayer and using them it will perform tasks like; keeping vigilance, bird and animal scaring, weeding, and spraying.

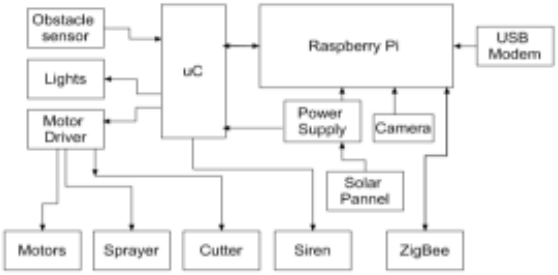

Figure 2. Mobile robot
Source: [12]

3.2. Node 2- werehouse

Warehouse it consists of motion detector, light sensor, humidity sensor, temperature sensor, room heater, cooling fan altogether interfaced with AVR microcontroller. Can also controls water pump depending upon the soil moisture data sent by node 3.

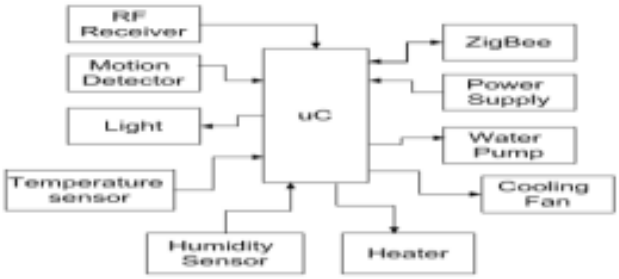

Figure 3. Node2- werehouse
Source: [12]

3.3. Node 3- Wirelles Moisture Sensor

Node 3 is a smart irrigation node with features like; Smart control of water pump based on real time field data i.e. automatically turning on/off the pump after attaining the required soil moisture level in auto mode, Switching water pump on/off remotely via mobile or computer in manual mode, and continuous monitoring of soil moisture.

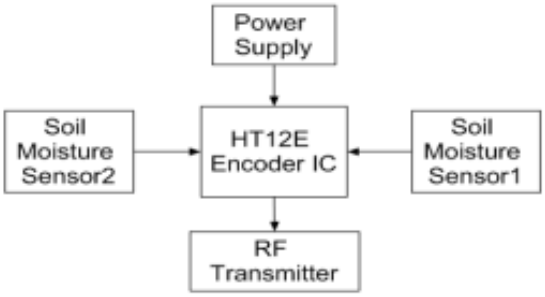

Figure 4. Node3- Wirelles Moisture Sensor
Source: [12]

4. CONCLUSION

Smart agricultural technologies, such as precision farming and automation optimize resource use, leading to increased crop yields and overall productivity. This is a vital for meeting the growing global demand for food. Smart systems enable precise menagment of resources like wather, fertilizers, and pesticides. This not only maximizes efficiency but also reduces waste, contributing to sustainable agricultural practices. By minimizing environmental impact through target resource application, smart agricultural systems promote sustainable farming. This is crucial for preserving ecosystem, minimizing pollution, and mitigating climate change. The enhanced productivity and efficiency brought about by smart agriculture contribute to global food security by ensuring a more reliable and abundant food supply. In rural areas, this technologies can lead to improved livelihoods, economic growth, and overall development in agricultural aommunities. In sumary, the global benefits of smart agricultural systems extend beyond individual farms, positively impacting food security, sustainability, and the well-being of communities worldwide.

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DRIVE UNITS IN ROBOTS FOR CONTROLLED PESTICIDE APPLICATION

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Abstract: *In order to reduce environmental pollution and negative impacts on human health, manufacturers of pesticide application machines started developing robotic systems which collect data on pests, harmful plants and diseases in order to provide information on the required amount of pesticides. One important design feature of a robot for controlled pesticide application is the robot locomotion system. Although unmanned aerial vehicles (drones) have been increasingly developed in recent years, wheeled robots have much higher payload capability. This paper analyses all the forces acting in the direction of the longitudinal axes of the wheels, as well as the main factors to be considered when selecting motors and reducers.*
Keywords: robots, controlled pesticide application, drive units

1. INTRODUCTION

The application of conventional pesticides is saddled with many problems such as negative effects on human health and the environment. Efforts to reduce these negative effects, enhanced by requirements of national and international regulations, have forced manufacturers to develop and promote more precise and more environmentally efficient machines. As a result, research and development activities have been intensified in the field of robotic systems related to controlled application of pesticides, which, according to available research data can detect and treat 85% to 100% of diseased areas, thus reducing the use of pesticides by 65% to 85% [1]. This results in substantial financial savings, which, for grain, amount to 12 EUR/ha for just one pesticide application [2].
Although robots for controlled application of pesticides consist of a large number of mechanical and electrical components [3,4,5,6], the drive unit of the locomotion system is one of the most important structural features. It makes it possible for a robot to overcome difficulties in complex terrains with longitudinal and transverse slopes and enables it to manoeuvre in small spaces, which is especially important for narrow rows in orchards and greenhouses. The aim of this paper is to analyze the forces acting in the direction of the longitudinal axes of the wheels, as well as the main factors to be taken into account when selecting motors and reducers.

2. DRIVE UNITS IN ROBOTS FOR CONTROLLED PESTICIDE APPLICATION

Generally, the drive units of robots for controlled pesticide application are mounted directly in the drive wheels (IWM). The main benefits of this design include an improved dynamic performance of the robot due to a more favourable mass distribution, the absence of need for complex transmission and a more flexible use of available space.

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Basically, the drive unit of the in-wheel hub system consists of an electric motor, a reducer and a wheel hub [7]. Development of permanent magnet synchronous motors (PMSM) made it possible to have directly driven wheels without a reducer. These motors provide higher torque and higher efficiency compared to induction motors (IM); however, they are much more expensive [8].

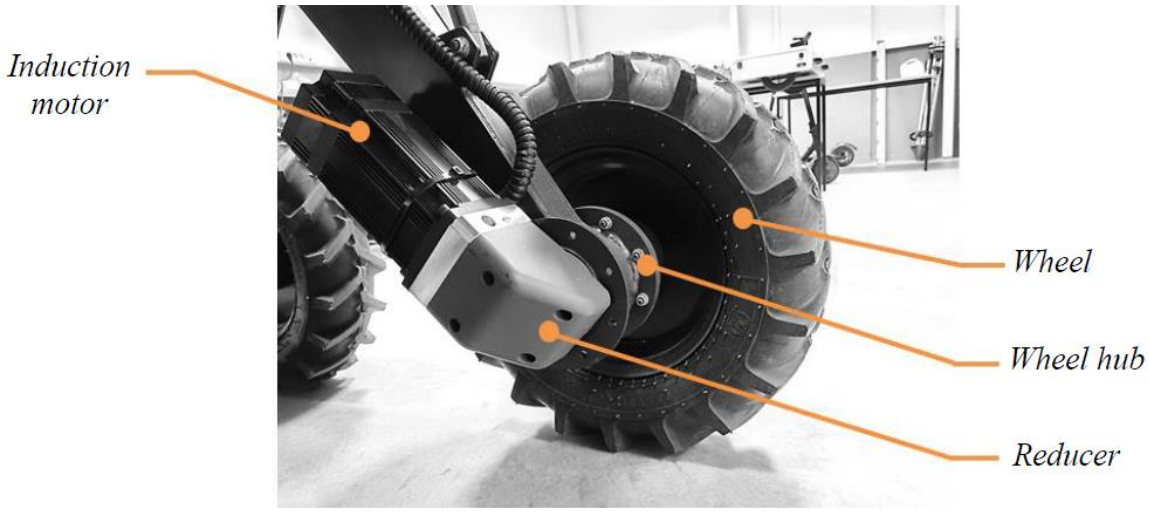


Figure 1. Drive units in an in-wheel-hub system
Source: own archives

3. TRACTION BALANCE, TORQUES AND MOMENTS OF INERTIA

The motion of the robot moving at a constant speed is opposed by: the rolling resistance (F_r), aerodynamic drag (F_{DF}), grading resistance (F_g), and, when moving at non-stationary speeds, by inertial forces (Figure 2). The values of these resistances are evenly distributed on the drive wheels. According to Newton's second law, the traction balance equation can be written as [7,9,10]:

$$m \cdot \frac{dv(t)}{dt} = F_T(\omega_{em}) - \left[F_r(t) + F_{DF}(t) + F_g(t)\right] \tag{1}$$

where: m – total mass, (Kg); $dv(t)/dt$ – change in speed per unit of time – acceleration, (m/s^2); $F_T(\omega_{em})$ – tractive effort as a function of the motor angular velocity, (N).

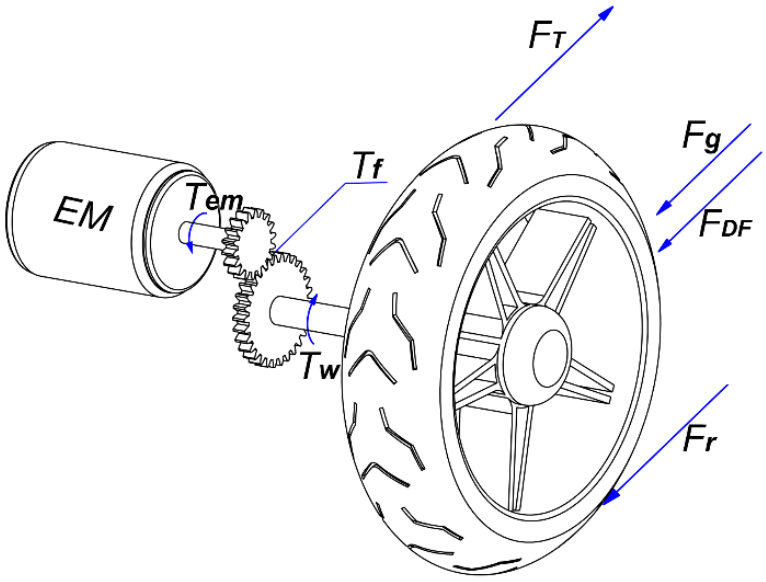


Figure 2. Drivetrain loading
Source: own archives

The total mass (m) is the sum of the actual mass of the robot for controlled pesticide application (m_v), the current volume of liquid in the tank expressed in mass (m_c), and the reduced electric motor mass (m_{em}), whereby the values of the other equivalent masses are neglected.

$$m = m_v + m_c + m_{em} \tag{2}$$

The reduced electric motor mass can be determined by the following expression [11]:

$$m_{em} = J_{em} \frac{4 \cdot {u_R}^2}{{d_w}^2} \tag{3}$$

where: J_{em} – moment of inertia of the electric motor, (kg/m^2); d_w – wheel diameter, (m).

The rolling resistance can be determined based on the expression [7,9,10]:

$$F_r(t) = m \cdot g \cdot \mu_r \cdot cos(\alpha) \tag{4}$$

where: μ_r – coefficient of the wheel rolling resistance; α – road grade angle, (°); g – acceleration of gravity, (m/s^2).

The rolling friction coefficient can be determined using the expression [10]:

$$\mu_r = \mu_0 \cdot \left(1 + \frac{v(t)}{161}\right) \tag{5}$$

where: μ_0 – basic friction coefficient; $v(t)$ – current velocity of the robot.

The aerodynamic drag can be defined as [7,9,10]:

$$F_{DF}(t) = \frac{1}{2} \cdot \rho_{air} \cdot C_d \cdot A_f \cdot \left(\frac{v(t)}{3{,}6}\right)^2 \tag{6}$$

where: ρ_{air} – air density, (kg/m^3); A_f – frontal area of the robot for controlled pesticide application, $A_f = 0{,}82 \cdot b_v \cdot h_v$, (m^2); b_v – maximum robot width, (m); h_v – maximum robot height, (m); C_d – aerodynamic drag coefficient which depends on the outer shape of the robot and the Reynolds number. The typical value of this coefficient ranges from 0.18 for a perfect aerodynamic body to 0.25÷0.30 when the tangential resistances and the surface discontinuity resistances are included [9].

The grading resistance can be determined based on the expression [7,9,10]:

$$F_g(t) = m \cdot g \cdot sin(\alpha) \tag{7}$$

The current value of the torque on the wheel can be defined as:

$$T_w(t) = \frac{\left[F_r(t) + F_{DF}(t) + F_g(t) + m \cdot \frac{dv(t)}{dt}\right] \cdot d_w}{2 \cdot N_w} \tag{8}$$

where: N_w – number of the drive wheels.

The current value of the torque that the motor needs to provide can be defined as follows:

$$T_{em}(t) = T_f + \frac{T_w(t)}{u_R} \tag{9}$$

where: T_f – total friction torque in the reducer.

The tractive effort that the motor can provide can be determined based on the motor characteristics:

$$F_T(\omega_{em}) = \left[T_{em}(\omega_{em}) - T_f\right] \cdot \frac{2 \cdot u_R}{d_w} \tag{10}$$

where: $T_{em}(\omega_{em})$ – the value of the torque which depends on the current speed of the motor (Figure 2).

4. CHARACTERISTICS OF THE INDUCTION MOTOR

Electric motors are mainly used in industrial machines which generally run at constant speeds, have little variability in load and have long running hours. However, in robots for controlled pesticide application, motors start and stop more frequently. Therefore, in addition to high reliability and efficiency, small size and low weight, electric motors used in robots must provide high torque for starting and climbing steep slopes and be able to withstand overload for a certain time period [11].
Figure 3 shows a typical characteristic of an induction motor. Here, three characteristic regions can be seen: the constant torque region, the constant power region and the reduced power region, which occurs at maximum speed [12].

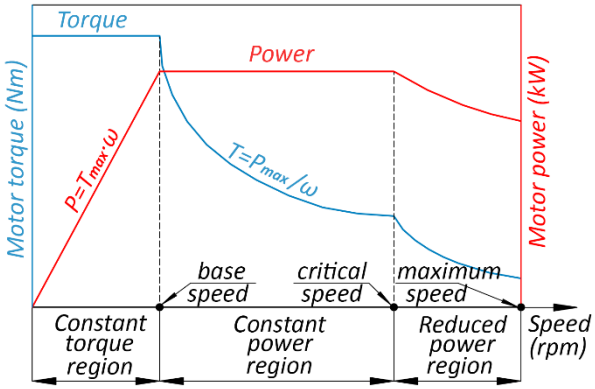


Figure 3. A typical characteristic of an induction motor
Source: own archives

5. SELECTION OF A REDUCER

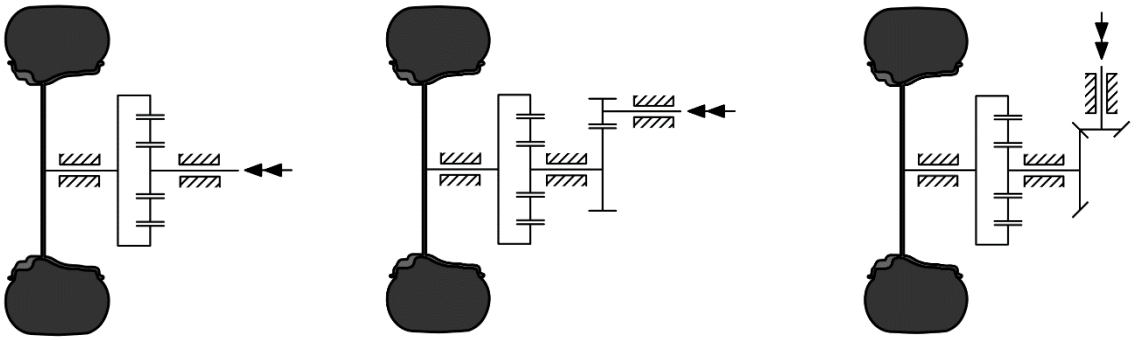
It is well known that a reducer significantly decreases the required torque, which affects not only the size and the weight of the motor but also the total weight of the robot for controlled pesticide application.
When designing the robot, special attention should be paid to the fact that the gear ratio of the reducer should enable the robot to achieve the maximum speed (v_{max}) and climb the maximum slope (usually α=16,7°, i.e. 30%). For that reason, it must be in the range defined as [13,14]:

$$u_{R\,min} = \frac{0{,}377 \cdot n_{max} \cdot r_{dyn}}{v_{max}} \tag{11}$$

$$u_{R_{max}} = \frac{r_{dyn} \cdot m \cdot g \cdot (f_r \cdot cos\alpha + sin\alpha)}{T_{em,max} \cdot \eta_{em} \cdot \eta_R} \tag{12}$$

where: n_{max} – maximum speed of the motor, (min^{-1}); v_{max} – maximum speed of the robot, (km/h); η_{em} – motor efficiency; η_R – reducer efficiency.

Depending on the mutual position of the input and output shafts, the reducers used to transmit the torque from the engine to the wheels can have either parallel axes or axes intersecting at a 90° angle. With reducers with parallel axes, the axes of the drive shaft and the wheel can be overlapping or the drive shaft axis can be above the wheel axis, which allows the motor to be be placed further up from the ground.



a) *b)* *c)*

Figure 4. Mutual positions of the reducer shaft and the wheel hub: a) parallel axes overlapping; b) parallel axes not overlapping; c) intersecting axes

Source: own archives

6. CONCLUSION

This paper describes the primary components of the drive units which enable robots for controlled application of pesticides to move around. The paper also analyses the forces acting in the direction of the longitudinal axes of the wheels (in the direction of the robot's motion) such as resistance to motion, required and available traction force. Some characteristics of induction motors and the most common designs of reducers which transmit torque to the drive wheels have also been analysed. Development of permanent magnet synchronous motors (PMSM) made it possible to have directly driven wheels without a reducer, however, these motors are much more expensive than the induction ones.
The methodology used in this paper can be applied to other robotic systems in agriculture as well as to electric vehicles, hence, it can be concluded that this paper makes a valuable contribution to engineering practice especially to the field of designing.

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DEEP LEARNING IN FRUIT DETECTION

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Abstract: *Over the past decade, there has been a marked surge in scholarly publications focusing on machine learning, the Internet of Things (IoT), and deep learning, particularly in the context of the fruit industry. Deep learning (DL) is a specialized approach within the broader field of machine learning (ML), which itself is a subset of artificial intelligence (AI). Deep neural networks serve as the backbone for constructing fast and reliable predictive systems that are increasingly vital in agricultural production. This paper aims to encapsulate the critical role that deep learning plays in shaping the future of the fruit industry.*
Keywords: artificial intelligence, fruit industry, Internet of Things

1. INTRODUCTION

The adoption of robotics in agriculture is on the rise, driven by the need to improve efficiency and enhance fruit production, especially in large-scale operations. Various technologies—from fruit detection and measurement to automated harvesting-are increasingly being integrated with robotic systems. While these advancements have brought transformative changes to the fruit industry, they also come with challenges that can impede their widespread adoption.
In this paper, we will explore the pivotal role of deep learning in fruit production. Deep learning is a specialized approach within the broader field of machine learning, which itself is a subset of artificial intelligence [1]. We aim to underscore the significance of deep learning technologies in shaping the future of modern agricultural practices.

2. WHAT IS DEEP LEARNING?

Deep learning, a specialized form of machine learning, represents a significant advancement in the field of computational science. In deep learning, neural networks comprise various interconnected layers that interact within an extended framework. This architecture allows artificial intelligence (AI) systems to tackle a wide range of complex, non-standard tasks. For instance, deep neural networks can process and recognize intricate images in real-time. The data fed into these networks is simultaneously analysed across multiple layers, each discerning unique input aspects. Without the foundational technologies of AI, machine learning, and deep learning, certain computational tasks—such as speech and image recognition or even playing board games like checkers—would be infeasible. The capability to process vast data sets and identify underlying patterns enables machines to execute tasks of varying complexity [2]
In simpler terms, machine learning is a methodology that empowers computers to perform specific tasks without the need for explicitly programmed algorithms [2]. The initial data sets often include the insights needed by experts across various domains. The ultimate goal is to leverage cutting-edge technologies to identify and implement effective solutions.

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3. DEEP LEARNING IN FRUIT DETECTION-SHORT REVIEW

In recent years, there has been a surge in interest in applying artificial intelligence (AI) techniques and robotic systems to automate agricultural processes. This is particularly true for developing intelligent agriculture and automating fruit harvesting. Automatic fruit harvesting involves two key tasks: (1) the sensor-based detection and localization of fruit on trees, and (2) the robotic arm's precise movement towards the identified fruit for harvesting without causing damage to either the fruit or its tree [3].

Various studies have explored sensor-based detection and localization of fruit on trees, with many of these works summarized in the review by Gongal et al.[4]. Spectral and thermal cameras are commonly employed in these methods. Spectral cameras struggle to detect fruit that lies in the shadow of other objects, while thermal cameras identify fruit based on temperature differences between the fruit and its background, a method influenced by fruit size and exposure to sunlight.

Different attributes, such as colour and shape, are used for fruit detection. For instance, colour cameras in conjunction with a K-means clustering algorithm have been effective in locating apples on trees or soil [5]. Deep learning has proven to be a potent tool for detection and classification, often utilizing fruits' colour and shape characteristics for segmentation and recognition [6]. Spectral features and depth information are also used in fruit detection [7, 8, 9].

Thanks to deep learning's robust capacity for extracting high-dimensional features from fruit images, researchers have proposed a plethora of fruit detection and recognition methods. These methods are often based on deep learning architectures like Single Shot Multibox Detector (SSD), Alex Krizhevsky Networks (AlexNet), Visual Geometry Group Networks (VGGNet), Residual Networks (ResNet), Faster Region-Convolutional Neural Networks (Faster R-CNN), Fully Convolutional Networks (FCN), SegNet, and Mask Region-Convolutional Neural Networks (Mask R-CNN) for automatic harvesting [11].

4. ROBOTS IN FRUIT DETECTION

Robots employed in agriculture vary in form and size but generally share three distinct characteristics: they are designed for specific tasks, equipped with electrical components for power and control, and programmed with specialized software. These robots typically consist of five main components: sensors, controllers, actuators, robotic arms, and end-effectors. The types of sensors often integrated into these robots include microphones, ultrasound sensors, acoustic vector sensors, cameras, infrared sensors, and chemical detectors. The robotic arm, outfitted with end-effectors and sensors, executes pre-programmed tasks. In agricultural settings, common end-effectors include grasping and vacuum pumps [12].

Modern agriculture, also known as precision farming, increasingly relies on algorithms, satellites, drones, and robots. Innovations include carbon nanotube sensors embedded directly into plant leaves, which send alerts to farmers' smartphones when the plants show signs of infection, dehydration, or sun damage [13]. This kind of AI has even found applications in automated labelling and pricing in grocery stores, with colour and texture serving as crucial parameters for natural image recognition.

Agricultural productivity is influenced not only by the technology available to farmers but also by government policies. Deep learning has shown promise in fruit farming, streamlining tasks traditionally carried out by human experts, such as fruit classification and sorting. Thus, research in deep learning should not merely remain an academic exercise; it represents a key aspect of future management in an era where global fresh fruit production has reached 887 million metric tons (global production of fresh fruit from 1990 to 2021) [14].

5. CONCLUSION

Advancements in research and development are driving the automation of various sub-sectors in agriculture, aiming to boost economic growth, productivity, and environmental conservation through the use of deep learning, robotics, and artificial intelligence (AI).

Fruit detection typically employs two primary methods: traditional image processing techniques and deep learning-based approaches. Existing research indicates that while traditional methods can be highly efficient, they often struggle with colour similarities, complex backgrounds, and varying lighting conditions, leading to inaccurate results. One of the primary challenges in developing deep learning algorithms for this application is the lack of standardized datasets and high-performance computing resources. Furthermore, the use of large datasets can slow down the training process, even for pre-trained networks.

For effective fruit harvesting, pinpointing the exact location for detachment is crucial for maintaining quality and optimizing storage. Current limitations in sensing technology and fruit and picking point detection algorithms offer important avenues for future research. These gaps need to be addressed to develop a fully automated robotic system that can enhance processing speeds and overall productivity.

In this brief review, we have examined various deep-learning methods that have been explored for fruit detection and classification. While earlier reviews have largely focused on traditional computer vision techniques, deep learning models have not garnered as much attention, despite their proven effectiveness in numerous image classification tasks.

A comprehensive study is still needed—one that takes into account feature description, detection algorithms, classification algorithms, and the diversity of datasets used in fruit production. After critically analysing the reviewed methods, we identified open challenges, particularly concerning datasets. We hope this review serves as a foundational guide to the basics and applications of deep learning models in fruit detection and classification, particularly for those new to the field.

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CHEMICAL PROPERTIES AND MICROBIOLOGICAL CONTROL OF FROZEN PLUM FRUIT

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Abstract: *Plum (Prunus domestica) is one of the most commonly grown and most important fruit species in Serbia. The plum fruit is oblong in shape. The edible part of the fruit (skin and flesh) makes up to 94-96% of the mass, and the rest is the pit and seeds. The substances found in the edible part of the plum fruit are: water, sugars, organic acids, fatty, nitrogenous, as well as colored and aromatic substances, vitamins, enzymes and mineral substances (ash). The aim of this work was to examine the chemical properties and to perform microbiological quality control of the fresh and the frozen plum fruit. The following parametres were examined within this analysis: dry matter content, pH value, acid content (such as citric), total sugar content, vitamin C content, total phenol and anthocyanin content. The microbiological quality control of the fresh and the frozen plum fruit included testing for food spoilage bacteria, such as Salmonella spp, Listeria monocytogenes and Enterobacteriaceae. The test results indicated that both the fresh and the frozen fruit is a good source of vitamin C, anthocyanins and total phenols, which indicates that the plum fruit has a significant protective, dietary and therapeutic value. The microbiological methods performed to test the frequency of Salmonella spp., Listeria monocytogenes and Enterobacteriaceae, showed the absence of Salmonella spp. and Listeria monocytogenes and the presence of Enterobacteriaceae in less than 10cfu/ml.*
Key words: *plum fruit, chemical analysis, anthocyanins, microbiological control*

1. INTRODUCION

Plums are, directly next to peaches, one of the most important types of stone fruit, with a world production of more than 12 million tons per year [1,2,3]. They represent a relatively young species discovered by the Southern Slavs upon their migrations to the Balkan Peninsula. Their origin is considered to be Eastern Europe and Western Asia, namely the Caucasus Mountains near the Caspian Sea [1]. Along with China, Chile, Turkey and Romania, Serbia is one of the world's greatest producers of plums. Plum is the most commonly grown fruit species in Serbia. It is grown on the whole territory of Serbia, the most prominent growing areas being Western Serbia, Šumadija and parts of Southern Serbia near the town of Prokuplje [4]. Based on the data of the Republic Institute of Statistics, the total yield of plums in 2019 was 558,930 t on 72,316 ha of growing area [5]. The best known plum varieties include ″Čačanska lepotica″, ″Stanley″, ″Čačanska rana″, ″Čačanska rodna″ and others [6].

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The plum fruit is characterized by its oval shape and blue skin. The share of the stone in the fruit is about 6.2%. The edible part of the plum fruit consists of water, sugars, organic acids, fatty, nitrogenous, colored and aromatic substances, vitamins, enzymes and mineral substances (ash). As for its composition, the plum fruit is mostly composed of fibers and phenols. It is an excellent source of vitamins C, A and K, and it is rich in phytonutrients - potassium, magnesium, phosphorus and copper. Plums protect our health and prevent serious diseases because this fruit is rich in antioxidants. Depending on the variety, plums are harvested from the second half of August till the end of September [7]. The dark skin varieties are the most valued because they are extremely rich in antioxidants, phenols and catechins, and they also have a high content of neochlorogenic and chlorogenic acids [8]. Because of their low calorie content , they are recommended in the reduction diets [9]. Wang et al. (*2016*) [10] proved that the plums have several times higher antioxidant capacity than the apples. They can be consumed fresh, but they can also be processed into jam, compote, preserves and cloudy fruit juice, whereas considerable quantities are dried or frozen [7].

2. MATERIAL AND METHODS

Plums (*Prunus domestica L.*) of the Stanley variety were collected at a plantation in the vicinity of Prokuplje (Toplica district). The fruit for testing was selected at the beginning of September, based on acceptable appearance, lack of damage, acceptable size and color. Hand-picked fruit was transported in polyethylene containers to the laboratory for further analysis. The pitted samples of fruit intended for freezing were frozen in the Frigoscandia continuous tunnel. The process of freezing lasted 10 to 15 minutes at an air temperature of - 35°C to - 40°C within the tunnel , so that a temperature of - 18°C was reached and stabilized in the thermal center of the fruit.

The following parametres were analyzed for the purpose of this work: dry matter content, pH value, acid content (such as citric), total sugar content, vitamin C content, total phenol content and anthocyanin content . All the analyses were performed on fresh and frozen fruit. In addition, microbiological quality control of the fresh and the frozen plum fruit was performed. All the analyses were carried out in the laboratory of the Department of Agricultural and Technological Studies at the Toplica Academy of Applied Studies in Prokuplje. 10 repetitions of tests were carried out. The dry matter content was determined refractometrically from the chopped samples of fresh and frozen plum fruit, using an Abbe refractometer [11].

The mother solution was prepared in such manner that a homogenized sample of fresh or frozen fruit was covered with a certain volume of hot distilled water, heated and filtered after cooling. The filtrate was used to determine the pH value, total acidity and the total sugar content.

The pH value was determined using a pH meter, the sufficient volume of the mother solution being taken for the immersion of the electrode [11]. The total acid content was determined by acid titration using a standard sodium hydroxide solution in the concentration of 0.1 mol/dm3, in the presence of the phenolphthalein indicator. The result was expressed in % as citric acid [11].

The total sugar content was determined by the volumetric method according to Luff-Schoorl. This method is based on the principle that the reducing sugars convert copper (II)-sulfate from Luff's solution into copper (I)-oxide. The result was expressed in % [11].

The content of vitamin C was determined by a spectrophotometric method based on the reduction of vitamin C with 2,4-dinitrophenyl hydrazine. The absorbance was measured at a wavelength of 510 nm. The vitamin C content was expressed as mg/100 g [12].

As for the anthocyanin content, it was determined spectrophotometrically, using the pH differential method according to Fuleki and Francis. The homogenized sample was extracted with 0.1% HCl in methanol. The resulting filtrate was used for analysis. The absorbances of plum extracts were measured at 510 and 700 nm in 0.025 M potassium chloride buffer (pH 1.0) and 0.4 M sodium acetate buffer (pH 4.5). The content of anthocyanin was expressed as mg equivalent of cyanidin 3-glucoside per 100 g [13].
Determining the content of polyphenolic compounds was performed according to the Singleton method [14] using the Folin-Ciocalteu reagent. The homogenized sample was extracted for one hour with 80% ethanol. After 5 minutes, distilled water, Folin-Ciocalteu reagent and 20% Na2CO3 were added to the filtrate . The absorbance was measured at a wavelength of 765 nm. A calibration curve of standard solutions of gallic acid was used for the determination of total polyphenols (mg of gallic acid/100 g of sample). All the measurements were carried out in triplicate, and presented as mean ± SD.
The microbiological quality control included testing for food spoilage bacteria *Salmonella spp., Listeria monocytogenes, Enteriobacteriaceae*. All the methods were performed on the basis of ISO standards, namely ISO 6579-1:2017 for *Salmonella spp*. , ISO 11290-1:2017 for *Listeria monocytogenes* , ISO 21528-2:2017 for *Enterobacteriaceae* , ISO 16649-1:2018 for *E. coli*.

3. RESULTS AND DISCUSSION

The results of the chemical analysis of fresh and frozen plum fruit of the Stanley variety are presented in Table 1.

Table 1. Chemical analysis of fresh and frozen plum fruit of the Stanley variety

Fruit	pH	Acidity (total acidity as citric %)	Dry matter (%)	Total sugars (%)
fresh	2.98 ± 0.130	1.58 ± 0.07	18.4 ± 0.527	16.5 ± 0.726
frozen	2.52 ± 0.07	1.95 ± 0.07	17.0 ± 0.701	16.0 ± 0.866

The concentration of anthocyanins (mg/100g), vitamin C (mg/100g) and total polyphenols (mg of gallic acid/100g) in fresh and frozen plum fruit are presented in Table 2.

Table 2. The concentration of anthocyanins, vitamin C and total polyphenols in fresh and frozen plum fruit

Fruit	Anthocyanins mg/100g	Vitamin C mg/100g	Total polyphenols mg of gallic acid/100g
fresh	70.24 ± 0.633	5.84 ± 0.09	175.2 ± 0.667
frozen	65.42 ± 0.386	4.2 ± 0.02	124.5 ± 0.882

A comparative analysis of the Stanley plum variety was performed in this paper, both in the fresh and the frozen state. The results showed that the pH value of the fruit is expectedly lower in the frozen state. In the fresh fruit of the tested variety, the acidity is lower compared to the frozen fruit, which is consistent with the change in pH value. The obtained values of acidity (as citric acid) of the fresh fruit are in accordance with literature data [15]. There is no significant difference in the proportion of dry matter when comparing the fresh (18.4 ± 0.527 %) and the frozen fruit (17.0 ± 0.701). The share of dry matter of the fresh fruit is lower

compared to literature data [16], while the research by Pashova *(2016)* [17] showed the same content of dry matter. The content of total sugars in the fresh fruit showed no significant deviations in relation to the frozen fruit, while Bozhkova *(2014)* [15] and Pashova *(2016)* [17] determined a lower sugar content in the fresh fruit.
The difference in chemical composition can be significant depending on the production-related factors, but also on the conditions that occurred after the harvest [18]. The results of the anthocyanin content testing in the fresh and the frozen state showed significant deviations. The fresh fruit had a higher concentration of anthocyanins (70.24 ± 0.633 mg/100g) than the frozen fruit (65.42 ± 0.386 mg/100g). The lower concentration of total anthocyanins in the frozen state was due to the change in the pH value and the temperature of the fruit processing [19]. The research of Miletić et al. (*2012*) [20] found a much lower concentration of anthocyanin content in the fresh fruit of the Stanley variety. The difference in the anthocyanin content can be explained by the differences related to the geographical area, agro-ecological conditions and the year of cultivation.
The comparative analysis of the vitamin C content (5.84 ± 0.09 mg/100 g) was in accordance with the research of Pashkov*(2016)* [17], while there were deviations in relation to the research of Bozhkov *(2014)* [15] , which determined a higher content of vitamin C (11.92 mg/100 g). The amount of vitamin C in the frozen fruit decreased. The content of total polyphenols in our research (175.2±0.667mg GAE/ 100g) was in accordance with the results of research by Kim et al. (2003) [8]. A lower content of polyphenols was also observed in the frozen fruit compared to the fresh.
The classic microbiological test according to ISO standards, which is used for the detection and enumeration of food spoilage agents and potential opportunistic pathogens in humans, showed a lower frequency of microorganisms of the *Enterobacteriaceae* family and the absence of *Salmonella* spp., *Listeria monocytogenes*.

Table 3. The results of the microbiological testing of the frozen plum fruit

Microorganisms	Method designation	Determined value
Salmonella spp.	SRPS EN ISO 6579-1:2017	no presence determined
Enterobacteriaceae	SRPS EN ISO 21528-2:2017	< 10 cfu/g
L. monocytogenes	SRPS EN ISO 11290-1:2017	no presence determined

4. CONCLUSION

Considering that plums are one of the most important fruit species grown in our country and that they are used extensively in nutrition, every research of the chemical composition and the microbiological control of this fruit is extremely important. Each year, large quantities of plum yields are frozen, so it is important to examine the chemical composition and the microbiological properties of the fruit in frozen state. The results of our research of the Stanley variety showed that the fresh plum fruit is rich in anthocyanins, vitamin C and polyphenols, whereas these values decrease in the frozen state. The microbiological control of the fruit quality in fresh and frozen state showed a lower presence of the microorganisms of the *Enterobacteriaceae* family and the absence of *Salmonella* spp. and *Listeria monocytogen*es. Future research should be focused on examining the concentration of individual anthocyanins in different varieties of plums from our region, in the fresh and the frozen state.

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APPLICATION OF MEDICINAL HERBS AND SPICES AS A FOOD ADDITIVE – CHALLENGES AND LIMITATIONS

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Abstract: *In recent decades there is a strong demand for limitation or completely elimination of synthetic food additives since it has been confirmed their harmful effect on human health. At the same time, application of medicinal herbs and spices for the same purposes is gaining more importance since certain plant species represent a rich source of bioactive compounds that can effectively prevent undesirable microbiological and chemical changes in food. However, the application of medicinal herbs and spices as food additive is often subject to numerous limitations. Optimizing the conditions for isolation of targeted bioactive compounds, purification of isolates, low yields and limited application due to the changed sensory characteristics of the food to which they are added, are just some of the challenges that researchers encounter. Therefore, in this paper will be represents the main challenges and limitations that researchers and food producers are most often faced in the application of medicinal herbs and spices as natural substitutes for synthetic ones.*
Keywords: Food additives, Challenges, Phytochemicals, Medicinal herbs, Spices

1. INTRODUCTION

The confirmed harmful effect of certain synthetic additives on human health places a strong demand on food producers to search for an alternative ways and equally effective substitutes. These expectations force the food industry in the use of antioxidant, anti-browning and antimicrobial ingreadiens with more natural origin, safely promoting the shelf-life and quality of foods [1]. Medicinal herbs and spices are recognised as one of valuable source of active compounds. These botanical row material have high contents of phytochemicals that could be used in food industry, pharmaceuticals, health supplements and cosmetics. Large amounts of phytochemicals (phenolics, flavonoids, carotenoids and volatile compounds) are responsible for wide range of biological activities including antioxidant, antibacterial, antihypertensive, antitrombotic i immunomodulatory [2,3]. The use of medicinal herbs and spices dates back to 5000 B.C. so they might be considered one of the first functional foods [4]. Although the use of medicinal herbs and spices for flavoring and extending the shelf life of food products is not recent, they are mostly used in tea formulations and row material for isolation of essential oils which could be partly attributed to the lack of knowledge on chemical profile and bioactive potential of underutilized plants [3]. However, there is the great interest of researchers and food producers for application of these valuable natural ingredients in food. So far, most common essential oils are approved by Food and Drug Administration of United States (FDA) as generally regarded as safe (GRAS) [4,5]. In Europe, European Food Safety Authority (EFSA) already registered many volatile consitutents of essential oils such as citral, *p*-cymene,

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limonene, carvone, cinnamaldehyde, menthol and thymol as safe food flavoring aromatizing agents. EFSA also ruled many essential oils for use in feed of animal husbandry, and it is a matter of time when their usage will be extended on food products as well [5].
Nowadays, the focus of researchers and food producers is on isolates of medicinal herbs and spices, their extraction in the most purified form, in an economical and environmentally friendly way. In this responsible work, they encounter numerous limitations and challenges related to the proper selection of the extraction technique and conditions. Also, full implementation of this supstitution is postponed by some challenges associated with bioactive ingredients, including their low chemical stability, off-flavor, low solubility and short-term effectiveness [1].
Therefore, in this paper will be represents the main challenges and limitations that researchers and food producers are most often faced in the application of medicinal herbs and spices as natural substitutes for synthetic ones.

2. CHALLENGES AND LIMITATIONS ASSOCIATED WITH CHEMICAL COMPOSITION AND MANUFACTURING OF THE MEDICINAL HERBS AND SPICES

The use of medicinal herbs and spices is associated with chemical composition of isolated extracts and essential oils. Many factors such as season of harvest, environmental conditions, region of cultivation, plant parts used, and type of processing can affect the levels and mechanisms of various compounds in extracts. All above factors are limiting for the reproducibility of the composition of herb extracts and essential oils so characterization and authentication of active compounds are necessary to be established quality control procedures [6].
Also, application of medicinal herbs and spices essential oils demands safety assessment. Depending on the dose of exposure, the potential benefits of phytochemicals in medicinal herbs and spices might be changed and reversed to toxic effects including carcinogenic, neurotoxic, genotoxic, teratogenic, cytotoxic, nephrotoxic, hepatotoxic and gastrointestinal toxic effects [7].
In this respect, specific protocols for essential oils chemical and toxicological analyses were developed as well as approved guides for processing and the safety restrictions for the volatile components content in essential oils as the synergistic and antagonistic effect may arise for specific essential oil. In case of medicinal plant and spices extracts, studies concerning the toxicity of the most promising extracts are major challenge for their use. Most extracts have not been evaluated so, the lack of this information regarding the actual toxicity of many extracts in concerning, since the adverse effects caused by the misuse of medicinal herbs and spices are characterized as a public health problem [6]. The solution for this challenge lays in permanent control and setting up the production standards.
Besides that, there is a rising aspect of medicinal herbs and spices safety in their possible contamination by chemicals such as pesticides [2].

3. CHALLENGES AND LIMITATIONS ASSOCIATED WITH EXTRACTION TECHNIQUE AND CONDITIONS

Extraction is a first critical step since it is necessary to extract the desired phytochemicals from the plant materials [8]. Well standardized procedures are mandatory, but it is not simple to establish a standardized extraction method for each plant source [8,9]. Process optimization is usually on a case-by-case basis and should be thoroughly investigated for each plant species [3].
Selection of proper technique and optimal extraction conditions for the isolation of active compounds form medicinal herbs and spices is one of the key steps. The choice of an appropriate extraction method depends on the nature of the plant material, solvent used, pH of the solvent, temperature, solvent to sample ration as well as use of the final products [10]. Conventional isolation techniques of bioactive compounds (maceration, percolation, Soxhlet extraction) are characterized by a number of disadvantages: low yield, long extraction time, high solvent consumption, cost and negative enviromental impact and thermal decomposition of thermolabile compounds and additional costs in

the form of processing and purification of isolates [9,11,12]. Many of these limitations have been avoided by developing alternative, nonconventional extraction techniques, or by improving existing ones. Depending on the type and mechanism applied for modification of the process, nonconventional techniques could be accelerated by ultrasounds, microwaves, enzymes, high pressure (subcritical and supercritical solvents), electric fields (pulsed electric fileds and high voltage discharge) and others [3]. In case of extraction of volatiles, the combination of conventional techniques with new methodologies has increased yields, purity and quality of volatiles [5].For the solvent extraction, the selection of the solvent is crucial. Selectivity, solubility, cost, reactivity and safety should be considered in selection of the solvents [10,11]. The properties of a good solvent for herbal plant extraction also include low toxicity, easy evaporation, inability to cause the extract to form complexes, preservative action and promotion of rapid physiological absorption of the extract [8]. Traditional extraction techniques usually involved large quantities of organic solvents which caused additional costs in term of purification of isolate. Furthermore, these solvents have substantially high costs, as well as environmental and human toxicity, even if they are present in traces [3]. Novel extraction techniques support concept of „green“ solvent which is aimed to minimize the negative environmental impact from the utillization of large amounts of solvent [9].
Another important step is purification of the isolate. This step is neccesary in case non-selective extraction procedure is applied, so several undesirable components are also co-extracted and may interfere targeted active compounds [13]. Therefore, the usage of high selective techniques or some of techniques which comprise extraction and purification is required.

4. CHALLENGES AND LIMITATIONS ASSOCIATED WITH FOOD INGREDIENTS AND SENSORIAL PROPERTIES

Influence on the activity of bioactive compounds could also have the characteristics of the food to which medicinal herbs and spices are added. External factors (storage conditions, type of packaging, characteristic of microorganisms that cause spoilage) as well as internal (the presence of interfering compounds such as fat, proteins, water, antioxidants, other additives and pH reaction) can have different influence the effectiveness of the active compounds [4,14].
The main limitation of usage medicinal herbs and spices as food additive is their influence on sensory characteristics of food. The complex nature of food requires higher concentrations of active compounds to achieve the same efficacy as *in vitro* conditions. On the other hand, higher concentrations are limited by development of negative organoleptic characteristics in food. These limitations can be overcome with several strategies: the use of synergistic interaction with other additives or combined action with heat treatment or vacuum-packaging. On the other side, medicinal herbs and spices in form as essential oils may be used in active packaging by incorporating low essential oil concentration in food packaging films [2,4]. Encapsulation into micro- and nano emulsions is other confirmed strategy to overcome these limitations. This approach allows the use of higher concentrations without the undesirable effects on sensorial properties of food or interacting with the food components and, at the same time, enables preservation of thermolabile components [5,14].

5. CONCLUSION

Medicinal herbs and spices are recognized as valuable source of active compounds which can contribute to food preservation and shelf life extension. Isolates of these plants represent a promising substitute for synthetic additives. However, the use of these herbs as food additive encounters numerous challenges and limitations associated with plant material, food ingredients and extraction procedure of active compounds. So far, several strategies have been developed to overcome them, but it is up to competent institutions and researchers to set certain standards and protocols in order to ensure the safest possible application.

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POLYCYCLIC AROMATIC HYDROCARBONS IN MEDICINAL HERBS: ANALYTICAL METHOD DEVELOPMENT

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Abstract: *Polycyclic aromatic hydrocarbons (PAHs) are among the most toxic compounds known to man. Several PAHs are proven to be carcinogenic, mutagenic and teratogenic. Due to their wide distribution in the environment and their toxicity, it is considered important to monitor the levels of these compounds in foodstuff. PAHs have been detected in many foods including plant-based such as vegetable oils, cereal grains, herbs, spices, teas and supplements. As the awareness for the healthy lifestyle has increased globally, the intake of medicinal herbs as tea and spices has also grown immensely. Therefore, even stronger emphasis must be made to monitor the toxic levels of PAHs in herbs. The legislations of the maximum concentrations of certain contaminants in food of the Republic of Serbia included PAHs values in dry herbs only by the end of 2019 (Official Gazette RS, No. 81/2019) in comparison to European Commission Regulation dating from 2011. Therefore, herein we focused on analytical method development for PAHs determination in medicinal herbs.*
Keywords: PAHs, medicinal herbs, validation, processing, HPLC-FLD

1. INTRODUCTION

Polycyclic aromatic hydrocarbons (PAHs) are organic compounds consisting of two or more condensed aromatic rings, they are toxic and have carcinogenic properties, and they are widespread in the environment [1]. PAH compounds can be produced naturally or anthropogenically. Naturally, a certain amount of PAHs in our region reaches the biosphere as a result of forest fires and hydrothermal processes. In urban [2] and industrial locations [3], PAHs are almost entirely emitted by human activity and are the main by-products of incomplete combustion of organic matter, and therefore become the main source of atmospheric pollution. These compounds from the air reach the soil and water environment through sedimentation or precipitation, from where they further reach fruits, vegetables and herbs, and finally the human body. People are exposed to PAHs in different ways. For non-smokers, the main source of exposure is the consumption of food and drink, as well as supplements. The special danger of PAHs for human health is due to their ability to bioaccumulate in the human body [4].

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The natural presence of wax on plant surfaces can concentrate low molecular weight PAHs, mainly through surface adsorption. The concentration of PAHs is generally higher on the surface of the plant (outer leaves, bark) than in the interior [5]. However, the origin of PAHs in fruits, vegetables and herbs is mainly of anthropogenic origin. Pollution of raw products (agricultural products) occurs during cultivation, growth, but also during transportation due to the deposition of aromatic hydrocarbons present in engine exhaust gases as well as during storage [6].
In order to put on the market products that are healthy and safe for human health, the criteria of standards and maximum allowed concentrations prescribed by the provisions of national and EU regulations must be met. There are a large number of different PAHs, however, for the research and monitoring of their concentrations in environmental samples (water, air, soil, treated waste, sludge) the European Union and the American Environmental Protection Agency (Eng. Environmental Protection Agency, EPA) defines only 16 of them as priority (European Commission, 2005). PAHs known for their carcinogenic, teratogenic and mutagenic properties are: benzo[a]anthracene and chrysene, benzo[b]fluoranene, benzo[j]fluoranene, benzo[k]fluoranene, benzo[a]pyrene, benzo[gy]perylene, coronene, dibenzo[a,h]anthracene, indeno[1,2,3-cd]pyrene and ovalene. Although these 16 PAHs are highly relevant for environmental monitoring programs, they have not entered food legislation. Historically, benzo[a]pyrene has been used as the sole marker of toxicity; however, data have shown that foods, herbs, and food supplements contain toxic PAHs without the presence of benzo[a]pyrene. A re-evaluation by the European Food Safety Authority (EFSA) suggests that at least a subset of four PAHs, designated as PAH4, should be monitored in food. PAH4 compounds are benzo[a]pyrene, chrysene, benz[a]anthracene and benzo[b]fluoranthene. In the Republic of Serbia, the maximum allowed concentration of PAHs is regulated by the Rulebook on Maximum Concentrations of Certain Contaminants in Food, Official Gazette RS, No. 81/2019, which entered into force in November 2019 [7]. The maximum permitted concentration of benzo[a]pyrene in dried herbs is 10 μg/kg, while the maximum permitted concentration for the sum of PAH4 compounds is 50 μg/kg.
The development of analytical methods for PAHs should now focus on this subgroup. In terms of analytical methods, EU legislation on food contaminants follows a "criteria approach". This means that the legislator does not prescribe specific analysis procedures, but allows laboratories to use different analysis methods, if they can be objectively shown to meet the analytical requirements prescribed by the relevant legislation. The analysis of PAHs in herbs is a challenging endeavour, as there are isobaric PAHs that interfere with the quantification of the PAHs of interest. Seeds and raw plants can be contaminated with PAHs through artificial drying and heating during processing if precautions are not taken.

2. MATERIAL AND METHODS

Preliminary tests based on a literature review and already existing standardized methods for determining the content of polycyclic aromatic hydrocarbons for other matrices such as water (SRPS EN ISO 17993:2008, ISO 28540:2011, SRPS EN 16691:2016) were performed on three different chromatography methods including measurements on a gas chromatograph, a gas chromatograph connected to a mass spectrophotometer and a high-performance liquid chromatograph (HPLC) with a fluorescence detector. After preliminary tests, HPLC with a fluorescence detector (HPLC-FLD) was chosen as a satisfactory chromatographic method according to the modified ERA 8310 standard. Determination of polycyclic aromatic hydrocarbons (PAHs) in medicinal and herbal plants was done by liquid chromatography with a fluorescence detector (LC-FLD) according to the modified ERA 8310 standard method.

2.1 Concentration range of the method

The concentration measurement range of the method for determining the content of PAHs, using the HPLC-FLD technique, is 4.0-200 μg/L.

2.2 Principle of the method

2.2.1. Polycyclic aromatic hydrocarbons from dried herb samples were extracted with methylene chloride in an ultrasonic bath. The extract was purified and evaporated to near dryness in the absence of light and the solvent exchanged with acetonitrile. Analytes were separated by liquid chromatography [8] and identified and quantified on a fluorescent detector (HPLC-FLD).

2.2.2. The methylene chloride extract is purified from the presence of plant pigments and fatty acids on a silica gel column.

2.3 Preparation of sample for testing

2.3.1. A 2.00 g sample of dried herbal tea was soaked in 20 ml of water and left to hydrate well for 2 hours. Then, by liquid-liquid extraction, the aqueous solution is extracted with 2x5 ml of methylene chloride. The collected organic extracts were purified over silica gel and evaporated almost to dryness in the dark and the residue was dissolved in 2 ml of acetonitrile in an autosampler vial.

2.4 Interferences

The cleanliness of laboratory glassware, solvents, and reagents was checked. For this purpose, extraction vials were taken and carried out the entire analytical procedure. The obtained value was the value of the blank sample, blank test. The value obtained by analysing the blank sample was not included in the calculation, but it did not exceed 10% of the sample value.

2.5 Reagents

2.5.1 Reagents: Solvent for extraction, pesticide grade, or organic pollutant residues, methylene chloride, CH_2Cl_2, Solvent for modification, quality for pesticides, or for residues of organic pollutants; Acetonitrile; Mobile phase solvent, pesticide grade, or organic pollutant residues; Acetonitrile; Water (deionized); Water in which the presence of interfering peaks at the lower limit of detection of the analytes examined by this method was not found. Solvents used for sample preparation (toluene/methylene chloride/cyclohexane/acetonitrile) were of chromatographic grade. Solvent chromatograms showed no PAH interfering peaks.
The stock standard solutions were prepared in the appropriate solvent and stored in vials with Teflon-lined stoppers in the refrigerator. Intermediate mix standard solutions were prepared by diluting the stock standard solutions with acetonitrile. Calibration standard solutions were prepared by diluting the intermediate standard solution with acetonitrile - concentration range for PAH 1.0-200 µg/L.

2.5.2 Instruments
HPLC-FLD (AgilentTechnologies 1260 FC-AS, Quaternary pump – AgilentTechnologies 1260 Infinity, Autosampler – AgilentTechnologies 1260 ALS, Tremostat for the column - AgilentTechnologies 1290 thermostat.); Agilent Technologies ZORBAX Extend C18 Reverse Phase Separation Column, Rapid Resolution HD, 1.8 µm (particle size), 150 mm (length) x 2.1 mm (inner diameter); Ultrasonic bath; Fridge.

3. RESULTS AND DISCUSSION

3.1 Method validation

The method for determination of the content of PAHs in dried herbs using the HPLC-FLD technique was applied and validated on the instrument Agilent 1260 FLD Spectra with a fluorescence detection according to the modified standard ERA 8310. The limit of detection (LOD) and limit of quantification (LOQ) of the analytical method and the standard method were determined using blank samples that were treated in the same way as real samples.

Table 1. Limit of quantification

Analyte	LOD*	LOQ*	LOQ (methods)
Benzo(a)anthracene	0.8	0.9	1.25
Chrysene	1.0	1.2	1.25
Benzo(b)fluoranthene	0.5	0.8	1.25
Benzo(a)pyrene	0.6	0.8	1.25

** data obtained on the basis of OpenLabCDS,* LOD= ≤1.0 µg/kg, LOQ=≤4.0 µg/kg

Linearity was tested in a range of different concentrations for each analyte individually on a series of standard solutions prepared according to a standard procedure. Linearity is confirmed because the correlation coefficient (R^2) is greater than 0.999.

Table 2. Linearity in the range 1.25-200 µg/L

Linearity		
Analyte	y= Ax+B	R^2
Benzo(a)anthracene	y=177.92x +2.3658	0.9997
Chrysene	y=21.175x -0.0144	0. 9993
Benzo(b)fluoranthene	y=233.87x +1.9446	0. 9999
Benzo(a)pyrene	y=453.54x +6.2165	0. 9997

Recovery - spiked samples of dried elderberry were prepared by added known concentrations of each analyte and their content was determined.

Table 3. Recovery SANTE/11312/2021 70-120%; repeatability SANTE/11312/2021 %RSD ≤ 20%

Analyte	Recovery 1.25 µg/L			Recovery 20.0 µg/L			Recovery 100.0 µg/L		
	%	stdev	%	%	stdev	%RSD	%	stdev	%RSD
Benzo(a)anthracene	83.7	0.59	82.2	82.2	0.74	0.94	79.6	0.64	0.85
Chrysene	79.8	0.17	77.7	77.7	0.32	0.43	74.5	0.47	0.66
Benzo(b)fluoranthene	89.6	0.23	88.5	88.5	0.34	0.34	88.0	0.53	0.53
Benzo(a)pyrene	80.3	0.35	80.7	80.7	1.49	1.51	74.4	1.22	1.24

3.2 Method application

The content of polycyclic aromatic hydrocarbons was determined for four forms: benzo[a]anthracene, benzo[a]pyrene, benzo[b]fluoranthene and chrysene, as their sum PAH4 in accordance with the regulations of the Republic of Serbia on maximum concentrations of certain contaminants published in the Official Gazette RS, No. 81/20191, Article 2 of Annex 2, Section 6, in force since November 2019. The maximum permitted concentration of benzo[a]pyrene in dried medicinal herbs is 10 µg/kg, while the maximum permitted concentration for the sum of PAH4 compounds is 50 µg/kg. Samples were collected after drying. From 25 analysed samples four different samples of medicinal herbs contained a higher concentration compared to the reference limit values of the corresponding regulation.

4. CONCLUSION

Determination of the content of benzo(a)anthracene, chrysene, benzo(b)fluoranthene and benzo(a)pyrene in dried medicinal herbal using the technique of liquid chromatography with a fluorescence detector (HPLC-FLD) according to the modified standard ERA 8310, can be considered validated and put into routine operation.

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NANOEMULSIONS OF PUMPKIN SEED OIL WITH TURMERIC EXTRACT

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Abstract: *A phase inversion concentration method was used in the preparation of pumpkin seed oil nanoemulsions for the encapsulation of turmeric extract. pH, refractive index, texture properties, morphology and stability of the nanoemulsions were studied. The optimal formulation that composed of 0.14% pumpkin seed oil, 2.2% surfactant Tween 80, 98% water and 0.02% turmeric extract is transparent, stable with smaller particle sizes and values for pH 5.27, RI 1.331, firmness 36.09 g, consistency 521.32 g·s. cohesiveness – 22.10 N and index of viscosity -11.07 N·s.*
Keywords: nanoemulsions, pumpkin oil, turmeric extract, stability.

1. INTRODUCTION

Nanoemulsion is a colloidal dispersion of two immiscible liquids: water in oil (W/O) or oil in water (O/W), stabilized by surfactants. It comprises droplets with a diameter ranging from 10 to 500 nm, mainly droplets from 10 to 200 nm. Nanoemulsion with a droplet size from 50 to 200 nm is transparent, while milky appearance is characteristic for droplet size to 500 nm. In the preparation of nanoemulsions, high-energy methods (high-pressure homogenization, microfluidization, and ultrasonication) and low-energy methods (phase inversion emulsification and self-emulsification) can be applied [1]. Nanoemulsions developed as delivery systems of drugs and bioactive substances with high efficiency to prevent the occurrence of creaming, flocculation, coalescence, and sedimentation, also, to protect bioactivity and to improve bioavailability are characterized by various applications mainly in cosmetics, pharmaceutical and food industries [2]. A promising application of nanoemulsions results in improving the barrier and mechanical properties of the packaging, which ensures the quality, safety, and extended shelf life of food products [3].
Turmeric (*Curcuma longa* L., fam. Zingiberaceae) is one of the most cultivated plants with a long tradition of use in food as a spice, preservative, and agent for colour and flavour. The curcuminoids, namely curcumin are the main biologically active turmeric compounds that possess a wide range of biological activities such as antioxidant, antimicrobial, anti-inflammatory, anticancer, etc. Curcumin is a hydrophobic substance, low soluble in water, very sensitive to light, and low bioavailability. At the same time, curcumin related to its spicy taste, significantly changes the sensory properties of the products where it is added [4]. For those reasons, possibilities to encapsulate pure curcumin or turmeric extract in lipophilic formulations such as nanoemulsions are being explored. High- and low-energy methods, various types of surfactants and sources of lipid phase in the formulation and preparation of nanoemulsions of curcumin or turmeric extract are used [5]. Application of these nanoemulsions is directed to improve the organoleptic and chemical characteristics, and shelf life of food products such as canned ham, cheese or food beverages [6,7] or in the prevention and treatment

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of some health problems for example against tumour incidence and metastasis, or as an antimicrobial and wound healing agent in burn wound infection [8,9].
In this study, the phase inversion concentration method was used in the preparation of nanoemulsions of pumpkin seed oil with turmeric extract. The influence of the nanoemulsion composition on the pH, refractive index, texture properties, morphology and stability was studied.

2. MATERIALS AND METHODS

2.1 Materials

Cold press pumpkin seed oil (Super Group Doo, Skopje, Republic of North Macedonia), surfactant Tween 80 (polyoxyethylene sorbitan monooleate, Sigma–Aldrich, Germany) and turmeric powder (BioCosmos, Skopje, Republic of North Macedonia) were used.

2.2 Preparation of turmeric extract

Turmeric powder (10 g, 0.1 mm particle size) was extracted by using the Soxhlet method with ethanol (250 mL) for 300 min at ethanol boiling temperature. The solvent was removed from the extract by rotary vacuum evaporator (Devarot Elektromedicina, Slovenia) at 40°C and 200 mPa. The extract was dried at 40°C and 105 mPa in a vacuum drier (Heraeus Instrument Vacuterm, Germany), cooled in a desiccator and weighed. The steps of drying, cooling and weighing the turmeric extract were repeated until the difference between two consecutive weights was smaller than 2 mg.

2.3. Nanoemulsion preparation

Nanoemulsions were prepared using cold press pumpkin seed oil (PO), Tween 80 (T80), distilled water (DW), and turmeric extract (TEX) in proportions given in Table 1. Firstly, the oil phase composed of pumpkin oil (PO), surfactant Tween 80 (T80) and turmeric extract (TEX) was prepared by mixing on a magnetic stirrer (VWR IKA VMS-C7, Radnor, PA, USA) at 800 rpm and a temperature of 25°C for 30 min. The distilled water was titrated drop by drop into the oil phase with constant stirring on a magnetic stirrer (800 rpm). After the titration was completed, the resulting dispersion continued to be stirred for 30 min.

Table 1. Nanoemulsion formulations

Sample	Concentration in formulation (%)				Ratio (g/g)			
	PO	T80	DW	TEX	DW/PO	T80/PO	TEX/PO	DW/ T80
E1	1.00	9.0	90	0.05	90	9	0.05	10
E2	1.50	8.5	90	0.05	60	6	0.03	11
E3	2.00	8.0	90	0.05	45	4	0.03	11
E4	0.32	2.9	97	0.03	300	9	0.10	33
E5	0.24	2.2	98	0.02	400	9	0.10	44
E6	0.20	1.8	98	0.02	500	9	0.10	56
E7	0.16	1.5	98	0.02	600	9	0.10	67
E8	0.16	1.6	98	0.07	600	10	0.40	60
E9	0.16	1.8	98	0.07	600	11	0.40	55
E10	0.16	2.0	98	0.07	600	12	0.40	50
E11	0.18	1.5	98	0.07	545	8	0.36	67
E12	0.17	1.3	99	0.06	583	8	0.33	78
E13	0.20	1.3	98	0.06	500	6	0.29	78

PO-Pumpkin seed oil. DW-distilled water. T80-Tween 80. TEX-Turmeric extract

2.4. Nanoemulsion characterization

pH values. pH values of nanoemulsion were determined at room temperature using a pH meter Mettler Toledo SevenEasyTM S20 (Switzerland). A constant pH value in the samples for 15 min was achieved.
Refractive index (RI). Abbe refractometer (WAY 2W Solid, Kirkland, WA, USA) was used to measure the RI values by placing one drop of nanoemulsion on the slide at 25°C. The RI value of DW used in the nanoemulsion preparation was 1.330.
Texture profile analysis. TA-XTplus Stable Micro System (UK) with the penetration test was used. The gel sample (75 mL) was poured into a glass beaker (100 mL with 50 mm diameter) avoiding air introduction and assuring a smooth upper sample surface. The " Mayonnaise Back Extrusion" method at a 25 mm distance and 10 mm/s speed was applied to measure nanoemulsion properties: firmness (g), consistency (g·s), cohesiveness (N) and index of viscosity (N·s).
Stability test. All samples were stored at 20°C for 24 h before undergoing the stability test by applying the "heating-cooling cycle" and "centrifugation test". At the "heating-cooling cycle" stability test the samples were submitted to three cycles of 48 h at 40°C in the refrigerator and then 48 h at 4°C in the thermostatic chamber. "Centrifugation test" - 1.5 g sample measured in Eppendorf was centrifuged at 5000 rpm and room temperature for 30 min by using Heraeus Biofuge Fresco centrifuge (UK). The instability of the samples visually was evaluated.
Morphology: One drop of nanoemulsion samples placed on a glass slide was observed under the optical microscope (M–100–FL, Konus, Italy) equipped with a digital camera (Vario–Tessar 8x, Sony, China), at a magnification of 40x.

3. RESULTS AND DISCUSSION

The values of the pH, RI and texture parameters determined for nanoemulsion formulations composed of pumpkin seed oil and turmeric extract are presented in Table 2.

Table 2. Nanoemulsion formulations

Sample	pH	RI	Texture parameters			
			FI±SD (g)	CN±SD (g·s)	CH±SD (N)	VS±SD (N·s)
E1	4.33	1.329	36.03±0.08	519.23±0.73	-21.84±0.34	-10.52±0.60
E2	4.24	1.456	36.28±0.02	520.92±1.03	-21.84±0.04	-10.64±0.11
E3	4.53	1.454	36.35±0.06	522.73±0.82	-22.06±0.14	-11.04±0.14
E4	4.67	1.325	36.22±0.06	522.56±3.50	-21.86±0.23	-10.68±0.44
E5	5.27	1.331	36.09±0.04	521.32±1.29	-22.10±0.08	-11.07±0.13
E6	5.33	1.338	36.15±0.12	521.38±0.43	-22.10±0.17	-11.26±0.20
E7	5.41	1.333	36.03±0.09	519.23±0.73	-21.84±0.34	-10.52±0.60
E8	5.55	1.357	67.37±0.24	762.56±1.43	-22.21±0.21	-10.88±0.34
E9	5.65	1.363	68.65±0.52	702.79±1.65	-22.12±0.15	-10.87±0.11
E10	5.89	1.367	60.78±0.04	625.13±2.91	-21.80±0.28	-7.81±0.18
E11	7.38	1.336	96.32±0.91	706.89±0.85	-21.74±0.19	-9.83±0.26
E12	7.44	1.339	79.23±0.37	685.52±0.25	-22.03±0.11	-11.11±0.24
E13	7.46	1.342	80.27±0.65	691.16±2.01	-22.19±0.03	-10.88±0.23

E1–E13-composition refers to Table 1. RI-refractive index. FI-Firmness. CN-Consistency. CH-Cohesiveness. VS-Index of Viscosity. SD-standard deviation. Mean value (n = 5).

pH. pH values ranged from 4.24 to 4.67 for samples E1-E4 where the ratio of water (DW) to Tween 80 (T80) was 10:1 w/w. By increasing the water content in the formulations pH values increased. The highest pH values were determined for samples E11-E13 formulated at the highest ratios DW/T80

(67:1 and 78:1 w/w). Increasing the concentration of surfactant (T80) in the formulation positively influences pH values. At a 600:1 w/w ratio of water (DW) to pumpkin seed oil (PO), pH values increased from 5.41 to 5.89 by increasing the ratio of T80/PO from 9:1 to 12:1 w/w, respectively. The resulting pH values from 4.53 to 6.4 are within the pH tolerance range (4.5 to 6.5) which is still safe for the skin (Table 2). Increasing surfactant concentration causes an increase in the pH because the used surfactant has a pH between 6÷8.6 [10]. Curcumin nanoemulsion prepared by applying ultrasound using clove oil as lipid phase, surfactant Tween 80 and PEG-400 as co-surfactant were characterised with pH 7.4 [9].

RI values. In the samples prepared at the lowest DW/PO ratio, respectively, 60:1 w/w (E2) and 45:1 w/w (E1), the highest RI values, 1.456 and 1.454, were determined. At a constant DW/PO value (600:1 w/w) by increasing the T80/PO ratio to 10:1, 11:1 and 12:1 w/w, the RI increased from 1.357 to 1.367 (Table 2). RI values close to water determined in other prepared formulations (Table 2) indicate transparency and isotropic stability of nanoemulsions, and small-sized particles [11].

Texture properties. The firmness and consistency increased for the nanoemulsions formulated at a higher quantity of T80. Increasing the quantity of oil caused a decrease in the values of firmness and consistency. The nanoemulsions (E1 to E7) prepared with a surfactant and oil ratio (T80/PO) of 9:1 w/w were characterized by the constant values of firmness and consistency, around 36 g and 530 g·s, respectively. In the nanoemulsions E8-E10 with the highest values for T80/PO the firmness increased to 68.65 g, while in the nanoemulsions E11-E13 increased values of firmness to 96.32 g are significantly influenced by the increased quantity of water. The influence of the quantity of oil phase, surfactant and water does not affect the cohesiveness and viscosity index. The cohesiveness ranged from -21 to -22 N, while the viscosity index values were from -7.81 to -11.26 N·s (Table 2).

Stability. Figure 1 shows the visual appearance of nanoemulsions after stability testing with the "heating-cooling cycle" method. The samples E1-E3 were evaluated as unstable due to the visible destabilization that occurred. Separation of lipid and aqueous phase was visible for sample E3 which was prepared with the lowest values for DW/PO (45:1 w/w), T80/PO (4:1 w/w), and DW/T80 (11:1 w/w). The samples E4-E7 prepared with 9:1 w/w T80/PO by increasing DW/T80 from 33:1 w/w to 60 w/w were highly in transparency without visible phase separation. Increasing the T80/PO ratio and DW/T80 ratio, the nanoemulsion samples (E8-E13) were low in transparency and high instability, susceptible to creaming and visible separation of oil droplets on the surface. A negative influence of the increased surfactant quantity on the nanoemulsion stability was reported in the literature [12].

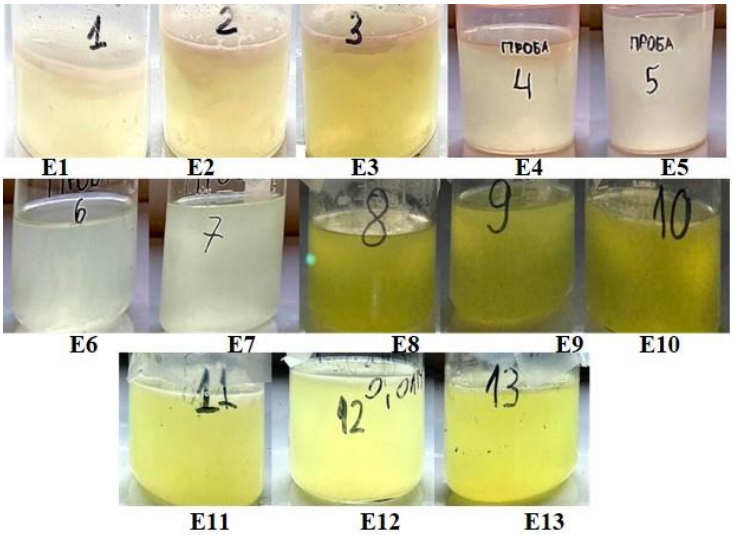

Figure 1. A visual appearance of the nanoemulsions after "heating-cooling cycle" stability testing (3 cycles, 48 hours at 40°C and 48 hours at 4°C)

After applying the centrifugation method, phase separation was observed in nanoemulsions E1-E4 and E8-E13. In contrast, formulations E5-E7 show high stability and homogeneity (Figure 2).

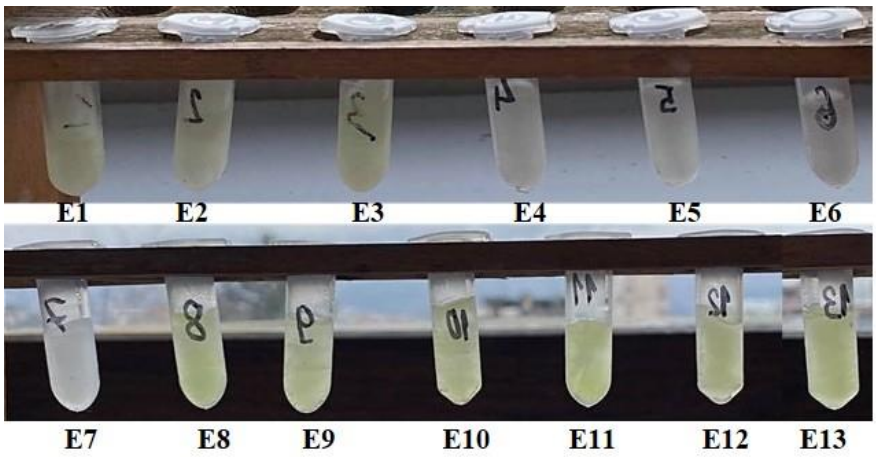

Figure 2. A visual appearance of the nanoemulsion formulations after stability testing by centrifugation method (5000 rpm, 30 min)

The microscopic appearance of the nanoemulsions is presented in Figure 3. The higher quantity of water and turmeric extract in E8-13 formulations increased the particle size. Small particles and narrow particle size distribution were determined in formulations E4-E7 that are characterized by RI values close to water, satisfactory transparency and stability without visible phase separation. The morphology, particle size and size distribution of the prepared pumpkin seed oil nanoemulsions with encapsulated turmeric extract are under high influence of the composition that corresponded with the literature findings [9,10].

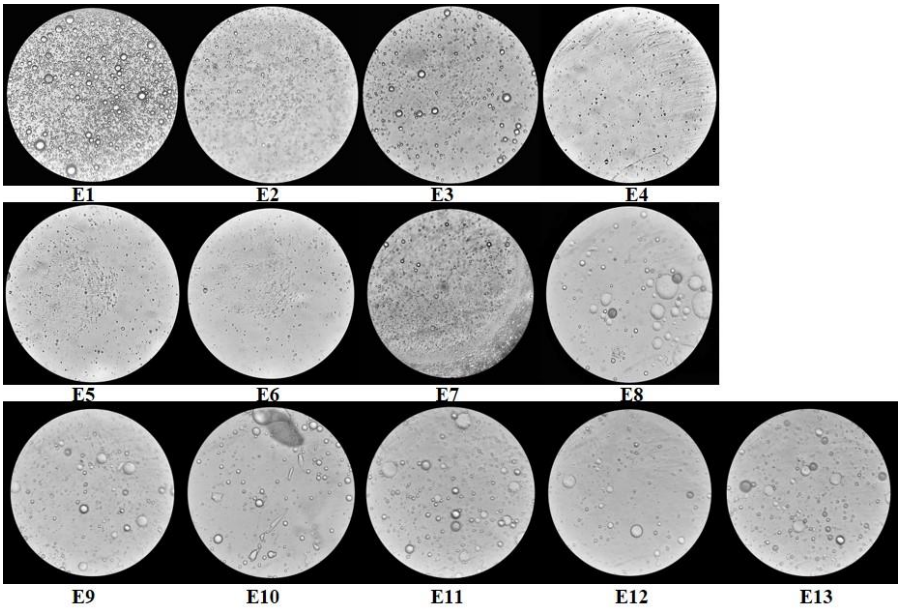

Figure 3. Microphotograph of nanoemulsion formulations, 40x (E1-E13 correspond to samples given in Table 1)

4. CONCLUSION

Based on the results, it can be concluded that increasing the ratio DW/PO and DW/T80, pH values and particle size increased, while RI values, transparency and stability decreased. Nanoemulsions prepared with a T80/PO ratio of 9:1 w/w, show a high degree of transparency and stability, small particle sizes and a larger distribution of smaller sizes. pH values, firmness and consistency of the nanoemulsion decreased by increasing the quantity of the pumpkin seed oil. The satisfied values of evaluated parameters were obtained for the nanoemulsion prepared with a ratio DW/PO of 500:1 w/w, 9:1 w/w T80/PO, 0.1:1 w/w TEX/PO and 58:1 w/w DW/T80.

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FORMULATIONS OF CARBOXYMETHYL CELLULOSE-BASED EMULGELS WITH TURMERIC EXTRACT

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Abstract: *This study aimed to formulate a stable carboxymethyl cellulose based emulgel formulation loaded with turmeric extract and coconut oil. Emulgels were evaluated for their visual appearance, microstructure, pH, refractive index, texture, colour profile, and stability. The obtained results indicated that the characteristics of emulgels are highly influenced by the concentration of gelator carboxymethyl cellulose and oil phase coconut oil. The emulgel formulations were stable at 4℃, while at 48℃ the phase separation was observed. Particles were smaller in emulgels formulated at lower concentrations of carboxymethyl cellulose and coconut oil. Developed formulations have a potential for transdermal delivery of turmeric extract.*
Keywords: emulgel, carboxymethyl cellulose, turmeric extract, stability.

1. INTRODUCTION

Emulsion gels also known as emulgels or emulsion-filled gels are soft solid materials in which one phase in the emulsion, either continuous or dispersed phase, forms a 3D gel network structure with oil droplets incorporated. These emulgels as functional colloids show a great potential application in the food industry in improving the quality of food products related to the thermodynamic stability, texture modification, and incorporation of various functional lipophilic and hydrophilic compounds. The emulgels increase the bioaccessibility indicating the fast release and solubilisation of the encapsulated compounds in the aqueous phase in the gastrointestinal tract. According to the nature of the biopolymers included in the composition, the emulgels are classified as polysaccharide-based (alginate, starch, or pectin), protein-based (milk proteins, gelatine, soy proteins), and mixed-based emulgels formulated of proteins and polysaccharides, and different types of proteins or polysaccharides [1,2].
Curcumin is a biologically active compound of the turmeric plant (Curcuma longa L.), highly effective in the prevention of some health problems such as cancer, obesity, infections and cardiovascular diseases or in reducing the conditions of inflammation or metabolic syndrome. Due to the wide range of bioactive properties, there is increasing interest in incorporating curcumin into food products as a natural agent for flavouring, colouring, and increasing shelf life [3]. The limitations of applications in foods associated with poor solubility of curcumin in water, as well as its reduced bioavailability and high sensitivity to light, can be overcome by encapsulation within biological matrices that are based on lipids, proteins and polysaccharides such as liposomes, emulsions or gel structures [4,5]. This study aimed to incorporate curcumin in the form of turmeric extract into the oil phase of the gel-like structure based on carboxymethyl cellulose. The influence of the emulgel

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composition on the pH, refractive index, texture properties, colour parameters, microstructure and stability was studied.

2. MATERIALS AND METHODS

2.1 Materials

Carboxymethyl cellulose sodium salt (Mw~90000, DS=0.7, Merck KGaA, Germany), organic coconut oil (Vitalia Healthy Food, Republic of North Macedonia), turmeric powder (BioCosmos, Republic of North Macedonia), and analytical grade ethanol (96%*v/v*, Alkaloid AD Skopje, Republic of North Macedonia) were used in this study.

2.2 Preparation of turmeric extract

Soxhlet extraction of turmeric powder (0.1 mm particle size) was carried out for 300 min with ethanol as a solvent with a ratio of solid to liquid phase of 1:25 w/v and extraction temperature corresponding to the boiling point of ethanol. The solvent released the extract by rotary vacuum evaporator at 40°C and 200 mPa (Devarot Elektromedicina, Slovenia). The solvent traces were removed by drying in a vacuum drier (Heraeus Instrument Vacuterm, Germany) at 40°C and 105 mPa, followed by cooling in a desiccator and weighed. The steps of drying, cooling and weighing the turmeric extract were repeated until the difference between two consecutive weights was smaller than 2 mg.

2.3. Preparation of emulgels

Emulsion gels were prepared using carboxymethyl cellulose (CMC), distilled water (DW), coconut oil (CO), and turmeric extract (TEX) in proportions as described in Table 1. The CMC was dispersed in DW and gelation was carried out on a magnetic stirrer (VWR IKA VMS-C7, Radnor, PA, USA) at 800 rpm and a temperature of 85°C for the time of 1 h. In the obtained homogeneous viscous CMC gel cooled to 30°C the oil phase was added continuing with stirring at 800 rpm, temperature of 30°C for 15 min until obtaining a homogeneous mixture. The oil phase for the samples with turmeric extract was prepared by mixing TEX in CO on a magnetic stirrer (800 rpm, 30°C, 15 min).

Table 1. Emulgel formulations

Sample	Ratio (g/g)			
	DW/CMC	DW/CO	CO/ CMC	TEX/CO
G1	100	100	1	/
G2	100	67	1.5	/
G3	50	25	2	/
G4	100	100	1	100
G5	100	67	1.5	75
G6	50	25	2	80

CMC-carboxymethyl cellulose. DW-Distilled water. CO-coconut oil. TEX-turmeric extract.

2.4. Emulgel characterization

pH value. The samples were homogenized with DW in a ratio of 1:10 before pH measuring using a digital pH meter Mettler Toledo SevenEasyTM S20 (Switzerland). A constant pH value in the samples for 15 min was achieved.

Refractive index (RI). RI was measured with an Abbe refractometer (WAY 2W Solid, Kirkland, WA, USA) with an accuracy of ±0.001 nD at a temperature of 25°C. The RI value of DW used in the sample preparation was 1.330.

Texture profile analysis. TA-XTplus Stable Micro System (UK) with the penetration test was used. The gel sample (75 mL) was poured into a glass beaker (100 mL with 50 mm diameter) avoiding air introduction and assuring a smooth upper sample surface. The "Shampoo Back Extrusion" method at a 15 mm distance and 10 mm/s speed was applied to measure gel properties: firmness (g), consistency (g·s), cohesiveness (N) and index of viscosity (N·s).
Colour parameters. L* lightness (100-white/0-black), a* (+red/-green) and b* (+yellow/-blue) were measured using a Dr. Lange spectra colorimeter (UK). The gel samples were placed in a 1 cm cell. L*, a*, and b* values were determined at a D65 light source and 10° observer angle. The standardized values for a white plate were L* = 95.93, a* = −0.19, and b* = 3.12. Chroma (C*), huge angle (h°), whitening index (WI) and yellowish index (YI) were calculated by using equations (1-4).

$$C^* = [(a^*)^2+(b^*2)]^{1/2} \quad (1)$$
$$h^o = \arctan(b^*/a^*) \quad (2)$$
$$WI = 100 – [(100 - L^*)^2 + (a^*)^2 + (b^*)^2]^{1/2} \quad (3)$$
$$YI = 142.86 \cdot b^*/L^* \quad (4)$$

Stability test. All samples were stored at 20°C for 24 h before undergoing the stability test by applying the “heating-cooling cycle” and “centrifugation test”. A “heating-cooling cycle” test was performed in three cycles, each cycle for 2 days. The temperature in the refrigerator was 4°C and 40°C in the thermostatic chamber. “Centrifugation test” - 1.5 g of gel sample measured in Eppendorf was centrifuged at 5000 rpm for 60 min at room temperature by using Heraeus Biofuge Fresco centrifuge (UK). The instability of the samples visually was evaluated.
Morphology: One drop of samples placed on a glass slide was observed under the optical microscope (M–100–FL, Konus, Italy) equipped with a digital camera (Vario–Tessar 8x, Sony, China) under 40x magnification. The drop was coloured with methylene blue.

3. RESULTS AND DISCUSSION

Table 2 presents the values of the pH, RI and texture parameters determined for carboxymethyl cellulose-based emulgels with turmeric extract and coconut oil.

Table 2. Characteristic of emulgel formulations

Sample	pH	RI	Texture parameters			
			FI±SD (g)	CN±SD (g·s)	CH±SD (N)	VS±SD (N·s)
G1	5.01	1.338	51.75±0.75	413.44±4.22	-10.29±1.15	-21.04±0.34
G2	4.94	1.340	76.17±1.03	504.46±2.64	-13.17±2.08	-48.94±1.25
G3	5.32	1.346	160.94±2.15	968.52±1.18	-57.50±0.73	-66.43±0.98
G4	5.15	1.339	49.77±1.05	383.35±1.25	-11.63±0.64	-23.83±1.82
G5	4.83	1.344	75.74±2.61	499.96±2.43	-12.16±0.83	-41.59±1.43
G6	4.95	1.348	116.54±3.15	724.67±3.09	-34.19±1.45	-56.85±1.04

G1–G6-composition refers to Table 1. RI-refractive index. FI-Firmness. CN-Consistency. CH-Cohesiveness. VS-Index of Viscosity. SD-standard deviation. Mean value (n = 5).

pH. pH. In the emulgels samples pH values ranged from 4.83 to 5.32. The influence of the emulgel composition on the pH was not significant (Table 2). The pH values of formulated CMC-based emulgels are in the range of pH tolerance values (4.5-6.5) that are required for topical products to ensure compatibility and skin safety [6]. Emugels with pH 4 could protect and control the release of curcumin by protecting some proteins from pepsin digestion and controlling the release of fatty acid. Related to the curcumin release rate and bioavailability at the intestinal stage, the emulgels with pH 6 showed the highest values, followed by the samples with pH 5 and pH 4 [7].

RI values. RI of all formulations were close to that of water as the external phase. The emulgel samples with turmeric extract (G4-G6) were characterised by higher RI values instead of the emulgels without turmeric extract (G1-G3). In the sample of emulgels formulated at the highest concentration of CMC and coconut oil, G3 and G6, the highest RI values were determined, 1.346 and 1.348, respectively (Table 2). The RI values determined in carboxymethyl cellulose-based emulgels with coconut oils and turmeric extract are comparable with RI data given in the literature [8], confirming their o/w structure and thermodynamical stability.

Texture properties. The quantity of gelator CMC and oil phase CO used affected the emulgel firmness. At higher CO concentrations in the formulations, softer emulgels were obtained. The CMC positively influenced the consistency of emulgels. The determined values for firmness and consistency were higher in emulgels without turmeric extract (G1-G3). Emulgel (G3) formulated at a ratio DW/CMC of 50:1 w/w and ratio CO/CMC of 2:1 w/w was characterized by the highest firmness (160.04 g) and consistency (968.52 g·s). At the lower concentration of CMC, the cohesiveness and viscosity index of the emulgels decreased. The CO quantity positively affected the cohesiveness and viscosity index, while turmeric extract decreased those parameters (Table 2). The CMC to 1.5% w/w provided the formation of a more uniform and compact gel network structure [9]. Increasing the virgin coconut oil to 10% w/w positively influences the emulgel texture profile [10].

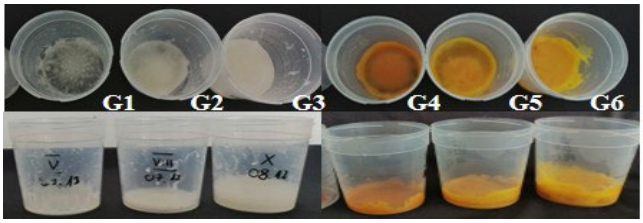
Table 3. Colour parameters of emulgel formulations

Parameter	Formulation					
	G1	G2	G3	G4	G5	G6
L*	35.48±0.92	34.59±0.61	33.48±0.97	50.47±1.34	51.90±0.82	52.19±1.34
a*	0.35±0.10	0.15±0.06	0.19±0.04	-17.55±0.85	-10.66±0.76	-10.88±0.85
b*	-6.70±0.51	-4.04±0.31	-4.33±0.31	44.49±0.24	46.68±0.48	47.18±0.14
C*	6.71±0.48	4.04±0.29	4.33±0.52	47.83±0.11	47.88±0.89	48.42±0.24
h°	92.99±2.08	92.13±0.84	92.51±0.36	111.53±1.13	102.86±0.78	102.99±1.37
WI	35.13±0.56	34.47±0.17	33.34±4.32	/	/	/
YI	/	/	/	125.93±1.64	128.49±0.69	129.15±1.04

G1–G6-composition refers to Table 1. L*-lightness (100-white/0-black). a* (+red/-green). b* (+yellow/-blue). C*-Chroma. Huge angle (h°). WI-Whitening index. YI- Yellowish index. SD-standard deviation. Mean value (n = 5).

Colour parameters. The values of the colour parameters determined in CMC emulgels are presented in Table 3. In terms of the L* parameter, emulgels without turmeric (G1-G3) are darker, than whiter emulgels with turmeric extract (G4-G6). The higher concentrations of CMC and CO insignificantly decreased the whitening index (WI). Turmeric extract increased the values of b, C, and h°. Increasing TEX quantity positively influenced the yellowish index (YI). Influence of the coconut oil on WI values is confirmed in the literature [10].

Stability. During stability testing in a thermostat at 40°C in the emulgel formulated with the lowest concentration of CMC (G1) visible small droplets of CO were observed, while no visible changes were detected in samples G2 and G3. In samples with turmeric extract, surface drying (G4) and insignificant phase separation (G5 and G6) were determined (Figure 1A). In samples, G1 and G3, formulated with a DM/CMC ratio of 100:1 w/w and CO/CMC of 1:1 w/w, the phase separation was observed. At a lower ratio of DM/CMC and a higher ratio of CO/CMC (sample G2, G3, and G5, G6), no changes in appearance were determined after testing at a temperature of 4°C (Figure 1B). In all formulated emulgel samples, phase separation appeared after applying the centrifugation method at 5000 rpm for 60 min (Figure 1C).



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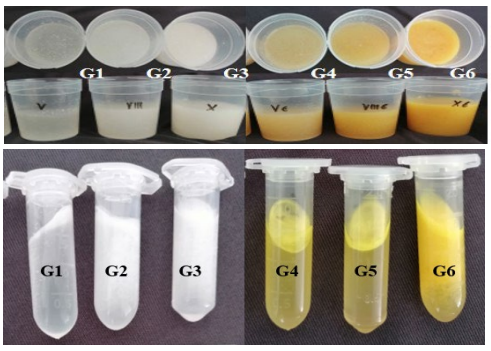

Figure 1. A visual appearance of the emulgels after stability testing with a "heating-cooling cycle" (3 cycles, 48 hours at 40°C-A and 48 hours at 4°C-B) and centrifugation method

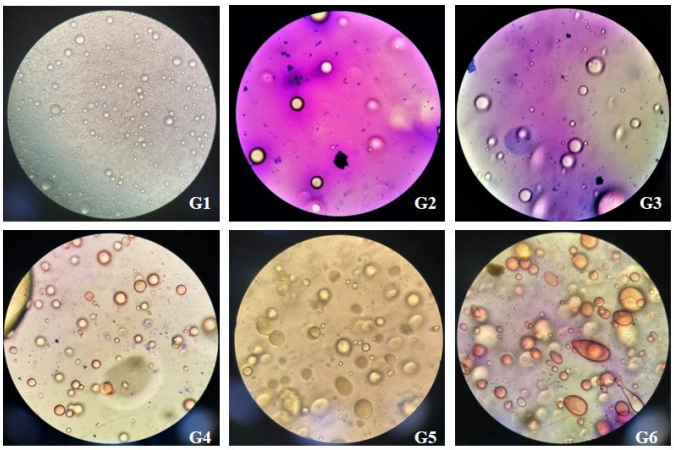

Figure 2. Microphotograph of emulgel formulations, 40x (G1-G4 correspond to samples given in Table 1)

Figure 2 shows the microstructure of the emulgels. The micrographs revealed that the emulgels studied consisted of a complex dispersion of turmeric extract in coconut oil droplets embedded in a matrix formed by a carboxymethyl cellulose gel. Small particles and narrow particle size distribution were determined in formulation G1. In the emulgel samples, G2 and G3, larger droplets were observed. The turmeric extract emulgels exhibited variations in particle size. The largest particles with visible deposition of turmeric extract in coconut oil were observed in sample G6 which is composed of the lowest ratio of water to carboxymethyl cellulose (50:1 w/w) and the highest ratio of coconut oil to carboxymethyl cellulose (2:1 w/w). The larger particles caused the instability of the emulgels which was confirmed by the stability testing at a temperature of 40°C presented in Figure 1. At elevated temperatures, the viscosity of the formulation reduces which may allow the globules to collide, subsequently resulting in increased globule size [11].

4. CONCLUSION

Based on the results, it can be concluded that the studied characteristics (pH, refractive index, texture, colour parameters, stability and microstructure were highly affected by the emulgel composition.

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POTENTIAL APPLICATION OF MULLEIN LEAF AS BIOSORBENT FOR EFFICIENT BIOSORPTION OF CU(II) IONS FROM SYNTHETIC SOLUTIONS

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Abstract: *In this study, the potential of mullein leaf (Verbascum Thapsus) as a ground powder for the biosorption of Cu(II) ions from synthetic solutions was examined. Several factors affecting the biosorption efficiency of mullein leaf powder were investigated, including the initial Cu(II) concentration (25–400 mg L^{-1}), solution pH (3–7), contact time (10–120 min.), and biosorbent dosage (2–20 g L^{-1}). The concentration of Cu(II) ions before and after biosorption using inductively coupled plasma optical emission spectrometer was determined. The biosorption efficiency of 58.74% was observed at a biosorbent dosage of 20 g L^{-1} and an initial Cu(II) concentration of 100 mg L^{-1}. Also, the good biosorption efficiency of 50.74% Cu(II) was reached at a contact time of 90 min. The optimal solution pH was determined to be 4, but the highest removal efficiency of 64.27% for Cu(II) was determined at pH=7. Thus, mullein leaf shows the potential of a cost-effective biosorbent for wastewater treatment, but further investigation of modified mullein will be applied.*
Keywords: Biosorption, Non-toxic plant biomaterial, Copper(II)

1. INTRODUCTION

Heavy metals in polluted waters and industrial effluents are considered as a threat to living organisms and may cause many diseases. Among all existing metals, copper is included in the group of essential trace elements, but high concentrations of copper are toxic to most life forms [1, 2]. In recent years, detailed studies on the copper impacts to human health have been conducted and because of adverse effects, significant research has been performed for treatments of removing copper from contaminated water [3]. Some of the proposed treatment methods were: ion exchange, adsorption, membrane separation etc. These conventional methods require high investment, and that is why researchers focus on the use of low-cost and locally-available materials for cheaper and environmentally friendly methods for water treatment [4]. Such a method is biosorption, treatment that uses sorbent materials with high binding affinity and surface area [5]. Various biosorbents can be used for copper-containing wastewater treatment, such as agricultural waste, which includes walnut, pistachio, rice straw, corn, orange, pine cone, straw, tea waste, local seashells etc. [6]. Mullein (*Verbascum thapsus*) is a tea waste generated from local tea supplier after the expiration date. According to the [2] mullein surface has C–H, C–O, O–H, C=O and COO– groups that can be used for the binding of metals; it also contains phenol, alkaloids, tannins, saponins, flavonoids, and triterpenoids.
The purpose of this study was to investigate the use of mullein leaves powder as biosorbent for the removal of Cu(II) ions from synthetic solutions.

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2. MATERIALS AND METHODS

The stock solution of copper sulfate (1 g L^{-1} Cu(II)) was prepared using deionized water. Samples of washed, dried and grounded mullein were collected from a local supplier of tea, Adonis, Serbia. Additionly, waste mullein was previously grounded in a blender, and then sieved to get particle size below 1 mm. Prepared biosorbent was stored in the paper bags until biosorption experiments.

2.1 Biosorption experiments

The biosorption of Cu(II) ions using waste mullein was performed in copper synthetic solutions (50 mL of each solution), at room temperature. The effects of initial biosorbent dosage (2–20 g L^{-1}), contact time (10–120 min.), solution pH (3–7), and initial Cu(II) concentration (25–400 mg L^{-1}) on biosorption were investigated, at a speed of 600 rpm. After filtration, Cu(II) ions concentration in treated sample solutions, were determined using an inductively coupled plasma optical emission spectrometer (ICP-OES Optima 8300; Perkin Elmer, USA). Biosorption efficiency (E, %) and adsorption capacity (q, mg g^{-1}) of waste mullein were determined using equation (1) and (2), respectively [4]:

$$E\ (\%) = \frac{C_0 - C_e}{C_0} \times 100 \quad (1)$$

$$q = \frac{C_0 - C_e}{m} \times V \quad (2)$$

where *Co* and *Ce* are initial and equilibrium Cu(II) concentrations in the synthetic solution (mg L^{-1}), *m* is mass of waste mullein (g) and *V* is volume of Cu(II) solution (L).

3. RESULTS AND DISCUSSION

3.1 Effect of biosorbent dosage

The effect of the biosorbent dosage of mullein on the removal of Cu(II) ions from the synthetic solution was investigated with five different biosorbent dosages (2, 8, 12, 16, 20 g L^{-1}) under the following conditions: contact time 90 min, solution pH = 4, temperature at 25°C, and initial Cu(II) ion concentration 100 mg L^{-1} (Fig. 1). The results showed that increasing mullein dosage until an effective level of 20 g L^{-1} enhanced the adsorption efficiency of Cu (II) ions, resulting in a biosorption efficiency of 58.74% for Cu (II) ions. This may be a result of the initially available active sites and negative surface charge of the mullein which can favour electrostatic attraction between sorbent and solute [7]. As can be seen in Fig. 1., as the biosorbent dosage increases, the adsorption capacity considerably decreases. Consequently, increasing the amount of mullein biomass gradually increases the final removal of metal ions, but it also leads to reduction of active sites and adsorption capacity of mullein [8]. Therefore, the optimum mullein dosage was achieved at 20 g L^{-1} for further experiments analysis.

3.2 Effect of contact time

The effect of contact time (10, 40, 60, 90, 120 min.) for biosorption of Cu(II) ions at pH = 4 for initial metal concentration of 100 mg L^{-1} by using 20 g L^{-1} of mullein was investigated and shown in Fig. 2. The results indicated slower increase of biosorption efficiency and adsorption capacity of mullein till a good degree of adsorption was achieved at 90 min for Cu(II) ions. The maximum biosorption efficiency and adsorption capacity at contact time were 50.74% and 2.54 mg g^{-1} for Cu(II), respectively. After 90 min., the biosorption rate decreases because the equilibrium condition was

achieved due to repulsive forces on the mullein surface [4]. The optimal contact time of 90 min was used for further analysis.

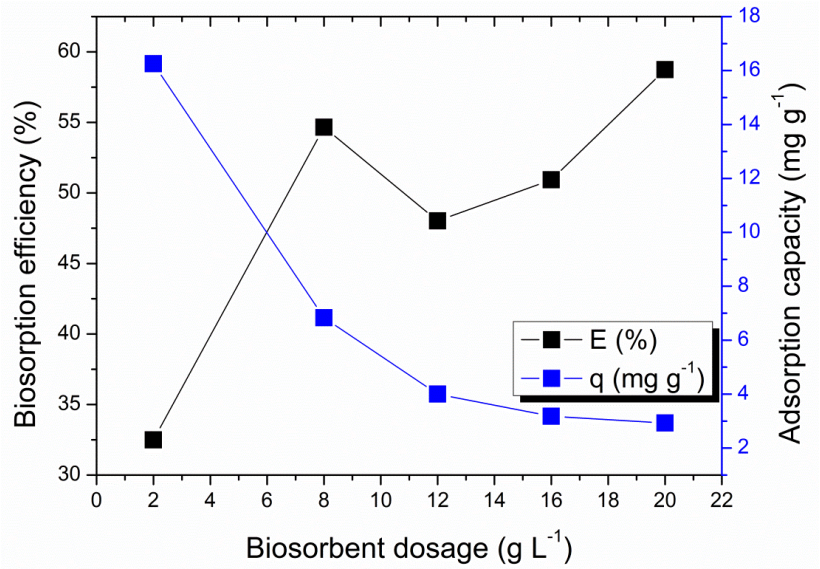

Figure 1. Effect of biosorbent dosage on adsorption capacity and efficiency of Cu(II) ions from synthetic solutions

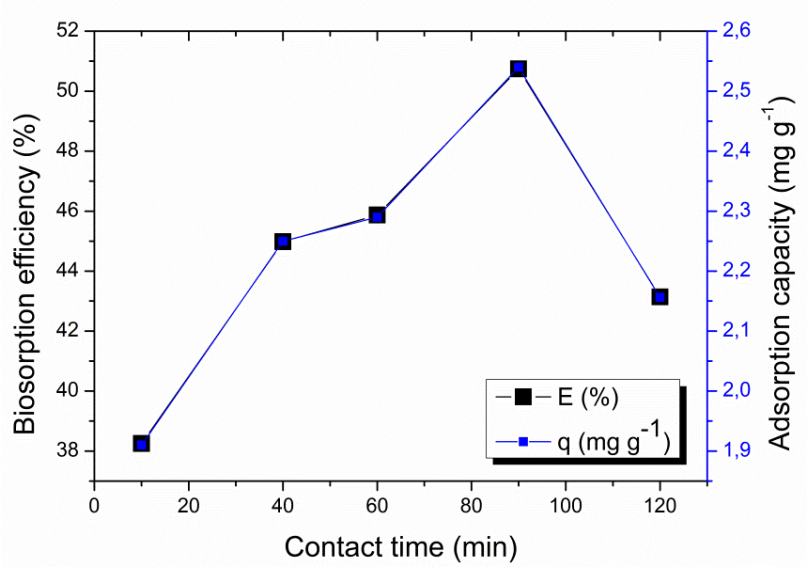

Figure 2. Effect of contact time on adsorption capacity and efficiency of Cu(II) ions from synthetic solutions

3.3 Effect of solution pH

Biosorption processes are highly pH dependent, because H^+ ion concentration may influence the charged biosorbent surface and the ionization degree of various contaminates. The effects of initial pH (3, 4, 5, 6, 7) on biosorption efficiency of Cu(II) ions were investigated by optimal contact time at 90 min and an initial Cu(II) concentration of 100 mg L^{-1} by using 20 g L^{-1} mullein. The biosorption efficiency of Cu (II) ions was raised by increasing the pH values, as shown in Figure 3.

Based on the results, it can be observed that the highest biosorption efficiency and adsorption capacity were observed at pH = 7. At higher pH, biosorption of Cu(II) ions can occur under the lower H^+ ion concentration, which further produces more negatively charged binding sites. This could free the functional groups on mullein surface, and in this way can be more suitable for Cu(II) ions adsorption

[5, 9]. The finding wasn't in agreement with the recently published result [2], where for the optimal pH value for Cu(II) biosorption using grounded mullein particle size below 2 mm, was 4.

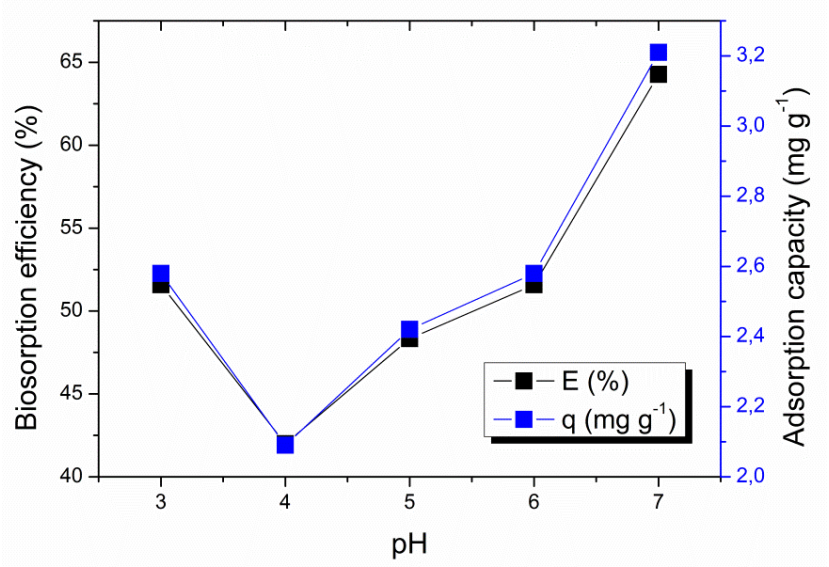

Figure 3. Effect of pH on adsorption capacity and efficiency of Cu(II) ions from synthetic solutions

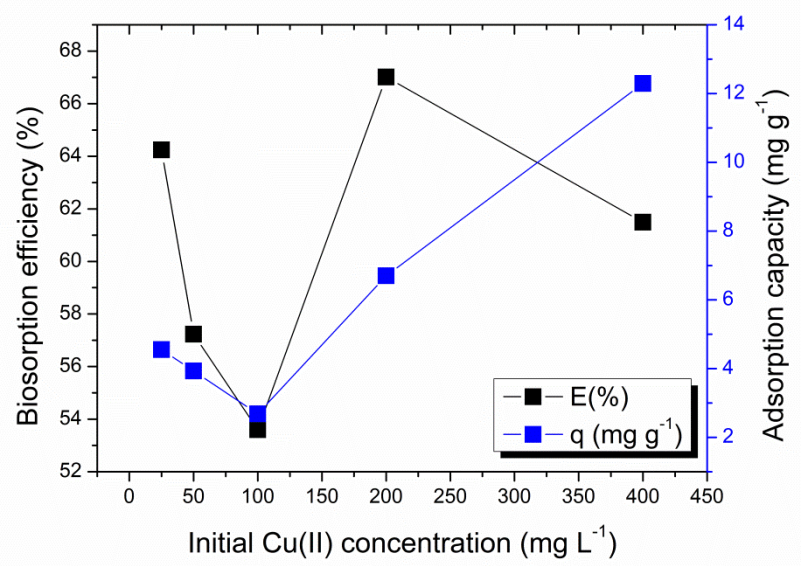

Figure 4. Effect of the initial Cu(II) concentration on adsorption capacity and efficiency of Cu(II) ions from synthetic solutions

3.4 Effect of the initial Cu(II) ions concentration

Initial Cu(II) ions concentration (25, 50, 100, 200, 400 mg L^{-1}) effect on biosorption efficiency of mullein was studied at previously optimized parameters (pH = 4, temperature of 25°C, contact time 90 min, and biosorbent dosage of 20 g L^{-1}). The results are presented in Fig. 4. It can be observed that an increase in the initial Cu(II) ion concentrations from 25 to 100 mg L^{-1}, leads to a decrease in biosorption efficiency and adsorption capacity. However, a further increase in the Cu (II) concentration resulted in an increase in Cu(II) removal. The highest removal efficiency (67.01%) of Cu(II) ions was observed with an initial Cu(II) ions concentrations of 200 mg L^{-1}. The results indicated that mullein gives maximum removal potential for Cu(II) ions at their higher initial concentrations. Higher initial concentrations lead to quick saturation of the mullein binding sites because the quantity of biosorbent stays constant [4]. However, a further increase in the Cu(II)

concentration resulted in a biosorption efficiency decrease. It can be seen that the highest removal efficiency (67.01%) using 20 g L^{-1} mullein was lower than results, given in our previously published paper [2], of copper removal (~79%) for 2 g L^{-1} mullein. Therefore, the initial Cu(II) ions concentrations of 100 mg L^{-1} was utilized for further experimental analysis.

4. CONCLUSION

This study presents the use of natural resource, a nontoxic edible plant and cost-effective biosorbent in wastewater treatment for biosorption of Cu(II) ions from synthetic solutions. Mullein with biosorbent dose of 20 g L^{-1} showed a good potential for biosorption of Cu(II) ions as compared to mullein with biosorbent dose of 2 g L^{-1}. Precisely, the maximum removal of Cu(II) ions was 67.01% at the initial Cu(II) ions concentration of 200 mg L^{-1}. Overall, it could be inferred that 2 g L^{-1} mullein was able to remove Cu(II) ions more effectively from Cu(II) solutions than the mullein of 20 g L^{-1} under the same conditions (pH=4, t=25°C, contact time of 90 min., and initial Cu(II) ions concentrations of 100 mg L^{-1}). For further investigations, the mullein could be examined under other various conditions or as new modified sorbent under the same conditions.

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POSSIBILITIES OF PRODUCTION OF A NEW FUNCTIONAL PRODUCT – MAYONNAISE WITH REDUCED FAT CONENT

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Abstract: *Excessive consumption of fat leads to various health problems, and for this reason, food with a reduced proportion of fat, which in addition to its nutritional content also has health benefits (functional food), is increasingly sought after. A product with a high proportion of fat (60-80%) is mayonnaise, a semi-solid emulsion of oil and water, with the addition of vinegar and egg yolk, salt and spices (optional). The high total caloric value, the intake of cholesterol derived from eggs and the rapid autoxidation of unsaturated fatty acids of the lipid fraction are the reasons that encourage researchers to search for new mayonnaise formulations. Substitutes for fat in mayonnaise can be carbohydrate-based (cereals, legumes, chia seeds, pumpkin seeds) and protein-based or their combination. The possibility of replacing whole or partial egg yolk with soy, wheat, and milk proteins is also being investigated. By the way, low pH and high fat content make mayonnaise an emulsion stable for microbes, but mayonnaise with reduced fat content requires additional ingredients to maintain stability, and natural antioxidants, phytosterols, prebiotics and probiotics that give mayonnaise and added value are being researched as such additives. This paper presents the possibilities for the production of functional mayonnaise.*
Key words: *mayonnaise, reduced fat content, functional product*

1. INTRODUCTION

Mayonnaise is the oldest and most commonly used sauce in today's world, it is a semi-solid emulsion of oil in water, with a large proportion of fat (65-80%), with the addition of vinegar and egg yolk, salt and spices (most often mustard). Yolk is still mostly used as a supplement, due to its high emulsifying ability. A high proportion of fat, i.e. high energy value and cholesterol derived from eggs, makes mayonnaise a product that is undesirable from a health point of view. According to the recommendations of the World Health Organization for health, and in order to reduce chronic cardiovascular diseases and obesity, fat consumption should be reduced, and to this end, the food industry is researching suitable substitutes for fats, in formulating new functional products such as mayonnaise. The low pH and high fat content make mayonnaise an emulsion stable for microbes, but reduced-fat mayonnaise requires additional ingredients to maintain stability. There is an effort to produce mayonnaise with a lower fat content, i.e. a lower energy value, with the use of new emulsifiers, which will replace egg yolks and additional ingredients to maintain stability. Also today, there is an increasing demand for products, including mayonnaise with a clean label, i.e. so-called products "without additives", "minimum processing" and "short list of ingredients" [1,2,7,31]. In general, the production of a new product - functional mayonnaise implies the use of substitutes for fat and/or egg yolks and the addition of some functional ingredients to mayonnaise (prebiotics, antioxidants or phytosterols). This paper presents some possibilities for the production of mayonnaise with a reduced fat content, that is, the possibility of producing a new functional mayonnaise in which

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part of the fat is replaced with carbohydrates or proteins and/or in which the egg yolk is partially or completely replaced, as well as the possibility of producing new mayonnaise formulations to which natural antioxidants, phytosterols, prebiotics and probiotics are added, which give mayonnaise and added value.

2. SUBSTITUTES FOR FATS IN MAYONNAISE

Oil-in-water emulsion is a very common form of food with many applications, especially in the fast food industry, which, like mayonnaise, has a certain texture, creaminess and taste thanks to fat, and for this reason fat substitutes must imitate the relevant properties in products with reduced by the proportion of fat. Rheological properties, such as viscoelasticity, thixotropy and stackability, which mayonnaise should possess, are also required from mayonnaise analogues with a low fat content. Fat substitutes in mayonnaise can be based on carbohydrates or proteins or their combination and are generally called fat mimics (mimetics), which cannot completely replace fat in food, but offer a similar mouthfeel and texture to fats. Carbohydrate-based fat substitutes are compounds derived from grains, legumes, and plants with digestible or indigestible carbohydrates. Studies have shown that corn dextrin, inulin, and polydextrose are the most acceptable fat substitutes in emulsion-based products. Modified rice starch, oat dextrin, inulin, pectin and konjac gel are also mentioned in the literature. Proteins with unique structure and functional properties, especially gelatin and whey protein, are often mentioned as fat substitutes. Whey proteins have a lower energy value (0-17. kJ/100g), but also the ability to coagulate a gel under different temperature and pH conditions. With microparticles, it covers the taste buds analogous to lipids, so this coating helps flavors to gradually reach the receptors and helps mask some astringent and bitter tastes in products with a low fat content. It is also very important that whey proteins have a generally recognized safe status (GRAS). which makes them suitable for use in food [4,6,9,21,27,33].

Starch-based fat substitutes are a type of fat mimetics that can be produced either chemically as modified starch or enzymatically as maltodextrins. Natural starch and modified starch are good fat substitutes because some starch granules have similar sizes and shapes to fat globules, which enables them to create a similar texture, i.e. they act like fat globules in modulating the structure and sensory characteristics of food. Modified starches increase water holding capacity and minimize starch syneresis, while maltodextrins can form thermoreversible gels [21,22]. Park J.J. et al (2020) examined the effect of using modified starch with 30% and 50% fat replacement on the physical stability of mayonnaise. Modified arrowroot starch (modified by octenyl succinic anhydride (OSA), annealing (ANN), citric acid hydrolysis (CA), acetylation (ACT), and heat moisture (HMT)) was used to replace fat in mayonnaise at 30% and 50% levels and different pastes with full-fat mayonnaise were compared. Mayonnaises with reduced fat content showed greater stability than full-fat emulsions. Those with starch obtained by annealing modification, OSA-starch and CA-starch were especially stable and are a suitable substitute for fat in mayonnaise [19]. In his research, Gaafar A. (2011) developed a light mayonnaise with the replacement of fat with mashed potato powder, at the level of 5, 10 and 15%, reducing the fat to 50% and the results showed a good potential for potato powder used as a substitute for fat in mayonnaise, i.e. all low-fat mayonnaise formulas have a significantly lower share of energy, a higher share of water, the color is better, the rheological characteristics are the same as those of commercial low-fat mayonnaise, and the microbiological picture was adequate during the entire storage period [13].

Although modified starch is used more in the food industry, because natural starch is not always suitable for all processing conditions, such as low pH, high temperatures and freezing, there is concern among consumers, even with some chemical modifications through which the ingredients of the status of safe are created (GRASS). Consumers are increasingly striving for natural ingredients and for this reason the demand for physical modifications of starch that will replace fat is growing. A study conducted by Werlang S. et al. (2021), confirmed the successful use of natural and heated oat starch as a natural fat replacement ingredient in mayonnaise. Annealing increased stability, smoothed texture, and reduced final viscosity, retrogradation, gel hardness, and gumminess. For both starches,

as the percentage of starch in the mayonnaise increased (0%, 50% and 75%), the stability of the mayonnaise increased [30].
In their research, Hosseinvand A. et al. (2019) used different levels of corn bran as a fat substitute for the production of low-fat mayonnaise. Four formulas were prepared including a control without corn bran, low-fat with 25% corn bran, low-fat with 50% corn bran and low-fat with 75% corn bran. Although the control formula without corn bran received the highest scores in some properties, such as texture, mouthfeel, viscosity and purchase intention, the low-fat mayonnaise samples had higher water activity and lower pH values during the storage period than the full-fat samples, the conclusion is that corn bran can be used in the formulation of low-fat mayonnaise as a fat substitute with acceptable physico-chemical and sensory properties [16]. Su H.P. et al. have developed a low-fat mayonnaise containing polysaccharide gums as functional ingredients. Xanthan gum ($15g/kg^{-1}$), citrus fibers ($100\ g/kg^{-1}$) and variable concentrations of guar gum were used to formulate optimal ratios of polysaccharide gums as a fat substitute. The proportion of fat in mayonnaise was reduced to 50% compared to full-fat mayonnaise, and the products still retained ideal rheological properties [26]. The complex of microparticles of whey protein and pectin proved to be a good gel-mimetic for the production of low-fat mayonnaise. A certain addition of fat mimetics (up to 60%) increased the stability of mayonnaise during storage, preventing coalescence and flocculation of droplets, and the application of fat mimetics (up to 40%) suppressed the reduced viscoelasticity of mayonnaise [27]. Research into functional foods with reduced fat content, such as is the addition of 6% pumpkin flour to mayonnaise with reduced fat, indicates a better physico-chemical quality of mayonnaise. Antioxidant compounds (carotenoids and polyphenols), as well as pectin in pumpkin flour, which serves as a stabilizer in the formulation of mayonnaise, and the composition of fatty acids (palmitic, oleic and linoleic), contribute to the functionality of this product [18]. One example of the production of mayonnaise with a low fat content is the formulation of an emulsion in which an emulsion gel made of alginate and konjac glucomannan is used, and which shows good thermal stability and stability during freezing and thawing [32].

3. SUBSTITUTES FOR YOLKS IN MAYONNAISE

The egg has excellent emulsifying properties, but there are some limitations such as the high cholesterol content and the possibility of contamination by *Salmonella sp.,* which is why in mayonnaise formulas it is tried to partially or completely replace the egg yolk. The use of vegetable proteins such as lupine proteins, soy proteins and pea proteins is the most common method for preparing emulsions, and one of the ways is also the use of egg yolk, which contains low cholesterol. Scientists have also investigated the use of animal proteins such as casein, protein whey and meat protein. A study done by Satriawan T.U. et al. (2022) showed that the use of whey protein concentrate as high as 15% gives the best low-fat mayonnaise [25].
One of the studies relates to the stability and rheological behavior (droplet size, microstructure, stacking ability, flow behavior and viscoelastic properties) of mayonnaise co-emulsified with konjac glucomannan at a concentration of 0.1-0.5% (w/w) and whey protein, at concentration of 1.0-3.0% (w/w) and the results showed that the mentioned mixture can be used as an efficient substitute for egg yolks in the production of cholesterol-free mayonnaise [20].The application of soybean oil as a substitute for egg yolks and as a raw material from which most of the mayonnaise is prepared also proved to be quite good, although the disadvantages were a low lecithin content and somewhat weaker stability and sensory properties. For this reason, Wang W. et al. (2022) conducted a study that showed that low-fat mayonnaise, where soybean oil was used as a substitute for egg yolk and in which xanthan gum, pectin and modified starch were added (ratio 2:1:1) as a stabilizer, it has good viscosity, stability, texture and microstructure. In addition, the storage stability was investigated and compared to whole yolk mayonnaise, this mayonnaise had better oxidative stability and bacteriostatic, which is important for mayonnaise storage [29].

The development of mayonnaise with the replacement of oil or egg yolk with the addition of chia mucilage (*Salvia Hispânica L.)* is something new when it comes to the production of a new functional mayonnaise. Chia mucilage is produced by the hydration of chia seeds and due to its properties such as the ability to emulsify and retain water, it can be used as a substitute for fat in various food products. In a study conducted by Fernandes S.S. et. al. (2018) mayonnaise was made with different levels of freeze-dried chia mucilage instead of oil or egg yolk. Replacing oil with chia mucilage in mayonnaise (45%) increased stability and improved texture, the proportion of lipids decreased by about 50% and sensory acceptability was good. When replacing the egg yolk, these properties were the same as with the control mayonnaise, i.e. it was not possible to significantly reduce the lipid content or maintain the stability of the emulsion [12]. The possibilities of using hydrocolloid emulsifiers, soy soluble polysaccharide, gum arabic and starch octenyl succinate were also examined, due to their ability to create oil-in-water emulsions such as mayonnaise. Xanthan gum was used as a stabilizer and/or thickener and the results showed a possible application [8].

4. ADDING SOME FUNCTIONAL INGREDIENTS TO MAYONNAISE

Milk protein, casein, which is a phosphoprotein, or a mixture of rice bran oil and casein powder or a mixture of rice bran oil and palm stearin are incorporated into some new mayonnaise formulations. Research has shown that mixtures of rice bran oil and palm stearin (7:3 and 6.5:3.5), as well as casein and rice bran oil (7:3 w/w) give a product that has a soft, creamy appearance, and in addition, due to the content of rice bran, it also contains antioxidants (oryzanol, squalene, tocopherols, tocotrienol) and polyunsaturated fatty acids such as linoleic [10]. According to the research of Vieira M.R. et. al. (2023), the use of fruit flour (apple, nectarine, pear and peach flour) in the production of mayonnaise as a substitute for sugar, preservatives and colors contributes to the incorporation of bioactive compounds (carotenoids and phenolic acids), which increases the antioxidant capacity, i.e. stability and the shelf life of mayonnaise, the color, viscosity and texture are better and the product becomes functional with a so-called "clean label" [28]. Another fruit has found its place in the formulation of mayonnaise, and that is watermelon, i.e. the addition of watermelon rind flour (6%) it can be used as a stabilizer because it has a significant effect on emulsion stability and moisture content, on ph, and does not affect the sensory evaluation of mayonnaise [11]. Beetroot powder (tested in conc.of 1.5, 3, 5 and 7%) can be used as a natural ingredient in the formulation of mayonnaise with added value because it is rich in antioxidants (betalain and polyphenols), and in addition, mayonnaise increases strength, adhesiveness and cohesiveness and improves viscosity [17].

A study conducted by Dipan Chatterjee and Paramita Bhattacharjee confirmed the possibility of formulating a 'new functional mayonnaise using the eugenol-lean fraction (a fraction low in eugenol) of clove buds as a flavor ingredient (replacing mustard in the classic formula) and as a source of natural antioxidants to improve shelf life and nutritional value of the product [5]. Mayonnaise has a sour, salty and slightly sweet taste that comes from sugar, and new research confirms the possibility of using stevia (stevia leaf flour - 0.5%), a natural sweetener that is used as a substitute for sugar in production new mayonnaise formulations (lower energy value, acceptable color, carbohydrate content strengthens emulsion droplets in mayonnaise) as a natural ingredient [14]. The addition of phenolic extracts to mayonnaise was investigated by Romeo R. et al. (2021) and all with the goal of producing enriched mayonnaise that will have better oxidative stability and antioxidant activity. Mayonnaise was enriched with different concentrations (50, 150 and 300 mg/kg) of commercial olive leaf phenolic extract and stored at 30°C for 30 days. Microbiological and sensory parameters, individual phenol content, oxidation stability, antioxidant parameters were monitored. Enriched mayonnaises showed good pH values and no microbial contamination was detected. The addition of 150 mg/kg of extract made it possible to obtain a mayonnaise more stable to oxidation, but it is better to use a lower concentration of phenolic extract (50 mg/kg) due to the taste of the final product, which must be acceptable to consumers[24]. Mayonnaises that contain microencapsulated oils can be a source of polyunsaturated fatty acids, and this has found application in the production of enriched mayonnaise with microencapsulated chia seed oil, pumpkin seed oil or palm oil (up to 5% by mass)

[23]. Microencapsulation has also found excellent application in encapsulating probiotics (*Lactobacillus casei* and *Bifidobacteria bifidum*) and adding them to mayonnaise, which makes mayonnaise bio-mayonnaise, and the probiotic flora embedded in mayonnaise has shown good results in improving the well-being of the intestinal microflora, and also reduces the possibility of mayonnaise poisoning [3]. A study done by Satriawan T.U. et al. (2022) showed that the use of whey protein concentrate of as much as 15% gives the best low-fat mayonnaise [25]. Not only is the goal of food technologists to produce a functional food product, but research is also being done where by-products are used, so it has been shown that the formulation of mayonnaise made with the addition of gum solution obtained from cold-pressed by-products of chia seed oil, flax seed and rocket seed can be use in low-fat vegan food [15]

5. CONCLUSION

Although fats provide good taste and texture and their replacement affects the properties of the final product, which limits consumer acceptance and the rate of commercial success, the association of fat in food products with increased cardiovascular disease and obesity has led to a great need for the development of new functional mayonnaise with a low fat content and/or replaced with egg yolk, and preferably enriched with antioxidants, phytosterols, prebiotics and probiotics, which will have rheological properties such as viscoelasticity, thixotropy and stackability that mayonnaise should have, with appropriate sensory properties. Today, mayonnaise as a product is increasingly demanded to have the so-called "clean label" and all that represents a big challenge for food technologists.

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UTILIZATION OF APPLE POMACE TO OBTAIN FUNCTIONAL BAKERY AND CONFECTIONERY PRODUCTS

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Abstract: *After the industrial processing of apple remains a large amount of low-cost agro-industrial apple pomace which is made up of the skin, pulp and seeds. Bearing in mind quantities generated annually, disposal of this by-product as waste in a soil and/or a water in addition to the economic one, creates a serious environmental problem. On the other hand, apple pomace represents a rich source of valuable phytochemicals such us phenolics, dietary fibres and fatty acids which benefits on health is well known. For this reason, apple pomace could be utilized as a functional ingredient in food industry, while at the same time avoiding the environmental problem. In this review paper, the application of apple pomace in bakery and confectionery products is presented. Added as substitute of wheat flour, apple pomace improves the textural characteristics and oxidative stability of them. Besides nutritional characteristics, this adding affects in techno-functional properties, such as water-holding capacity, oil-holding capacity and swelling capacity.*
Keywords: Utilization, Apple pomace, Bakery products, Confectionery products.

1. INTRODUCTION

The apple (*Malus* sp.) is one of the most popular fruits in the world, with an annual production of 87 million tons in 2019 [1]. About 18% of the world's apple production is processed, which creates significant amounts of apple by-products [2]. Apple pomace makes up 25-40% of the mass of processed apples, which depends on the processing technology [3]. Several million tons of apple pomace are generated annually as, mostly, the waste or used as animal feed. The disposal of apple pomace as waste is an ecological problem, due to its high water content and numerous nutrients [4]. It's necessary to find profitable ways to dispose of apple pomace waste or to discover value-added uses that are both economically and environmentally beneficial [5].

By recycling the by-products of the food industry, the amount of discarded materials dumped into the environment would be reduced, the economic efficiency related to the circular economy would be improved, and it would contribute to sustainable development [6,7]. In this regard, it's important to create new recipes for bakery and confectionery products that contain ingredients rich in natural antioxidants (polyphenols) and can be obtained in large quantities at a reasonable price. Dried apple pomace seems to meet all these requirements.

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2. APPLE POMACE

2.1 Chemical composition and nutritive value of apple pomace

The largest part of apple pomace consists of skin and flesh (95%), followed by seeds (2-4%) and stems (1%) [8]. Due to its high water content, apple pomace is highly susceptible to microbial spoilage, so it's necessary to dry it immediately after processing to stop and slow down this deterioration [4]. Dried apple pomace is microbiologically stable and grounded into flour it can be used as an alternative to wheat flour [9]. It is considered a concentrate of various ingredients useful for health, mainly polyphenols, such as phenolic acids (especially chlorogenic acid), flavonoids (catechins, epicatechins) and phloridzin [10]. The content of polyphenols in apple pomace powder ranged from 17.83 - 38.83 mg gallic acid (GAE)/g [3]. After the juice extraction process during apple processing, it's estimated that 82-99% of polyphenols remain in the apple pomace [4]. These components show numerous properties that improve health, such as a hypoglycemic effect, hypocholesterolemic, anti-carcinogenic, anti-inflammatory, antiviral, antibacterial, anti-allergic, anticoagulant properties, and reduce the risk of diseases such as atherosclerosis and other cardiovascular diseases, cataracts, diabetes, genetic damage, degenerative bone changes, neurodegenerative diseases, including Alzheimer's and Parkinson's disease [11]. Apple pomace also contains simple sugars (glucose, fructose and sucrose), pectin, crude fiber, proteins, vitamins and minerals (Table 1).

Table 1. Quantity of nutritive compounds of dried apple pomace
Source: *[4]*

Compounds	Quantity (g/100g)	Compounds	Quantity (g/100g)
Moisture	3.97 – 9.75	Sodium	2 – 200
Fats	0.26 – 8.49	Potassium	449
Proteins	1.2 – 6.91	Calcium	50 – 150
Fructose	11.5 – 49.8	Phosphorus	50 – 950
Glucose	2.5 – 22.7	Magnesium	20 – 45
Total Dietary Fiber	26.8 – 82.0	Iron	2.4 – 23
Pectin	3.5 – 14.32	Zinc	0.22 – 1.5
Total polyphenols	0.17 – 0.99	Copper	0.11 – 0.22
Malic acid	0.05 – 3.28	Manganese	0.61 – 0.9
Ash	0.5 – 4.29		

Total dietary fibers (TDF) make the greatest contribution to the chemical composition of apple by-products (55.48±0.7g/100g of dry matter). Insoluble dietary fiber (IDF) makes up the largest proportion (43.58±0.6g/100g of dry matter), while soluble dietary fiber (SDF) makes up a smaller proportion (11.06±0.1g/100g of dry matter) [7]. Studies have shown that dietary fiber can also improve the functional properties of food such as increasing water-holding capacity, oil-holding capacity, emulsification and gel formation. Added to food products, dietary fiber can modify textural properties, prevent syneresis, stabilize high-fat foods and emulsions and extend shelf-life [12].
Dietary fiber and polyphenols are the two key ingredients in functional foods that are believed to provide health benefits. The combination of apple pectin and apple concentrate rich in polyphenols had a significant effect on the reduction of plasma cholesterol and triglyceride levels, as well as the absorption of cholesterol in the intestines [3,5].
In addition to the mentioned nutrients, apple pomace also contains triterpenoids and fatty acids. Apple terpenoids can be found either in the epidermal cells of the peel or in the epicuticular wax. Triterpene

acids show various pharmacological properties and health effects, such as antioxidant, anti-inflammatory or antimicrobial effects. Regarding fatty acids, recent studies have shown the presence of unsaturated fatty acids in apple seeds and peel [7]. Apple seeds contain significant amounts of oil. Oil content ranges roughly from 12 to 27.5%. Apple seed oil consists of unsaturated fatty acids (90%), mainly oleic and linoleic acids. In this way, apple seed oil belongs to the group of olein-linoleic type oils, which are considered to have positive effects on lowering LDL cholesterol and reducing the risk of heart disease [5]. Also, the antimicrobial and antiproliferative capacities of apple seed oil have been proven in studies [7].

2.2 Utilization of apple pomace in production of bakery and confectionery products

Based on literature data, various types of fruit and vegetable by-products, including apple pomace, were well incorporated into the composition of functional foods, such as bakery and confectionery products.

The influence of the addition of apple pomace in different proportions (10%, 20% and 30%) on the properties of cake was examined. With an increase in the percentage of added pomace, there is a decrease in volume and an increase in the density of the enriched cakes, due to the strong water binding properties of the apple fibers. Cakes prepared with a 25% of added apple pomace and wheat flour had 14.2% TDF with highly acceptable quality. Cakes prepared with apple pomace had a pleasant fruity taste [9].

The utilization of 20% apple pomace instead wheat flour significantly increased the total content of flavonoids, polyphenols and proanthocyanidins in baked scones by 4, 3.3 and 3.1 times, respectively [13].

Dried apple pomace was used as a substitute (15% and 20%) for wheat flour in the preparation of cookies and muffins. The resulting cookies and muffins had a higher amount of fiber, but significantly darker than the control ones, due to possible non-enzymatic browning. The enriched cookies and muffins were softer than the control ones, but there was no adverse effect on physico-chemical and textural characteristics of the final product [14].

In study [15] the utilization of apple pomace in proportions of 5%, 10% and 15%, instead of wheat flour in biscuits, showed that there was no significant difference in the overall acceptance between the control sample and samples with added 5% apple pomace. A further increase in the addition of apple pomace led to evidently lower sensory properties, due to a harder consistency. It was concluded that apple pomace powder can be used as an alternative source of dietary fiber with amount 51-52% of total dietary fiber.

The dough performance and bread quality, with the addition of 10% apple pomace, were examined. The addition of apple pomace significantly increased dough yields. The crumb and crust structure of enriched breads were very similar to control sample. There was a significant change in the color of the crumb and crust of the enriched products, compared to the control, and a smaller volume and thickness, which is similar to other studies described [12].

The total phenolic content and total flavonoid and antioxidant activity, as well as the quality and quantity of phenolic compounds in gluten-free breads with the addition of apple pomace in different proportions (5, 10 and 15%), compared to control sample with 100% wheat flour. Bread with 15% apple pomace had the highest content of phenolic compounds and the highest antioxidant potential, but the lowest organoleptic characteristics. The best results of the organoleptic analysis were obtained by bread with a 5% addition of apple pomace. Bread with this level of apple pomace has 2.5 times more polyphenols, 8 times more flavonoids, 4 times more chlorogenic acid and 21 times more phloridzin than the control sample, resulting in 6.5 times more antioxidant potential [10].

Examination of the chemical composition and physical properties of gluten-free cookies with 15%, 30%, 45% and 60% added apple pomace is described in [11]. It was found that the presence of apple pomace in gluten-free cookies caused an increase in the content of all polyphenols, a decrease in protein content, a slight increase in fat content and an increase in mineral content ranging from 14% to 58% compared to the control sample. Increasing the proportion of apple pomace caused a significant increase in fiber content, insoluble fraction 8–29 times, soluble fractions 1.5–5 times, and total fiber 3.5–13 times, compared to the control samples. As for the organoleptic characteristics, there was an increase in the hardness and darkening of the cookies, along with a decrease in their volume.

The study [16] describes the development of a sweet gluten-free bread with the addition of apple pomace flour. This addition leds to a denser dough structure and firmer breads, which was offset by a positive effect on taste.

The effect of the addition of apple pomace and rice flour on the physical and chemical characteristics of two enriched wheat breads was described. In the recipe for bread sample number 1, wheat flour was replaced with 25% rice flour and 10% frozen apple pomace, and in sample number 2, part of the wheat flour was replaced with 12.5% of rice flour and 10% of fresh frozen apple pomace. The results showed a superiority in the quality of enriched breads, compared to bread with 100% wheat flour. Sample number 2 had a more pleasant taste, texture, aroma, color and crumb. Sample number 1 had the holes in the structure. The use of rice flour and apple pomace in the production of enriched bread had an effect on increasing the content of iron and phosphorus in the finished product [17].

The addition of apple pomace to wheat flour in proportions of 5, 10, 15, 20 and 25% to prepare cookies resulted in a decrease in width (from 45.13 mm for 0% to 44.75 mm for 25% apple pomace) and cookie thickness (from 1.47 mm for 0%, to 1.21 mm for 25% apple pomace). The water absorption capacity of flour is increased by the addition of apple pomace (from 2.06% for 0%, to 2.83% for 25% apple pomace), because a higher fiber content increases water absorption. Sensory properties were also affected by the addition of apple pomace powder, but cookies with 10% apple pomace were found to have the best color and aroma, while crispness was similar to the control sample, which was rated best in taste, as well as mouthfeel, texture and overall acceptability [18].

The effect of replacing wheat flour with crude apple pomace flour (APF) in amounts of 25%, 50% and 75% on cookies showed that the crude APF gave better sensory properties, content and retention of dietary compounds and antioxidant activity. Cookies with an optimal proportion of coarse APF (50%) contained 21g/100g dietary fibers and several times higher amounts of polyphenols, flavonoids, as well as antioxidant activity, than control cookies, retaining health-promoting compounds and maintaining an intense fruity aroma and crunchy texture, which lasted throughout 12 months of storage. They were acceptable to consumers according to the hedonic test. Consumer evaluation using the hedonic test confirmed that replacing up to 50% of wheat flour with coarse APF is possible at the industrial level of cookie production, without compromising the acceptability of the product [19].

3. CONCLUSIONS

Enriched bakery and confectionery products with apple pomace have a significantly higher amount of dietary fiber and polyphenolic compounds compared to control samples, without apple pomace. This makes apple pomace an excellent alternative source of dietary fiber and antioxidants. On the other hand, the sensory characteristics of the enriched products are acceptable for consumers, at the share of 10% added apple pomace. It especially contributes to a very pleasant fruity taste and aroma. With a larger amount of apple pomace added, their density and hardness increase, while their volume and thickness decrease. They get a darker color of the crumb and the crsut, a denser structure, and the taste is more bitter. Dried apple pomace or APF can be considered an excellent functional ingredient for the production of new bakery and confectionery products with health-promoting compounds.

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ALTERNATIVE PACKING IN WINE PACKING TECHNOLOGY

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Abstract: *In wine packaging technology, glass has been the dominant packaging material for many years. A glass bottle with a cap or stopper provides good protection against spoilage agents and contributes to the preservation of wine quality. For traditional wine lovers, the glass bottle is status symbol of the quality of this drink. New trends in the field of wine packaging are focused on the development and application of alternative packaging such as PET bottles, cans, Tetra Pak and BIB packaging. The use of the mentioned packaging depends primarily on its attributes in protecting the wine compared to glass packaging. For wine producers, the option of cheaper packaging and easier distribution while preserving product quality is acceptable, but the sustainability of this concept also depends on the habits of wine consumers. In the paper, we present an alternative packaging for wine packaging with an analysis of its impact on wine quality and consumer acceptability.*
Keywords: wino, quality, packaging, glass, alternative packaging.

1. INTRODUCTION

Packaging materials intended for food packaging differ from each other in terms of their permeability to gases, moisture, light and microorganisms. They also differ in physical and mechanical characteristics of shaping, printing and closing. The mentioned properties give greater or lesser advantages to the material when choosing packaging material for packing different foods.
Wine is a drink created by the complete or partial alcoholic fermentation of grapes of various varieties of *Vitis Vinifera.*Wine it has a complex chemical composition with participation of water 80 85%, ethanol as the primary alcohol of 9 -15% and a number of other compound such as organic acids, sugars, phenols, nitrogen and other compounds that contribute to the specific taste and aroma of wine.
The quality of wine depends on several factors, which include the assortment of grapes, growing conditions (soil type, climate), processing technique (yeast strain, fermentation conditions), wine oenology, storage and packaging conditions [5]. The choice of packaging material and packaging achieves several functions, of which the most important one is the protection of wine from external spoilage agents (oxygen, moisture, light and microorganism) and preserving the integrity of the packaging. The fulfillment of the protective function of the packaging depends on the properties of the packaging material because inertness is required, i.e. a barrier between the product and the external environment while avoiding the migration of molecules between the material and the product [17].
Glass is the dominant packaging in wine packaging technology, and other packaging materials such as plastic, metals and multilayer materials belong to alternative packaging for wine.

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2. PET PACKAGING AS AN ALTERNATIVE TO GLASS FOR WINE PACKAGING

Polyethylene terephthalate (PET) is a polyester consisting of ethylene glycol and terephthalic acid. Injection and blow molding processes produce PET bottles used for packaging water, juices, soft drinks, beer and wine. During wine aging, its composition changes through a series of complex chemical reactions primarily on phenols (anthocyanin, flavon-3-ols, flavonol, hydroxycinnamic acid) and volatile organic compounds such as esters, fusel alcohols, aldehydes, ketones and acids. Oxidation is one of the factors that can negatively affect the color, taste and aroma of the product, which is why it is necessary to constantly monitor the amount of oxygen that comes into contact with the wine during production, storage and packaging. Oxygen can be considered the main gas present during the bottling of wine. The oxygen content of wine can change after bottling by diffusion from the surrounding atmosphere depending on the permeability of the packaging material. The presence of oxygen also facilitates the development of aerobic microflora, which can damage the quality of the product.

Permeability to oxygen and other gases is the dominant parameter that gives glass an advantage over PET packaging. Undesirable changes in the sensory profile of wine occur under the influence of oxygen, which reduces the shelf life of wine. During wine packaging, in order to slow down oxidative deterioration, about 20-40 mg/l of sulfur dioxide is added, and the first signs of undesirable oxidative changes in aroma and color become noticeable as soon as the level of free sulfur dioxide falls below 10 mg/l of the product. The advantage of glass compared to PET is that glass is practically impermeable to oxygen and other gases, i.e. the minimum permeability is related to the bottle cap.

Ghidossi R et al. (2012) analyzing the influence of the type of packaging (glass, single-layer and multi-layer PET and BIB) on the physical and chemical properties of red and white wine during 18 months of storage indicate that the highest degree of oxidation occurs with wine packed in single-layer PET with a thickness of 0,3mm. especialy with white wine. Concentrations of compounds such as phenyl acetaldehyde, methional and sotolone, which are associated with the oxidation of white wines, were registered above the level of perception. One of the solutions for reducing the permeability of PET material to oxygen and other gases is the application of multilayer PET by combining different films or adding oxygen scavengers.

For a better gas barrier, three-layer or five-layer PET/gas barrier/PET are suggested [22]. With the oxygen scavenger, one of the options is to incorporate it into the polymer coating on the inside of the closure or to integrate the scavenger directly into the structure of the polymer film. Mentana et al. (2009) in their study on the taste and aroma profile of red wines packed in PET and OkSC-PET packaging during a six-month storage period indicate a change in taste due to the loss of various organic compounds before all alcohol, acids and esters. The stated loss levels were lower for packaging than OkSC-PET.

Research on the development of the aromatic profile of rose wine packaged in glass bottles, PET and recycled PET, by Dombra et al. (2015) indicate the appearance of new compounds (derivatives of furfural, 5-hydroxymethyl furfural and ethyl pyruvate or dioxin) regardless of the type of packaging, as well as the appearance of specific compounds diethyl tartrate in glass, ethyl pyruvate in both PET and vanillin in pure PET in. Aroma changes that can negatively affect the shelf life of wine are related to sorption processes in the packaging material,as well as to the degradation process within the product [7].

Bottles of the same shape and volume as glass can be made from polyethylene terephthalate, bottles are closed with plastic caps, and plastic foil is used to unify the package. PET bottles are lighter than glass bottles, there is no breakage, lower transport costs.

3. BAG IN BOX PACKAGING AS AN ALTERNATIVE TO GLASS FOR WINE PACKAGING

Bag in box packaging unit is composed of two parts. The first outer part is a folding cardboard box, and the second part is a double flexible bag with a one-piece, flexible valve that opens and closes when a lever is activated. The outer layer of the bag is made of polyester, and the inner layer is made of low-

density polyethylene (LDPE) or ethylene vinyl acetate (EVA). The films used for this type of packaging have the property of absorbing non-polar compounds from the wine due to the hydrophobic nature of the polyolefin.
The wine is filled under vacuum, and nitrogen is added to the bags to remove residual oxygen. When the wine is poured, the bag collapses, protecting the wine from oxygen. The bag is exposed to constant bending pressures and it is necessary to be made of polymer films with high flexibility, because otherwise there will be perforations that can cause a reduction in the barrier properties of the material. The bag does not lose its integrity in terms of wine leakage, but oxygen enters, reduction of free sulfur dioxide and premature degradation of wine occurs. [9]. It is recommended to avoid contact of the wine with the outer film and to prevent the penetration of oxygen inside the films, which most often happens around the valve for pouring wine.
Analyzing the influence of the packaging material on some oenological parameters of dry white wine packed in BAG end BOX packaging leads to the sorption of flavor compounds into the polymer material. LDPE BIB packages have a higher potential for undesirable absorption of flavor compounds. Changes in titratable acidity, total and free sulfur dioxide and wine color were determined so that the product can be stored optimally for three months after packaging [18].
Moreira et al. (2016) reported similar results when looking at the effect of wine packaging and aging on the variable and sensory attributes of red wine. Due to the greater permeability of the bag-in-bax design, the wine should be consumed quickly and not aged.
Compared to a glass bottle, this type of packaging is practical for carrying, opening and closing the packaging unit. It is attractive to consumers because the freshness of the wine is maintained for three weeks after opening the bag, which relaxes the consumption of a certain volume of drink. In Australia, Sweden and Norway, more than 50% of purchased wine is packed in Bag and Box packaging. [10]

4. ALUMINUM CANS AS AN ALTERNATIVE TO GLASS FOR WINE PACKAGING

Aluminum cans as an alternative packaging for wine packaging is a fast-growing product category with great market forecasts and increasing consumer demand. Packaged wine has become available to wine lovers at sporting, cultural and themed events where access to glass packaging is limited. The global market for canned wine is valued at approximately USD 211.4 million in 2020., and is likely to grow at compound annual growth rate of 13.2% through 2028. [10]
Metals as packaging materials are impermeable to oxygen, light and microorganisms from the outside environment. With the use of cans for wine packaging, defects related to quality and shelf life appeared. The appearance of an unpleasant odor due to the reduction of sulfur dioxide to hydrogen sulfide and the transfer of aluminum to the wine related to the corrosion potential of cans are undesirable reactions in packaged wine. In theory, Al in food packaging is quite resistant to corrosion because it quickly forms a thin layer of aluminum oxide (Al_2O_3) on the surface in contact with oxygen. However, this metal is sensitive to salty, basic and acidic foods (including wine) that dissolve it, leading to its transfer into food. All canned food can interact with the metal inner surface of the package and cause metal corrosion, which is mainly due to a faulty coating.
According to Maslov-Bandic and Saks (2019), the high corrosivity of wine in cans can mainly be attributed to the following factors:

- low pH and high concentrations of bisulfite and Cl–, which can threaten the integrity of the internal Al coating;
- the expected low rH of canned wine, which hinders the regeneration of the Al coating; and
- the presence of Cu+, which can catalyze pitting corrosion inside the can

Recent studies by Allison et al. (2021) show that when SO_2 and Al come into contact, the reaction accelerates corrosion on the inner metal surface of the can and leads to the formation of hydrogen sulfide in the wine. Montgomery et al. (2023) found that wines stored in cans with epoxy coatings, with or without bisphenol A (BPA-NI), produced less H_2S compared to wines stored in acrylic-coated cans Although the coatings protect the metal surface, their constituents can migrate into food and beverages [19]. Moreover, they can reduce the amount of volatile compounds of the product by absorbing them[23]. The production of reductive aroma during the storage of canned wine is thought to occur through two main pathways: the reaction of metallic Al with SO_2 [6] and the decomposition of polysulfane, which does not imply a bond with Al [3; 12]. From a thermodynamic point of view, H_2S production is favored over other VSCs and is therefore most relevant in preserved wines [20].

5. TETRA PAK AS AN ALTERNATIVE TO GLASS FOR WINE PACKAGING

In the wine industry, the use of Tetra Pak for wine packaging began in 2006 and has a growing tendency. Tetra Pak is a multi-layer packaging made of: cardboard, polyethylene polymers and aluminum foil. The mentioned materials contribute to the integrity of the container, good printing and barrier properties of the packaging. The presence of Al foil protects the product from oxygen and light. To close the container, plastic closures are used, usually plastic lids with a screw with a protective film that is destroyed when the container is opened [17].

The impact of this packaging on the quality of the wine is related to the reactions between the ingredients of the wine and the polyethylene polymers, as well as the transfer of aluminum if the layers of the container wall are damaged. The manufacturers of Tetra Pak confirm that the shelf life of the wine is from three to six months after packaging. Cheap packaging is also suitable for wineries that tend to produce table wines and where wine aging and long-term storage are not required.

6. CONCLUSION

Production and consumption of wine is a growing category of world trade. The choice of packaging for packaging protects the quality of the wine and facilitates sales and distribution. Due to its inertness and good barrier properties, glass will be an irreplaceable packaging for wine for a long time. The attitude of traditional wine consumers and quality are looking for diminishes the possibility of greater participation of alternative packaging in the wine market. Nevertheless, cardboard, aluminum and polymer packaging is establishing is presence on the wine market because it provides lower production and sales costs, which is in the interest of wine producers with satisfactory product quality.

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POTENTIAL MIGRATION OF PHTHALATES FROM DIFFERENT POLYMERS INTO FOOD

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Abstract: *Plastic materials are commonly used for food packaging due to their excellent physical-mechanical, thermal, chemical, and barrier properties. They are also easy to process, can be combined with other materials, and are cost-effective. In order to improve flexibility, transparency, and durability, plasticizers such as phthalates can be added to the chemically stable polymers. The detection and determination of phthalates in articles of general use is crucial as they account for up to 50% of the mass and can easily migrate due to their physical and chemical properties. Exposure to phthalates can lead to various health problems, e.g. allergic diseases, asthma, thyroid dysfunction, fertility issues, endocrine disorders, and cardiovascular disease. There are several factors (temperature, ultraviolet radiation, ultrasound, mechanical forces, etc.) that influence the migration of phthalates. Thus, food products can be contaminated with phthalates by migration from plastic packaging. Therefore, it is important to investigate the migration of phthalates from plastic items and packaging into food. Packaging materials and packaging used in the food industry must be tested to ensure that they do not pose a health risk. The legal framework relating to these materials was created to ensure the safety of food that is consumed and sold.*
Keywords: Phthalates, migration, polymers, food

1. INTRODUCTION

Selecting the appropriate packaging material plays an important role in protecting the packaged product and ensuring its safety and quality. Polymers, which are commonly utilized as food packaging materials, are enhanced with a variety of additives including fillers, colors, plasticizers, softeners, and stabilizers. These additives are usually not chemically bonded to the structure of the basic macromolecular chain which may result in their potential migration into the package contents during transportation, handling, and storage.

Phthalates are a group of semi-volatile organic compounds and most commonly used plasticizers worldwide due to their wide range of industrial applications. [1]. Certain ortho-phthalates, including Di(2-ethylhexyl)phthalate (DEHP), dibutyl phthalate (DBP), benzyl butyl phthalate (BBP), and diisobutyl phthalate (DIBP), may interfere with our hormonal system and are on the candidate list of substances of concern.

These phthalates are extensively used as a plasticizer in many products, especially medical devices, furniture materials, cosmetics, and personal care products, building materials, household furnishings, clothing, cosmetics, pharmaceuticals, nutritional supplements, medical devices, children's toys, glows, modelling clay, food packaging, furnitures, automobiles, lubricants, waxes, cleaning materials and insecticides [2].

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Polymeric (plastic) materials that come into contact with food products can be a potential source of phthalates in food. Therefore it is necessary to examine the health safety of packaging materials and packaging, which is carried out by specialized and authorized institutions and laboratories.

2. POLYMER FOOD PACKAGING

The role of packaging is to protect the product from physical and mechanical factors and external environmental conditions (light, gases, moisture and microorganisms), communicates with the consumer, and serves as a good marketing tool. Food packaging that comes into direct contact with food must be made of a material that does not impair the organoleptic, chemical, and physical properties of the food and must not contain or release any substances that are harmful to health over the quantities specified in the regulation [3]. Polymer packaging accounts for the largest proportion of food packaging, and generally is not harmful to human health. However, some additives found in polymer-based packaging can be harmful if they migrate into food causing adverse effects.
During the production of food packaging, plasticizers are added to serve as softeners and color carriers. Since they have a relatively low molecular weight and are not covalently bound to the polymer, they can potentially migrate from the packaging material into the food and thus become indirect "food additives" [4]. Many additives, solvents, and pigments used in the production of plastic packaging materials are also found in the food product [5], and many can be converted into toxic metabolites, most of which are difficult to identify.
Examples of potentially toxic substances (PoTS) that have been studied for their possible migration from various plastic packaging include phthalates, bisphenol A (BPA), bisphenol A dimethacrylate, lead, tin, and cadmium, as well as formaldehyde and acetaldehyde, 4-nonylphenol, MTBE (methyl tert-butyl ether), benzene, and many other volatile organic compounds [6,7,8,9,10].

3. PHTHALATES IN PLASTIC MATERIALS

Polymers can be transformed into polymer (plastic) materials by adding plasticizers such as phthalates, citrates, and phosphates. Diesters of 1,2-benzenedicarboxylic acid (phthalic acids), better known as phthalates, are widely used as plasticizers, solvents and additives in the manufacture of plastics [1]. They are commonly used to increase the flexibility, durability, elasticity, and transparency of plastics. For example, rigid polyvinyl chloride (PVC) can be transformed into a wide range of flexible materials and processed more easily by adding plasticizers such as phthalates (up to 40 % w/w), citrates, and phosphates. In addition, phthalates can be used in a variety of general-use products such as toys, personal care and household products, electronics, various solvents, adhesives, glues, pesticides, food packaging, medical devices, pipes, and building materials. Due to their non-polarity, phthalates have a low solubility in water, but dissolve well in a non-polar medium and have a high solubility in oil.
Although phthalates are usually used in the manufacturing of PVC, they are also used as part of the catalyst (Ziegler-Natta catalyst) during the polymerization process of polypropylene (PP), polyethylene (PE), and polystyrene (PS) [11]. Therefore, they have also been found in food packaging materials that are not made of PVC [12].

4. POTENTIAL MIGRATION OF PHTHALATE FROM POLYMERS INTO FOOD

Migration is the transfer of potentially harmful substances from the packaging material and packaging into the food. The legislation on plastic packaging materials that come into contact with food ("food-contact" legislation) has defined two types of migration: specific and general migration. Specific migration refers to the migration of substances that are present even in low concentrations can pose a risk to consumer health and therefore require strict control. General migration refers to the migration of components that do not pose a major risk to consumer health but are still undesirable. Since phthalate are not chemically bound to the macromolecular chain, but are merely attached to the polymer structure, they can leach, evaporate, or migrate from the plastic packaging into the

environment. Various factors influence the migration of phthalates, e.g. temperature, ultraviolet radiation, ultrasound, mechanical forces, or contact with a non-polar environment. It is very important to be aware of these factors and handle plastic products and packaging with care to prevent phthalate migration.

According to the European Union Directive [13], FCM suppliers are required to demonstrate that their materials comply with the relevant limits (EUROPEAN UNION, 2002), which are defined by the following values: Overall Migration Limit (OML), Specific Migration Limit (SML) and Maximum Permitted Quantity (QM). Several studies have shown that phthalates migrate from plastic packaging mainly into fatty foods such as oil, milk, butter, meat, fish, etc. [14]. Food in plastic packaging heated or cooked in a microwave oven is also a source of phthalates, and it was reported that phthalates easily migrate into fatty foods under high temperatures [15]. Monitoring of potential contamination of milk and dairy products with phthalates is important as milk is the main food source for children [16]. It has already been reported that cow's milk can be contaminated by the plastic utensils used in processing. In addition, human milk can also be contaminated with phthalates through the use of breast pumps [17].

The investigation of phthalates in alcoholic beverages revealed a negligible migration of phthalates from plastic packaging into alcoholic beverages. The detected phthalate concentrations were low, although most of the samples in this analysis were packaged in plastic bottles [18]. The study carried out by Del Carlo et al. also showed that the increased phthalate concentration in alcohols is not due to the interaction between plastic packaging and alcoholic beverages, but to the migration of phthalates during the technological process [19]. When comparing the results of phthalate concentration in plum brandy bottled in glass and plastic packaging, it was found that there is no migration of phthalates from plastic packaging into alcoholic beverages, as there is no significant difference in phthalate concentration between brandy in different packaging [20]. On the other hand study with showed extremely high migration of phthalates (350%) in olive oil, from the sealing material of closures [21].

Generally, it is recommended to avoid heating of food in plastic packaging in the microwave as well as washing the plastic material in the dishwasher. It is suggests to use glass packaging as far as possible, and to check the composition of the plastic on the product declaration.

Phthalates in food, beverages, and other products are analyzed using various analytical methods, including liquid and gas chromatography with mass spectrometers or UV spectrophotometers. The most important method for determining phthalates is gas chromatography-mass spectrometry (GC-MS) [16]. However, Fourier transform infrared spectroscopy (FTIR) is also used.

5. TOXIC EFFECT OF PHTHALATES

The annual production of phthalates in 2009 and 2010 was about 230,000 tons per year, of which 210,000 tons were DEHP [22]. Humans are frequently exposed to phthalates, which can enter the human body through the skin, by inhalation, or through food. Due to their lipophilic nature, fatty foods in particular are contaminated with phthalates. When phthalates enter the body, they are rapidly metabolized and excreted in urine and feces. Their half-life is short, and more than 60 % are excreted within 24 hours, the rest in less than 48 hours [23]. However, endocrine-disrupting chemicals (EDCs) which include phthalates can interfere with the synthesis, secretion, mechanism of action, metabolism, and excretion of hormones in humans and animals, with adverse health consequences, including the occurrence of obesity and diabetes mellitus [24, 25].

According to the World Health Organization, individuals can be exposed to phthalates through the daily use of common plastic items. A growing number of studies are investigating the health effects of exposure to phthalates, which have been linked to various conditions such as allergic diseases, asthma, cancer, thyroid dysfunction, fertility issues, endocrine disorders, and cardiovascular disease [26, 27]. Phthalate exposure is associated with cardiovascular risk factors including obesity, lipid metabolism, blood pressure, and atherosclerosis [28]. During the prenatal period, in newborns, and during puberty, human sensitivity is at its highest level. Due to this reason, the European Union has

imposed restrictions on the use of some phthalates in children's toys and products intended for children. The results of the exposure assessment indicate that children are exposed to higher levels of phthalates compared to adults. Based on the latest data from human biomonitoring, it has been established that the intake level considered safe is exceeded in children. In some cases, the excess is up to 20 times the safe level. Due to their chemical properties, exposure to phthalates does not lead to bioaccumulation. However, there are health concerns regarding the developmental and/or reproductive toxicity of phthalates, even at environmental concentrations [29].

6. LEGAL REGULATION

In order to protect public health, various legislative bodies have been established to prohibit or regulate the use of harmful substances. European Union legislation, better known as the REACH Directive [30] (Registration, Evaluation, Authorization and Restriction of Chemicals), created the European Chemicals Agency (ECHA). In 1963, the Food and Agriculture Organization of the United Nations (FAO) and the World Health Organization (WHO) jointly established the Codex Alimentarius Commission (CAC), which is commonly known as Codex and deals with international food standards. The RAPEX system (Rapid Alert System for Non-Food Products) was also established in the European Union to quickly alert authorities and consumers about dangerous non-food products. According to EU regulations, the maximum migration limit for all contaminants from plastics into food is 60 mg/kg of food or 10 mg/dm² of the surface of the food contact material [31]. The specific migration limit is determined individually for each phthalate. Commission Regulation (EU) No 10/2011 establishes specific migration limits (SMLs) for individual phthalates and a limit for a group of phthalates (SML(T)) . The SML values for DnBP, DEHP, and BBP are 0.3, 1.5, and 30 mg/kg of food respectively. Meanwhile, the SML(T) value for the group of phthalates is 60 mg/kg of food [32].

In the Republic of Serbia, there are the National Consumer Organisation of Serbia (NCOS), the Sanitary Border Inspection, and the Public Health Laboratories. The Institute for Standardization of Serbia is the leading authority for the Codex Alimentarius. It is responsible for harmonizing food safety standards and regulations between the EU and Serbia, taking into consideration the differences in tradition and culture. The regulation on health and safety conditions of items of general use that can be placed on the market [33] specifies that synthetic materials used for making tableware and accessories, which come in direct contact with drinking water, milk, milk products, waxed food, foods that contain essential oils, alcoholic beverages, fats, oils, or foods whose outer phase consists of fat, must not contain plasticizers, unless a special regulation expressly stipulates otherwise.

The list of restrictions and prohibitions includes regulations on the production, marketing, and usage of certain hazardous substances, mixtures, or products [34]. Specifically, the list restricts and prohibits the use of phthalates and imposes a limit of 0.1% by weight of the plasticized material in toys and childcare products. Bis(2-ethylhexyl) phthalate (DEHP), dibutyl phthalate (DBP), benzyl butyl phthalate (BBP), and diisobutyl phthalate (DIBP) can cause damage to growth hormones and development, and lead to heart disease and obesity.

7. CONCLUSION

Migration is the transfer of potentially harmful substances from the packaging into the food. One of the main sources of phthalates is food packaged in plastic material, especially fatty foods such as oil, milk, butter, meat, fish, etc. Food products can be contaminated with phthalates through migration from polymers and during food processing from production facilities, but also during food storage. Monitoring the contamination of milk and dairy products is of utmost interest as milk is the main food source for children.

According to the legislation, the overall limit for the migration of all contaminants from plastics into food is 60 mg kg^{-1} of food or 10 mg dm^{-2} of the surface of the food contact material. In the EU, the specific migration limit (SML) for the group of phthalates is 60 mg kg^{-1} of food.

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FOOD LABELLING – MONITORING OF ALLERGEN INFO IN BAKERY RETAIL STORES

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Abstract: *Establishing general principles, requirements and responsibilities in relation to food information, and in particular in relation to food labeling, is the basis for achieving a high level of consumer protection. Due to today's fast lifestyles, bakeries are taking the place of preparing homemade baked goods for everyday meals, school functions, and special occasions. When foods are labeled incorrectly, or an allergen warning is not properly declared, this can make a food product dangerous to sell to certain sensitive individuals. Improperly labeled food can cause someone to become ill and/or trigger a costly recall of products. For the purpose of monitoring of allergen info in bakery retail stores located in Belgrade 120 bakery retail stores were visited. It was concluded that 105 of them label their products according to labelling regulation. Further trainings and dissemination of information is needed in order to raise awareness among small bakery retailers.*
Key words: labelling, bakery, allergens, monitoring.

1. INTRODUCTION

Due to today's fast lifestyles, bakeries are taking the place of preparing homemade baked goods for everyday meals, school functions, and special occasions. Baked goods may range from those prepared in manufacturing facilities and sold at retail stores to specialty baked items prepared and sold in the stores themselves. Among other factors labeling is also to be consider when evaluating food safety risks in retail bakery products.
The primary purpose of food labels is to inform the consumer regarding nutrition, ingredients, claims, or allergen information. When foods are labeled incorrectly, or an allergen warning is not properly declared, this can make a food product dangerous to sell to certain sensitive individuals. Improperly labeled food can cause someone to become ill and/or trigger a costly recall of products. Therefore, providing an accurate list of all ingredients is vital.

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2. FOOD LABELLING

The free movement of safe food is an essential aspect of the internal market and contributes significantly to the health of citizens, and to their social and economic interests. In order to achieve a high level of health protection for consumers and to guarantee their right to information, it should be ensured that consumers are appropriately informed as regards the food they consume.
Knowing the basic principles of nutrition and having appropriate information about the nutritional value of food significantly contribute to better informed consumers when choosing. Therefore, establishing general principles, requirements and responsibilities in relation to food information, and in particular in relation to food labeling, is the basis for achieving a high level of consumer protection [1].
The right to the availability of information must be guaranteed when choosing food and is the main reason why this regulation applies to subjects in the food business at all stages of the food chain, to all food intended for final consumers, including food offered by public catering facilities and food intended for supply public catering establishments.
Food labelling should be done in a way that does not mislead the end consumer, especially in terms of:

- characteristic features of food, especially its nature, identity, properties, composition, quantity, durability, country of origin or country and place of origin and method of production;
- attributing properties and properties to food that it does not possess;
- indicating the special properties of food and if similar food has the same properties, especially by highlighting the presence or absence of certain ingredients and/or nutrients;
- indicating the presence of a certain food or ingredient by appearance, description or pictorial representation, when in reality the ingredient that is otherwise naturally present or used in that food has been replaced by another component or another ingredient.

Food information should be accurate, clear and easy to understand for the consumer. Food business operators are responsible for the information on both packed and unpacked food.

When labelling unpackaged food following information are necessary:

- the name under which the food is placed in the marketed;
- information on ingredients that can cause allergies and/or intolerances;
- data on the entity in the food business that packs the food at the point of sale to the final consumer [1].

3. ALLERGEN INFO

Food allergy is an adverse immune reaction to a food allergen that can trigger mild (*e.g.*, rash, itchy sensation) to severe (*e.g.*, anaphylaxis) reactions [2]. Almost any food can trigger an allergic reaction in a susceptible individual, but some foods are more common than others. Studies from medical research show that 74% of allergen related food incidents can be linked to foods sold loose (in shops and in restaurants) [3,4].
Even though this disease is chronic, people tend to overlook its severity due to limited knowledge about it [5]. Food avoidance is one of the many methods to prevent food allergies [6]. Despite various preventions consumers may take to avoid food allergens, some have encountered difficulties when eating out. Therefore, it is important that information on the presence of

substances or products with a scientifically proven allergenic or intolerance effect should be given to enable consumers, particularly those suffering from a food allergy or intolerance, to make informed choices which are safe for them.

4. MONITORING PLAN

A food safety monitoring system is a tool that helps food businesses operator to ensure that their food is safe for consumers. The food safety monitoring system provides food business operators data and insights that can help them to improve their food safety practices.
For the purpose of monitoring of allergen info in bakery retail stores located in Belgrade 4 major food retail chains, 4 large bakery retail chains (each chain consisted with more than 20 stores), 4 small bakery retail chains (each chain consisted with less than 5 stores) and 20 single bakery retail stores were visited. Monitoring of allergen info compliance was conducted by visual inspection of the labeled products.

5. RESULTS AND DISCUSSION

All bakeries placed in huge food retail chains were following the correct procedure of listing the allergens when labeling products. Large bakery retail chains with over 20 stores complied with the labeling regulation as well (Table 1). On the other hand every 75% of bakery stores from 4 visited small bakery retail chains was labeling allergens according to the labeling regulation and 50% of single bakery stores clearly labeled allergens (Figure 1). Centralized production and certified quality control systems, well trained and well informed staff are the reasons for absolute compliance of the large food retail and bakery chains. On the other hand, lack of employes and information could be the reasons for partially successful compliance when it comes to small bakery retail chains and single bakery stores.

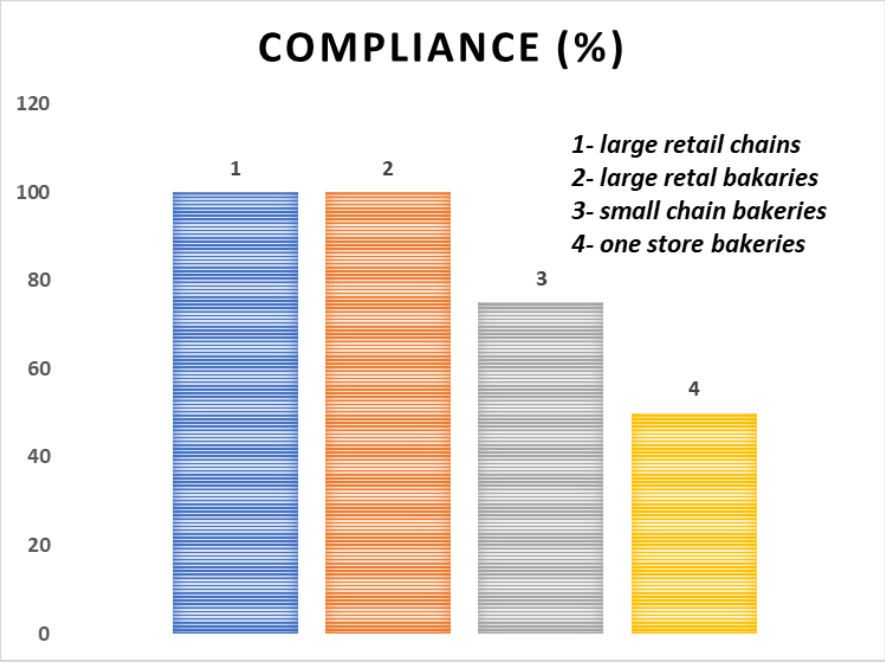

Figure 1. Compliance of monitored bakeries

Table 1. Monitored bakeries

FBOs	Total number of visited stores	Number of complied stores	Number of non complied stores
Food retail chains	40	40	0
Large bakery retail chains	40	40	0
Small bakery retail chains	20	15	5
Single bakery stores	20	10	10

6. CONCLUSION

Eating out at bakeries has become common over the years for almost all population. However, the risks of exposure to food allergens in bakeries have increased over the last few decades, prompting the bakery industry to be better prepared for such events. All major food retail and bakery retail stores in Belgrade proved to be compliant with the labelling regulation. On the other smaller bakery chains and single bakeries need further improvement when it comes to labelling their products.

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THE INFLUENCE OF RAW MATERIALS AND PRODUCTION PROCESS ON THE QUALITY OF ROSÉ WINE

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Abstract: *Serbia is rich in vines. Serbian vineyards are fruitful and they are characterized by different varieties of grapes. The vines and the tradition of producing this divine drink are present in the south of Serbia, and the Čegar vineyards are also famous, located near the city of Niš. Wine has been produced in this area for centuries and, therefore, a lot of traditional methods have been retained in the production process, which were used in the process of obtaining the wine referred to in this paper. This paper examines the influence of raw materials, locality, and technological production process on the quality of produced rosé wine. The standard physical and chemical analyses were applied in the analysis of the wine, as well as the evaluation of the sensory characteristics of the wine (colour, clarity, smell, taste). The characterization of the produced rosé wine involved determining the content of the most important ingredients: relative density at 20/20°C 0.9936; alcohol 12.0% v/v; total extract 23.7 g/L; extract without sugar 17,4g/l; total acids 4.9 g/L; volatile acids 0.21 g/L; reducing sugars 7.3 g/L (semi-dry wine); total sulphur dioxide 85 mg/L; ash 1.51 g/L; pH 3.4. The wine is light red in colour, it is clear, and it has a distinctive aroma and a harmonious taste. The established chemical and sensory characteristics of the examined wine indicate that the grape varieties Prokupac can be considered good raw materials for the production of rosé wine.*
Keywords: grapevine, wine, production, quality, sensory characteristics

1. INTRODUCTION

Each grapevine variety possesses a unique combination of traits, which, along with applied agricultural and viticultural practices, geographical location, and ecological characteristics of the site, as well as winemaking techniques, impact the quality of grapes and the resulting wine [1]. With their distinctive characteristics, they play a crucial role in wine production, especially in the production of high-quality wines [2]. Behind each wine, there are one or more grape varieties, and each grapevine variety has a unique combination of properties, including the aroma, taste, and color of the wine. Knowledge of the spatial distribution of vineyard regions and conducting subsequent analyses is of essential importance for understanding the sustainability of wine production [3].

The locality of Sićevo is situated in the valley of the Nišava River, at an elevation of 365 meters above sea level. According to regional zoning, it is located within the 545 elevation level of the Čegar Vineyard, part of the Niš Region. The Vinkler index is 1736,7. The predominant soil types are colluvium and eutric cambisol. In this area, there are numerous vineyards on private properties. These are small areas primarily planted with wine and high-quality table grape varieties. The advantage of small vineyards is that they can receive full attention: manual pruning, coating each graft union with grafting wax, dedication to removing unwanted shoots, manual defoliation, and so on.

Aroma represents the most complex chemical component of grapes and wine. It consists of a large number of compounds whose concentration varies under the influence of the grape variety [4] and the terroir [5]. Several factors can influence the grape's aroma, including the application of specific viticultural techniques, the timing of harvest, and stressful growing conditions such as drought [6] . Additionally, the yeast strain used during fermentation, the type of wood from which the vessel is made, and the length of wine aging can also impact grape aroma [7,8].

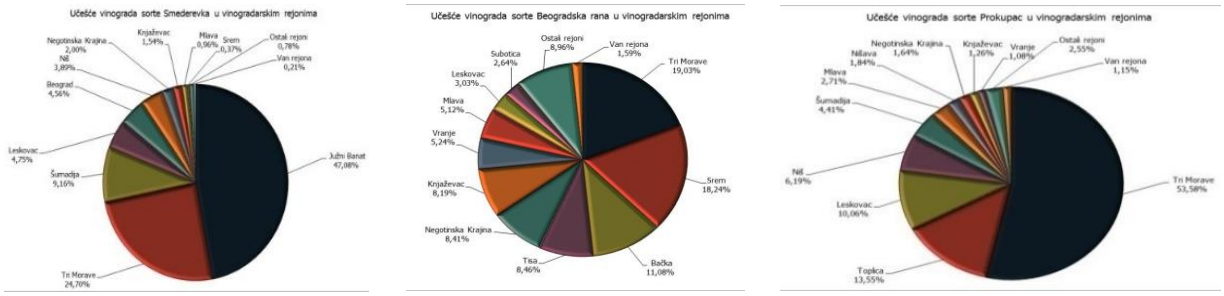

Figure 1. Participation of different varieties in wine-growing regions

2. MATERIALS AND METHODS

The grape harvest was conducted in sunny weather but not under high temperatures. The grapes were crushed during the harvest, with the removal of stems. The process took place in the shade. The prepared grape juice was stored in barrels located in a cellar room that had been previously treated with sulfur and had no direct sunlight, with a room temperature of 19°C. The entire process was carried out to avoid heating the juice. The grape juice had a sugar content of 21%, it settled for 48 hours, followed by racking, and then 10 grams of potassium metabisulfite per 100 liters of must be added, after which an S-shaped airlock was placed. Fermentation was completed in the middle of November, and the wine was racked in December.

The wine was produced in the Mladenović family vineyard. O.I.V. descriptors were used to determine the grape varieties. Phenological observations covered all phenophases to apply all necessary ampelotechnical measures adequately.

Variety Prokupac - the tip of the young shoot is very hairy, reddish-green in color. The developed leaf is of medium size, more or less entire with pronounced three sinuses. The upper side of the leaf is smooth and bare, while the underside is hairy. The berry is medium-sized, round, slightly flattened, with thick skin, bluish-black in color, and covered with numerous spots sprinkled with abundant bloom.

Beogradska rana - a vigorously growing vine. The developed leaf is of medium size, three-lobed, with deep closed sinuses. The cluster is large, conical in shape, and moderately compact. The berry is of medium size, slightly flattened, with moderately thick skin, yellow-green in color.

Afuz ali- a vine with very vigorous growth. The tip of the young shoot is green, without fuzz. Mature shoot thick, with long internodes. The developed leaf is of medium size, three-lobed, the upper side intensely green, without fuzz. The underside of the leaf is fuzz-free and pale green. The cluster is large, conical in shape, and loosely packed. The berry is large and elongated, amber-yellow in color, with specks and a dusting of grayish-white.
Smederevka - the vine is moderately vigorous. The tip of young shoots is green with a reddish shade, and it's hairy. Mature shoots are of medium thickness, with long internodes. The developed leaf is large, three-lobed, and heart-shaped. The upper side of the leaf is dark green and without fuzz, while the lower side is light green and hairy. The cluster is of medium size, cylindrical, and loosely packed. The berry is of medium size, oval, yellowish-green, and with amber spots on the sunny side.
Laboratory research was conducted in the laboratories of the Department of Agricultural and Food Studies in Prokuplje, which is part of the Toplica Academy of Vocational Studies. The physicochemical analysis of wine was carried out using methods prescribed by the International Organisation of Vine and Wine OIV (http://www.oiv.int/). The analysis included the following parameters: relative density at 20/20°C; actual alcohol %v/v; total extract g/l; extract without sugar g/l; total acids (as tartaric) g/l; volatile acids g/l; reducing sugars g/l; total sulfur dioxide mg/l; ash g/l; pH, with the addition of documented oenological methods [9].
In addition to the chemical analysis of the wine, a sensory evaluation of the wine was performed. The assessment of the sensory characteristics of the wine was conducted using the method of positive points from 0 to 100 [10]. For the obtained wine, visual, olfactory, gustatory, and gustatory-olfactory perceptions were scored.

3. RESULTS AND DISCUSSION

The vineyard was planted in the 1980s. Wine grape varieties Prokupac (40%) and Smederevka (15%) are represented, while table grapes include Beogradska Rana (15%) and Afuz Ali (30%). Afuz Ali is on a pergola, while the other varieties are trained using the Guyot double-cordon system. The rows are planted in cascades from east to west due to a slope of approximately 45 degrees, maximizing sun exposure and ventilation, which has a favorable impact on the vine microclimate. The support system is a trellis composed of concrete posts and three rows of wire. At the middle wire level, the wires are doubled, allowing shoots to be positioned in between, providing additional protection against damage from adverse weather conditions and crop load. In contrast to table grapes, short pruning is applied to wine grape varieties. In the case of Prokupac grapes, a significant presence of powdery mildew was observed, and the clusters were loosely compacted. The inter-row space is sown with medicinal herbs, horseradish, and other plants considered natural enemies of many diseases and pests. Thanks to the fact that Prokupac and Smederevka are indigenous varieties, Beogradska rana is a domestic variety, and Afuz ali showed loosely compacted clusters, there was no need for excessive use of chemical treatments. During pruning, which was done in a timely manner, each cut was coated with grafting wax, and two days after pruning, the vineyard was thoroughly sprayed with copper sulfate. The soil was enriched with potassium-based fertilizers. During the growing season, the shoot growth was monitored, and all green pruning measures were performed on time. During the flowering phenophase, there was no access to the vineyard. At the time of the veraison phenophase, shoots were trimmed to the level of the third wire, and leaf removal was carried out in the cluster zone. The territory of Serbia was divided into four homogeneous categories through cluster analysis. The most suitable region

includes cluster 3, which also covers the Sićevo area. This cluster abounds in warmth and light, with a favorable water regime and suitable temperature fluctuations, so according to Zirojević (1974) [11], the grapevine varieties of the examined vineyard can be successfully cultivated, which is equivalent to the data from the re-zoning extract (Table 1).

Table 1. Characteristics of grape varieties in the observed vineyard in the Čegar wine region

Variety	Origin	The use of	Characteristic
Prokupac	Autochthonous	Quality rosé wines	recommended/allowed
Smederevka	Autochthonous	Quality rosé wines	recommended/allowed
Beogradska rana	locally developed	Table grape	recommended/allowed
Afuz ali	International	Table grape	recommended/allowed

The physical-chemical analysis of the sample, which encompassed the examination of all relevant parameters for determining the properties, characteristics, and quality of the wine, is presented in Table 2.

Table 2. Results of the physical-chemical analysis of the examined sample.

Characteristic	Unit of measurement	Analysis method	Measured values	Values prescribed by the Regulations
Relative density at 20/20°C		VDM 14	0,9936	0,9850 - 0,9970
Actual alcohol content	% v/v	VDM 01	12,00	min. 8,5
Total extract	g/l	VDM 01	23,7	
Extract without sugar	g/l	VDM 01	17,4	min. 16,0 g/l
Total acids (as tartaric acid)	g/l	A10 (OIV-MA-E-AS313-01)	4,9	min. 4,5
Volatile acids	g/l	A11 (OIV-MA-E-AS313-02)	0,21	max.1,2g/l
Reducing sugars	g/l	VDM 02	7,3	4 g/l - 12 g/l
Total sulfur dioxide	mg/l	A17 (OIV-MA-E-AS323-04)	85	max. 250
Ash	g/l	A6 (OIV-MA-E-AS2-04)	1,51	min. 1,4

Table 2 shows that the alcohol content in the examined wine was 12.00% v/v, total extract 23.7 g/l, extract without sugar 17.4 g/l, total acids 4.9 g/l, volatile acids 0.21 g/l, reducing sugars 7.3 g/l (semi-dry wine), total sulfur dioxide 85 mg/l, ash 1.51 g/l, pH 3.4. The wine is light red in color, clear, with a characteristic aroma and a harmonious taste. In terms of quality, it is classified as table wine, in terms of color as rosé wine. Regarding the content of unfermented sugar, it falls into the semi-dry wine category. The alcohol content is within the range of ordinary vine. The extract without sugar in g/l is above the minimum of 16.0 g/l prescribed for rosé wines, and the total acids (as tartaric acid) are above the minimum of 4.5 g/l. The ash content expressed in g/l is above the minimum of 1.4 g/l prescribed for rosé wines. Sensory analysis of the sample is provided in Table 3."

Table 3. Sensory analysis of the tested sample

Serial number		Visual observations	Olfactory observations	Gustatory observations	Gustatory-olfactory observations	Total points
1.	Evaluator 1	13,33	18,00	18,00	12,00	61,33
2.	Evaluator 2	14,00	19,33	18,67	13,33	65,33
3.	Evaluator 3	14,67	20,33	21,00	14,00	70,00
4.	Evaluator 4	14,00	20,00	20,33	14,00	68,33
5.	Max. points	20,00	30,00	30,00	20,00	100,00

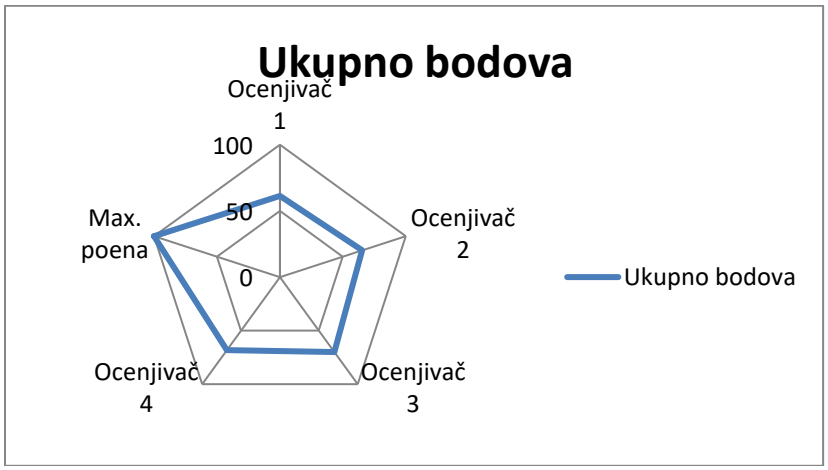

Figure 2. Graphic display of scoring

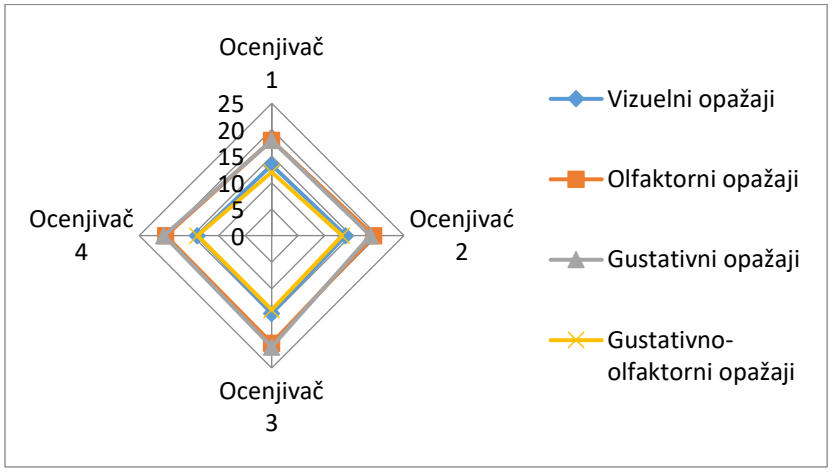

Figure 3. Graphic representation of sensory evaluation

4. CONCLUSION

Agroecological conditions in Serbia are extremely favorable for the cultivation of grapevines. The grapevine variety is the primary determinant of wine quality, both in terms of its chemical composition and sensory characteristics: color, aroma, and taste. The indigenous grape variety Prokupac is recommended for the production of rosé and red wines. The basic components of wine vary depending on the influence of various factors (raw materials, location, and production technology). The parameters of the chemical analysis of the examined wine corresponded to the values prescribed by the regulations. The wine is light red in color and clear. It has a fruity aroma, and the taste is fresh with a discreet bitterness and satisfactory aroma persistence. The established chemical and sensory characteristics of the examined wine indicate that Prokupac, which is the most dominant variety, along with Beogradska rana, Smederevka, and Afuz ali, can be considered good raw materials for the production of rosé wine.

IN VINO VERITAS !!!
(In wine, there is truth)

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OCCURRENCE OF OCHRATOXIN A IN WINE IN SERBIA IN 2022

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Abstract: *Wine production in Serbia has a long tradition and represents one of the increasing branches of agricultural production in last decade. Wine produced in Serbia have for many years a reputation of good quality products. Health benefits of wine related mostly to cardiovascular diseases are well known. However, wine is also recognized as one of the main contributors to the dietary intake of ochratoxin A. Ochratoxin A is a widespread mycotoxin that is produced by several Aspergillus and Penicillium species and main mycotoxin occurring in wine. In this study, a total of 200 samples of red, white and rose wine were collected from Serbian market in 2022. The samples were analyzed for ochratoxin A (OTA) content by using an enzyme-linked immunosorbent assay Ridascreen® Ochratoxin A 30/15. The occurrence of OTA in tested red wine samples was 69%, with average concentration 0.71 µg/kg and maximum OTA content of 1.86 µg/kg. On the other hand, only two out of 136 analyzed white and rose wine samples were detected positive for OTA presence. These results suggest very high level of occurrence of OTA in tested red wine samples. The limit of 2.00 µg/kg imposed by Serbian legislation for OTA content in wine was not exceeded in any of the studied samples. It can be concluded that levels of OTA in wines from Serbia do not pose a risk for human health.*
Key words: wine, ochratoxin A, ELISA.

1. INTRODUCTION

The presence of ochratoxin A (OTA) in wine is mainly due to the contamination of grapes by *Aspergillus carbonarius* and *A. niger*, still in the vineyard or at stages prior to winemaking. Throughout winemaking process, although there is a reduction in OTA levels, modified mycotoxins may also be formed. Factors such as grape variety, damages in grape berries, vineyard, location, temperature, relative humidity, precipitation, microclimate, harvesting period, pesticide application and good agricultural practices in the vineyard, oenological steps and good manufacturing practices during winemaking will be decisive for OTA levels present in wine [1] Ochratoxin A (OTA) is a mycotoxin produced by some fungal species belonging to genera *Aspergillus* and *Penicillium* [2]. OTA can survive most food processes, such as baking, brewing, and heating because of their highly stable molecular structure and thermal stability. The

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winemaking process strongly influences the OTA content, since higher concentrations have been reported in red wines than in rosé and white wines in general [3] due to differences in applied oenological practices: especially the maceration step [4]. During winemaking, crushing of grape berries and the maceration steps favor OTA release to must, suggesting grape skin is the main source of OTA [3]. After maceration for red wines and crushing for white and rosé wines, alcoholic fermentation occurs, a process by which the sugars present in the grapes, thanks to the metabolism of yeasts, are converted into alcohol. Although mycotoxigenic fungi can accompany the grapes from the time they are on the vine, the fermentation process inhibits their growth [5]. The reduction in OTA levels during winemaking has been justified by the partition of OTA between liquid and solid phases (due to the adsorption of OTA in the solid particles of the must) and subsequent natural sedimentation [6]. The second reason is adsorption or degradation by yeasts (composed of mannoproteins and-glucans) and/or lactic acid bacteria (LAB). It was shown that chitin,-glucan, and their hydrolysates could remove 64 to 74% of OTA from contaminated wine. However, this reduction is limited and, due to its partial stability, OTA is not completely eliminated throughout the oenological steps and residues of this mycotoxin are still detected in the final product [5]. Also, there is possibility of degradation or transformation into modified mycotoxins during fermentation processes [1].

2. MATERIALS AND METHODS

2.1.Collection of samples

Present study examined 200 samples of wine (red, rose and white), collected from markets from all over the Serbia in 2022. Before analysis, the samples were stored at refrigerator (4-6ºC), protected from light.

2.2.Sample preparation

All collected samples were prepared and analyzed in accredited laboratory for testing food and feed safety „Jugoinspekt Beograd“. Samples of red wine were prepared according manufacturer's instructions. Prior to analysis, 5 ml of each sample was pipetted into a 50ml PP-tube and mixed with 20 ml of diluted ECO extractor. The mixture was shaked vigorously (manually) for 5 minutes. The extract was centrifuged for 5 minutes at 3500g, RT and 1 ml of supernatant was diluted with 1ml of ready to use wash buffer. According to manual instructions 50 µl of diluted sample was used in the test.

2.3.Ochratoxin A analysis and instrumental conditions

Determination and quantitative analysis of ochratoxin A was done by Enzyme Linked ImmunoSorbent Assay (ELISA) method, using RIDASCREEN® Ochratoxin A 30/15 (RBiopharm) test kit. Multiskan FC microplate reader with absorbance range 0 - 6.000 A was used. Normal reading mode was used with reading speed t = 13 s Analysis were performed according to manufacturer's instructions (RIDASCREEN Ochratoxin A 30/15 Art.No.:1312). Limit of detection (LoD) was set on 0,1 µg/kg while limit of quantification (LoQ) was calculated at 0,3 µg/kg. Measuring range was confirmed from 0,3 to 25 µg/kg, while recovery rate was ranging from 94 to

116 %. The measurement is made photometrically at 450 nm. The absorbance is inversely proportional to the ochratoxin A concentration in the sample of red wine.

3. RESULTS AND DISCUSSION

Ochratoxin A has been detected in 44 out of 64 (68%) samples of red wine, at levels ranging from 0.37 μg/kg to 1.86 μg/kg. Average concentration was 0.71 μg/kg and maximum OTA content of 1.86 μg/kg (Table 1). In majority of the contaminated samples (39) OTA concentration ranged from 0.3 μg/kg to 1.00 μg/kg. Only in 5 samples of red wine concentration exceeded 1.00 μg/kg.
On the other hand in only 2 samples out of 136 analyzed samples of white and rose wine were quantified with ochratoxin A (Table 1). Overall, this suggests very high level of occurrence of OTA in tested samples of red wine. High level of occurrence could be explained by the red wine making process. Maceration, which occurs just in red wine making process allows the migration of OTA from the grape to the must [4]. Žurga et al. [7] have found that 92% of studied samples of red wine were contaminated with ochratoxin A which is in correlance with this study (89%). Furthermore, in United States more than 85% of the samples evaluated were found to contain OTA [8]. The limit of 2.00 μg/kg imposed by Serbian legislation for OTA content in wine was not exceeded in any of the studied samples, which is comparable to those performed in some other studies. Mariño-Repizo et al. [6] have found that wines produced in Argentina have OTA concentrations far below the proposed European limit (2.00 μg/kg). Furthermore, Remiro et al. [9] have reported that concentrations in all examined samples of red wine were even 10 times lower than the maximum limit of contamination (2.00 μg/kg). Although high level of occurrence was detected contamination levels were way below a provisional tolerable daily intake (PTWI) established for this toxin by JECFA (112 ng/kg bodyweight) [10], which proves that wine from Serbia, consuming in reasonable amounts, are safe for consumption.

Table 1. OTA levels in Serbian wine in 2022.

	Wine		
	Red	**White**	**Rose**
No. of contaminated/Total No.	**44(64)**	**1(118)**	**1(19)**
Range (μg/kg)	**0.37 – 1.86**	**≤0.60**	**≤0.61**
Average of contaminated (μg/kg)	**0.71**	/	/
Median of contaminated (μg/kg)	**0.62**	/	/

4. CONCLUSION

Ochratoxin A has been detected in majority of the analyzed samples. This leads to a conclusion that presence of fungi and its metabolites is natural and hardly can be avoided. Also, it was confirmed that the process of making red wine is more favorable to occurrence level of OTA. However, the levels of contamination did not exceed maximum limit imposed by the Serbian law which proves that with good agricultural practice the level of contamination can be managed. Furthermore, contamination levels were way below a provisional tolerable daily intake (PTWI) established for this toxin by JECFA which proves that wine from Serbia are safe for consumption.

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AFLATOXIN M1 LEVELS IN MILK IN SERBIA IN 2022

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Abstract: *Aflatoxins are secundary metabolites of toxigenic fungi from the genus Aspergillus such as A. flavus and A. Parasiticus. They are considered to be most spread mycotoxins, infecting grains during storage, spices, nuts, milk and animal feed. Major forms of aflatoxins include B1, B2, G1, G2 and M1. Mammals that ingest AFB1 contaminated food eliminate amounts of the main hepatic metabolite known as milk toxin or aflatoxin M1 (AFM1) via milk. The incidence of contamination of aflatoxin M1 (AFM1) in milk samples collected from the Serbian producers was investigated by using the competitive enzyme linked immunosorbent assay (ELISA) technique. In this study, a total of 68 samples of raw, pasteurised and UHT milk was examined in 2022. AFM1 was quantified in 39 samples (57.3%), at levels ranging from 0.02 to 0.19 µg/kg. In Republic of Serbia, maximum residue limit of AFM1 is 0.25 µg/kg. These results suggest that number of milk samples contaminated with AFM1 is not negligible. The occurrence of aflatoxins in milk is one of the most serious problems, as milk is a key source of nutrients for human. Therefore, continuous monitoring over milk is necessary.*
Key words: Aflatoxin M1, milk, ELISA.

1. INTRODUCTION

Aflatoxins are secundary metabolites of toxigenic fungi genus *Aspergillus* such as *A. flavus* and *A. Parasiticus*. Due to their toxicity, which can cause a multiple negative effects on both human and animal health they represent the most examined mycotoxins [1,2]. Even in low concentrations, they are highly toxic. Depending on the amount, frequency, age, gender and physical state of the human ingestion can cause a development of series of illnesses [3]. Its toxicity is proved in numerous studies, both *in vivo* and *in vitro* [4]. Major forms of aflatoxins include B1, B2, G1, G2 and M1. Mammals that ingest AFB1 contaminated food eliminate amounts of the main hepatic metabolite known as milk toxin or aflatoxin M1 (AFM1) via milk [5,6,7] and is classified in the 1st group of toxins by the *International Agency for Research on Cancer, IARC* [8,9].
Aflatoxins are mostly detected in agricultural products from tropical and subtropical climatic conditions like those existing in Latin American, Asian and African countries, southern regions of US and certain parts of Australia [10]. However, as a result of climate change in Balkans aflatoxins became a greater concern for food safety in Serbia [11].

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Milk is a widely consumed beverage that is essential to the diet of several millions of people worldwide because it provides important macro- and micronutrients. However, contamination of milk with AFM1 is considered to be a great risk for human health. Even low level of contamination can cause concern due to a high level of exposure of consumers [12,13].
Continuous monitoring of AFM1 contamination in milk is necessary and the aim of this research is determination and evaluation of levels of AFM1 in milk in Serbia in 2022.

2. MATERIALS AND METHODS

2.1.Collection of samples

Present study examined 68 samples of raw, pasteurized and UHT milk. All samples were collected during 2022, as a part of the food safety control. Before analysis, the samples were stored at refrigerator (4-6ºC), protected from light.

2.2.Sample preparation

All collected samples were prepared and analyzed in accredited laboratory for testing food and feed safety „Jugoinspekt Beograd“. Milk samples were prepared according manufacturer's instructions. Prior to analysis, 20 mL of each milk sample was centrifuged for 10 min at 3000 × g. The upper creamy layer was removed by aspirating through a Pasteur pipette. Skimmed milk (defatted supernatant) was used in the test (100µl per well) plate.

2.3.Aflatoxin M1 analysis and instrumental conditions

Determination and quantitative analysis of aflatoxin M1 was done by Enzyme Linked ImmunoSorbent Assay (ELISA) method, using RIDASCREEN Aflatoxin M1 (R-Biopharm) test kit. Analysis were performed according to manufacturer's instructions (RIDASCREEN Aflatoxin M1 Art.No.:1121). The measurement is made photometrically at 450 nm. The absorbance is inversely proportional to the aflatoxin M1 concentration in the sample. Multiskan FC microplate reader with absorbance range 0 - 6.000 A was used. Normal reading mode was used with reading speed t = 13 s. Special software Rida® Soft Win (Art. No. Z9999, R-Biopharm, Germany) was used for the evaluation of enzyme immunoassays. Limit of detection (LoD) was 0,005 µg/kg.

3. RESULTS AND DISCUSSION

The results on occurrence of aflatoxin M1 in raw milk, pasteurized milk and UHT milk are represented in Table 1.

Table 1. Occurrence of aflatoxin M1 in milk (monthly)

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Detected AM1/Total number of analyzed samples	3/8	11/13	1/6	3/6	1/4	4/7	2/4	1/4	3/4	3/4	4/5	3/4
Detected AM1/Total number of analyzed samples (%)	37.5	84.6	16.7	50	25	57.1	50	25	75	75	80	75
Range of concentration (µg/kg)	0.02 - 0.04	0.02 – 0.19	0.02 - 0.04	0.02 - 0.04	≤0.02	0.02 - 0.06	0.03 – 0.04	≤0.03	0.02 – 0.03	0.03 – 0.04	0.02 – 0.04	0.02 – 0.04

Aflatoxin M1 was detected in 51 out of 68 milk samples (75%), at levels ranging from 0.02 to 0.19 µg/l. In 4 % of samples, maximum EU level for AFM1 in milk (0.05 µg/kg) was exceeded which is significantly lower frequency of AFM1 contamination than reported by Jakšić et al. [14] for the period 2013-2015, where 73.3% of the samples exceeded concentration of AFM1 of 0.05 µg/kg in 2013, 39.4 % in 2015 and 28.6% in 2015.

4. CONCLUSION

The presence of AFM1 was detected in 51 out of 68 analyzed samples of raw milk, pasteurized milk and UHT milk. The highest percentage of contaminated samples was detected in February (84.6%). The maximum contamination level of AFM1 (0.19 µg/kg) and the highest range as well was detected in February. In 4 % of samples, maximum EU level for AFM1 in milk (0.05 µg/kg) was exceeded. Obtained results suggest still high contamination frequency of AFM1 in examined samples. Considering that aflatoxins are highly toxic and since milk represents one of the main foodstuffs in human diet in Serbia, there is a concern regarding human exposure to AFM1. Although, high contamination levels seldom occur in commercial milk, there is a need for permanent control and continuous monitoring over milk in order to avoid health risks related to presence of AFM1.

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ADVERSE EFFECTS OF PESTICIDES ON PUBLIC HEALTH

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Abstract: *The use of pesticides, in agriculture for food safety and epidemiology-wise for vector control purposes, has a future growth potential due to the estimate of the Earth's population reaching 9.9 billion inhabitants by 2050, with the primary growth in the developing countries accompanied by the increase of food production in line with the population's needs. Global climate changes contribute to the pests' distribution change leading to their extensive use. Pesticides can persist for a long while in the environment and are imminently part of everyday life. Because of its toxicity, they present a detriment to humans and eco-systems. They are used not only in agriculture, food production through weed growth control and pest extermination, on animal farms, households, forestry and wood-processing, but also in urban areas such as public parks, gardens and playgrounds. Wide population using urban green areas is exposed to pesticide toxicity risk, especially the children and the elderly whose organisms tend to be more sensitive. The pesticide residue in food and the environment presents a public health problem since it is linked to a series of health problems demanding monitoring on a regular basis. This paper presents an overview of pesticides in the light of their division, environment distribution, exposure maps, different properties, toxicology effects and health risks*.
Keywords: pesticides, residue, environment, toxicity, public health

1. INTRODUCTION

Pesticides are a group of chemical compounds used control and extermination of all pests ranging from insects, weeds to microorganisms. Indisputably, the mankind has benefited a lot from its wide use in agriculture, economy and medicine, but their toxicity captures global attention regarding the frequency certain illnesses compared to different exposure maps. There is massive evidence of the role of pesticides in the incidence growth of many illnesses due to oncogenic and other toxic potential primarily affecting the nervous and endocrine systems. The direct exposure is professional, and it is indirectly executed through food and water residue intake, aerosol inhalation or skin absorption. It is estimated that 1.8 billion people worldwide work in the agriculture sector, while the rest of population gets in touch with pesticides though the commercial use or application of pesticides in parks, gardens and households. Also, they can be traced in groceries, the pesticides used the agricultural production processes or the protection of the agricultural products from vermin in warehouses and storerooms. Many of the pesticides decompose over time, so it is important to keep track of the pre/harvest interval for pesticides, that is, the minimal time needed from the final pesticide treatment of the plant to the harvest or picking period.

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2. PESTICIDE CLASSIFICATION

Pesticides (the name comes from the Latin words “pestis” = pestilence, plague or illness and “caedare” = to kill) are toxic substances or mixtures of substances used for selective extermination of macro- and micro-organisms which are found highly intrusive by the humans and the communities. According to FAO (Food and Agriculture Organisation of the United Nations) pesticides are “substances or mixtures of substances used for preventing attacks, exterminating or controlling any kind of vermin/pests (human/animal disease carriers, intrusive plants / weeds and animals which are accountable for losses during production, processing, storing, transporting or market-placing of food, agricultural products, wood, wood products or animal food) including the ones parasitising inside or outside an animal’s body”.
Pesticides include numerous substance groups used for vermin/pest protection: insecticides, herbicides, fungicides, rodenticides, wood preservatives, garden chemicals, household disinfectants and other compounds. The most common pesticides classification systems are:

A. Classification according to ways of entering the human organism
B. Classification according to the pesticide function and targeted organisms – vermin/pests exterminated
C. Classification according to the chemical composition of the pesticides

According to the organism entry ways, they are classified as systemic, contact, oral, fumigants and repellents.
According to the intended use, they are classified based on the type of vermin/pest they exterminate, thus the name (Table 1)
According to the chemical composition, they are classified based on the active substances, functional groups, effect and toxicity, which is the most common in use.

Table 1: Classification of pesticides according to intended use or effect mechanism

Pesticide Type	Pest/Vermin they exterminate/effect mechanism	Example
Insecticides	Insects	Malathion
Fungicides	Fungi (mildew, mold)	Carbamic acid derivatives
Herbicides	Weeds	Paraquat and Diquat
Acaricides	Mites and ticks	Permethrin
Rodenticides	Mice and rats	Warfarin
Algaecides	Algae	Copper sulphate
Larvicides	Insect larvae	Methoprene
Repellents	Repel vermin, primarily insects	N-diethyl-meta-toluamide
Weed pesticides	weeds	Boric acid
Ovicides	Inhibit egg growth, insects and mites	Clofentezine
Viricides	Herbal viruses	Beta-Caryophyllene
Nematicides	Nematodes	1, 3-Dichloropropane
Avicide	Birds	4-Aminopyridine

3. THE SIGNIFICANCE OF PESTICIDES

The UN Population Department estimates that the Earth will be populated by 9.7 billion inhabitants by 2050, which entails a necessary growth of food production by 80% according to FAO. There are some 9 000 types of insects/mites, 50 000 types of plant pathogens and 8 000 types of weeds, so, without the use of pesticides, the agricultural production losses would be huge.

4. POPULATION EXPOSURE TO PESTICIDES – FOOD RESIDUE

A contaminant is every substance detrimental to human health which is inadvertently added to food, obtained during the process of producing, processing, treating, packaging, transporting or storing food. Regardless of the food contamination origin – biological organisms, chemical substances or objects, the public eye has been predominantly focused on the presence of food additives and pesticides over the recent years. The food pesticide residue is detrimental to health because of its fat solubility, fat accumulation and long-lasting effects owing to high stability. For the sake of food safety and human healthcare, regulators dealing with this issue in all developed countries worldwide determine two key criteria aimed at limiting of the amount of permitted food contaminants: pre-harvest interval for pesticides and Maximum Residue Limit (MDK) found in groceries. The maximum residue limit refers to the amount or concentration of a pesticide which is still permitted. The health safety of a product is determined by comparing the measured pesticide level to maximum residue limit (mg/kg) which is legal in food. Higher level quantities are regarded as detrimental and such grocery must not be used in mass nutrition. It is determined for each substance respectively which is legal to be used in herb protection for every herb permitted to use the pesticide. Each developed country is obliged to legally regulate monitoring mechanisms of the pesticide amount in food products aimed at keeping a constant track of the pesticide value. Every increase in the MDK value is an alarm for the producer to correct the ways of pesticide application and adjust it with the instructions. It is vital to draw the inspection authorities' attention to strict and zealous control of the product samples coming from the producers/distributers whose products have been ascertained to contain MDK excess. Pre-harvest interval for pesticides is the minimum time needed for the pesticide decomposition or elimination between the final pesticide treatment and the harvest/picking period.

According to the toxicity level of a substance, types of human hazard have been ascertained. The first type of hazard includes substances whose borderline dosage is known or the concentration of a potentially detrimental substance followed by threshold effect if the exposure lasted long enough. The second type of hazard refers to the substances that exhibit non-threshold effect, because it emerges with the lowest concentration, like genotoxic effect substances, and the poisoning intensity depends on the poison dosage size that reach the human organism. The first-type hazard substances are permitted in food if below the borderline dosage, while the second-type hazard substances are banned, even in smallest quantities.

A special issue is health risk assessment after exposure to a certain toxic substance whose essence lies in the determination of the correlation of the poison dosage taken into organism and the type/intensity of the toxic effects on the human organism. International scientific committees, The Joint FAO/WHO Expert Committee on Food Additives (JRCFA) and Joint FAO/WHO Meeting on Pesticides Residues (JMPR) deal with the determination of the acceptable daily intake of the first-type hazard substances which exhibit the toxicity threshold. In this context. It is significant the differentiate the chronical exposure during a long period and the acute exposure during a short period of time. In both cases of exposure, the poison dosage taken into organism is compared to the Acceptable Daily Intake (ADI) and Acute Reference Dose (ArfD). Acute Reference Dose is the amount of the chemical substance which can be taken into the organism during one meal or during one without harmful effects. A certain type of food is regarded safe if the estimated intake of a harmful intake does not exceed the acceptable daily intake, or acute reference dose. The acceptable daily intake is calculated based on the dose obtained from animal experimentation. No-adverse-effects-level (NOAEL) is its highest dose which did not cause any harmful effect on the animals which took the dose during the experiment. Divided by the safety factor (which is 10 at least, usually 100) provides the acceptable daily intake.

Acceptable Operator Exposure Level (AOEL) is the dose which will not cause harmful effects in the people professionally exposed to pesticides within one-day, one-week, one-month period, and depending on the duration of exposure the short-term AOEL refers to the exposure during several weeks or during one season, and long-term AOEL on the repeated exposure for one year. The determination of AOEL and ADI value is aimed at preventing poisoning – bearing in mind that this refers to the professional exposure to potential poisonous substances. The primary exposure route in

the case of professional risk id through skin and because of that AOEL for many substances is determined in studies with experiment animals by skin tests.

5. TOXICOLOGICAL SIGNIFICANCE AND DETRIMENTAL EFFECTS OF PESTICIDES ON THE HUMA HEALTH

Depending on the toxicity level, World Health Organisation (WHO) has classified pesticides into four categories. Based on the experiments conducted on animals which yielded increasing pesticide doses, the medium lethal dose is determined for each pesticide (LLD 50 – the dose that leads to 50% mortality of the exposed animals), shown in Table 2.

Table 2: The Pesticide Classification according to the Toxicity Level

Classes according to toxicity level	**Toxicity level**	**LD 50 for rodents in mg/kg of the body weight**		**Examples**
		Oral	***Local***	
Class Ia	Extreme Toxicity	<5	<50	Parathion, Dieldrin
Class Ib	High Toxicity	5-50	50-200	Eldrin, Dichlorvos
Class II	Moderate Toxicity	50-2000	200-2000	DDT, Chlordane
Class III	Low Toxicity	>2000	>2000	Malathion
Class IV	Low probability of causing poisoning with normal use	>5000		Carbamate, Cycloprothrin

The uncontrolled application of pesticides and lack of pre-harvest interval for pesticides lead to adverse effects on the human health, useful insects and animals. Long-term use of the food containing pesticide residues can lead to serious disturbances due to the chronical organism poisoning. The estimated figures show that some 5 000 to 20 000 people die because of pesticides and some 500 000 to a million people get poisoned by pesticides. Bearing in mind these figures, 50% to 75% of all the people whose death cause can be traced in adverse pesticide effects are agriculture workers, while others get exposed by the contaminated food consumption. Half of the total number of the poisoned and two thirds of the deceased come from third-world countries, while at the same time as much as 80% of all pesticides is in the developed countries. WHO has issued the data that one person dies of pesticides each minute in the third-world countries due to mishandling pesticides. Even though the real consequences of chronical pesticide poisoning are not known, the literature features neurotoxicity, reproductive toxicity, immunosuppression, and cancerous effects and thus the involvement into the pathogenesis of many illnesses. The evidence brings to light the oncogenic potential of the chronical intake of arsenic which increases the possibility of lung cancer. The problem is becoming even more serious due to an increasing exposure to pesticides by humans. More than 98% of the used insecticides and 95% of the used herbicides gets on people through food, water or air, at least in small doses. After treating a plant/herb with a pesticide, the majority of the active substance is removed mechanically and gets into the ground or is decomposed, but a certain amount can be permanently stored in the plant tissue and reach the humans and animal through the food intake. The quantities of pesticides permanently kept on the treated plants are called pesticide residue. Pesticide metabolites can be more toxic than the initial active substance , such as paraoxon – parathion metabolite. The majority of pesticides get on food after the direct plant treatment, and the minority comes from rivers and subterranean water infected with pesticides. By raining down agricultural areas, pesticides reach surface water and groundwater. Pesticides that decompose slowly are evaporable liposoluble and can be transferred further away from the initial point of treatment. In the food chain, pesticides get to humans through animals, so a necessary and justified control of pesticide

residue is required for all the food, plant and animal origin. A part of the food pesticides can be removed while processing food. Most pesticides are kept on the fruit and vegetable skin, so washing and skin removing are efficient methods of pesticide removal. As for meat and fish, heat treatment is an efficient method.

6. CONCLUSION

Pesticide residues in water and air are the major concern because they pose a serious threat to biological communities, including humans. They are various ways that pesticides can enter water such as accidental spills, industrial waste, surface runoff from soil treated with pesticides, washing of spray equipment after spraying, and the like. The presence of pesticides in the air can also be caused by number of factors, including wind blowing and evaporation from cultivated areas. To what extent we will manage to limit the harmful effect of pesticides on the environment depends solely on our conscience and respect for the principles of their safe applicatiom.
Exposure to pesticides is imminent because their use is an integral part of the modern life in different walks of life including public health and modern agriculture. Given the widespread application, law-abiding approach is a must, coupled with strict contamination control and the effects on the environment and organisms which are not the target in order to reach the needed safety level of any biological system or people. Besides this, it is important to alert the public regarding the necessary hygiene measures and steps.

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EXPOSURE TO POTENTIALLY TOXIC ELEMENTS DUE TO CONSUMPTION OF CAPSICUM ANNUM IN DIFFERENT PARTS OF SERBIA

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Abstract: *Potentially toxic elements (PTEs) are transferred to vegetables primarily through agricultural soil or irrigation water. PTEs in agricultural soil originate from pedogenic and anthropogenic sources. In most cases, soil contamination with these elements happens via river systems or air pollution. Furthermore, food is now imported from many regions and countries, where it is grown in various conditions and on various agricultural lands. Peppers (Capsicum annuum) are popular vegetables in Serbia and worldwide. They are consumed in numerous dishes as fresh fruits, spices, or ingredients. Peppers are reach source of carotenoids, vitamins, antioxidant compounds, and other nutritive compounds. This study aimed to estimate the human exposure to thirteen PTEs present in fresh, dried, and processed peppers obtained from the Serbian market. The exposure assessment was conducted for people in four regions of Serbia by calculating the target hazard quotient (THQ) and carcinogenic risk (CR). The comparison across areas was made due to significant disparities in pepper consumption between them.*
Keywords: Heavy metal(loid)s, Cancer Risk, Hazard Quotient, Non-carcinogenic risk, Vegetables

1. INTRODUCTION

Peppers (*Capsicum annuum*) are one of the most widely cultivated vegetables in the world. Pepper fruits are consumed fresh and processed (as a condiment, spice, and ingredient in numerous dishes) [1]. These vegetables represent an excellent source of vitamins, phenolic compounds, carotenoids, and other antioxidant compounds [2]. Fruits differ in shape, color, and whether they are pungent or non-pungent [3]. Capsicum is also a very popular vegetable species in Serbia, which is the most cultivated vegetable after potatoes. Serbia has many traditional processed pepper foods such as stuffed peppers, pickled peppers, peppers in sour cream, ajvar, pinđur, ljutenica, trljenica and many others [4].

Vegetables as well as other plants can accumulate potentially toxic elements (PTEs) in different parts. Food contamination with PTEs occurs through soil, water, air, dust, and the application of fertilizers and pesticides [4,5]. PTEs in soil originate from lithogenic or anthropogenic sources [6,7]. Anthropogenic activities include urbanization and industrialization, particularly mining activities. Additionally, contamination of agricultural soils happens due to wastewater irrigation, which causes aggregation of PTEs in the crops [8]. Vegetables are one of the main routes for PTEs exposure in humans. Therefore contaminated vegetables could cause human health risks [9]. Consumption of vegetables contaminated with PTEs can cause serious problems, such as damage to the kidney and

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heart, nervous, cardiovascular, and gastrointestinal systems, development of cancers, and many other health issues [8,10]. Special concern has to be taken for toxic elements such as As, Pb and Cd which are classified as carcinogen of first category by the International Agency for Research on Cancer (IARC) [11]. The safety of vegetables is always a concern, so it is essential to monitor and evaluate human health risks arising from the accumulation of PTEs. Besides that, consumption of the same vegetables isn't the same in various regions. Therefore, exposure to PTEs for population from two regions can be different even if they eat the vegetables grown in the same agriculture field.
The aim of this study was to compare the health risk due to PTEs in pepper fruits between four regions in Serbia. The samples were purchased in local markets in Belgrade, and were imported from different countries in Europe.

2. MATERIALS AND METHODS

2.1 Samples and chemicals

The selected pepper fruits were obtained from local markets in Belgrade in February 2021. Selected samples (n=28) were fresh and processed pepper (pickle peppers, peppers in sour cream, stuffed pepper, and dried peppers). We assumed that peppers of the same or comparable origin are available on the markets in other parts of Serbia. Consumption of fresh and dried peppers in four regions in Serbia is given in Table 1. Nitric acid (65%), hydrogen peroxide and hydrochloric acid were supplied from Sigma Aldrich. Standard solutions were purchased from AccuStandard (New Haven, USA).

Table 1. Ingestion rates of peppers for adults and children in four regions of Serbia [12].

	Adults		Children	
	Dried	Raw or processed	Dried	Raw or processed
IR (g/day) Belgrade region	0.276	24.43	0.110	9.77
IR (g/day) The region Vojvodina	0.265	23.51	0.106	9.40
IR (g/day) The region of Šumadija and Western Serbia	0.443	39.23	0.177	15.70
IR (g/day) Region of Southern and Eastern Serbia	0.733	64.92	0.293	25.97

2.2 Sample preparation and analysis

The microwave digestion was carried out in PTFE containers, where 0.5 g of homogenized sample was mixed with 7 cm^3 65% HNO_3 and 2 cm^3 30% H_2O_2. A microwave oven system model CEM Mars 6 (Matthews, USA) was used to digest pepper samples.
The obtained supernatants were used for analysis of thirteen PTEs: As, Pb, Cd, Hg, Fe, Zn, Cu, Mn, Co, Cr, Li, Ni, and Al. The concentrations of elements were determined by ICP MS (iCAP Q, Thermo Scientific, UK). Good linearity was assumed since the correlation coefficients (R^2) were greater than 0.999. The detection limits ranged from 0.19 μg/kg to 12.5 μg/kg. The recovery ranged from 82.2% to 151%. Relative standard deviation (RSD) percentages vary from 5.12% to 42%. The value 42% represent RSD obtained for Hg (concentration level of 1 ppb). The accuracy of the results of the analysis was acceptable.

2.3 Health risk assessment

Health risks of PTEs ingested via food consumption can be estimated by calculating non-carcinogenic (NCR) and carcinogenic risk (CR). Those risks are calculated using the formulas introduced by the USEPA [13]. The NCR is determined by calculating target hazard quotient (THQ) (Eq. 1):

$$\mathrm{THQ} = \frac{\mathrm{C} \times \mathrm{IR} \times \mathrm{EEr} \times \mathrm{ED} \times 10^{-3}}{\mathrm{AT} \times \mathrm{BW} \times \mathrm{RfD}} \quad (1)$$

THQ is the ratio of chronic daily intake and oral reference dose (RfD) of pollutants. When THQ>1 risk is unacceptable and can cause adverse health effects. Table 2 shows parameters that were used for calculation of THQ. Data for ingestion rates for adults and children were calculated based on to the Household budget survey data in Serbia for 2019 [12]. Ingestion rate for children was assumed to be 40% of ingestion for adults. RfD for Hg, As, Cd, Cr (VI), Mn, Ni, Zn, Cu, Fe, Al, Co, Mo and Pb were 0.0001, 0.0003, 0.001, 0.003, 0.14, 0.02, 0.3, 0.04, 0.7, 1, 0.0003, 0.005 and 0.0035 mg/kg-day [14,15].
The CR is calculated using Eq. 2:

$$CR = \frac{C \times IR \times EEr \times ED \times 10^{-3} \times CSF}{AT \times BW} \quad (2)$$

Input parameters for calculation of CR are given in Table 2. Carcinogenic slope factors (CSF) for Cr, As, Pb, Cd and Ni were 0.5, 1.5, 0.0085, 0.38 and 1.7 mg/kg/day, respectively [1,15,16].

Table 2. Input parameters for calculation of THQ

Exposure parameter	Symbol	Unit	Value
mean concentration of element	C	mg/kg	-
daily ingestion rate	IR	g/day	0.411 of dried pepper for adults 36.39 of raw pepper for adults 0.164 of dried pepper for children 14.56 of raw pepper for children
exposure frequency	EEr	day/year	350
exposure duration	ED	years	20 for adults 6 for children
averaging time for non-carcinogenic	AT	days	365×20 for adults 365×6 for children
averaging time for carcinogenic	AT	days	25550
average body weight	BW	kg	70 for adults 15 for children

Total target hazard quotient (TTHQ) and incremental lifetime cancer risk (ILCR) were used to estimate non-carcinogenic and carcinogenic risk when the health risk of more than one PTE is considered. Those two cumulative risks are calculated as the sum of THQ, i.e. as the sum of the CR for individual elements (Eq. 3 and Eq. 4).

$$TTHQ = THQi + THQii \ldots + THQn \quad (3)$$

$$ILCR = CRi + CRii \ldots + CRn \quad (4)$$

3. RESULTS AND DISCUSSION

3.1 Descriptive statistics

The summary of PTEs concentrations in pepper samples is presented in Figure 1 using box-plots. This figure shows two groups of elements, the right that consists of elements with higher concentrations - mg/kg fresh weight (Fe, followed by Al, Zn, Mn, Cu, Ni, Cr, and Mo) and the left that represents elements found in lower concentrations - μg/kg fresh weight (Pb, Co, As, Cd and Hg). Mercury is the only element that wasn't detected in all samples (10 out of 28).

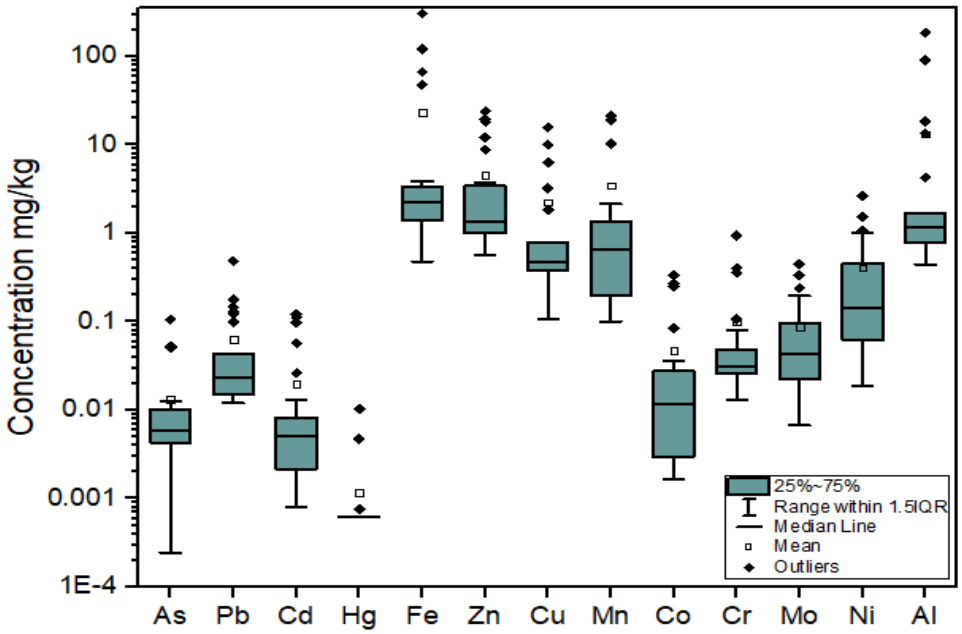

Figure 1. Boxplot of concentration of elements in pepper samples. Lognormal scale was used for element concentrations.

Dried pepper had higher concentrations of all analyzed elements due to lower water content. Generally, dried samples had higher Fe and Al content compared to fresh even when results are expressed on dried mass. For dried peppers concentrations of analyzed element were in following ranges: Fe from 48.0 to 306 mg/kg, Al from 13.4 to 184 mg/kg, Zn from 12.2 to 23.8 mg/kg, Mn from 10.3 to 21.4 mg/kg, Cu from 6.37 to 15.8 mg/kg, Ni from 0.447 to 2.73 mg/kg, Cr from 0.108 to 0.937 mg/kg, Mo from 0.188 to 0.449 mg/kg, Pb from 0.114 to 0.484 mg/kg, Co from 0.085 to 0.340 mg/kg, As from 0.013 to 0.106 mg/kg, Cd from 0.019 to 0.134 mg/kg and Hg from not detected to 0.011 mg/kg.

For fresh and processed peppers concentrations of analyzed element were in following ranges: Fe from 479 to 3880 µg/kg fresh weight, Al from 738 to 2636 µg/kg fresh weight, Zn from 559 to 8893 µg/kg fresh weight, Mn from 101 to 2146 µg/kg fresh weight, Cu from 108 to 3228 µg/kg fresh weight, Ni from 18.6 to 1011 µg/kg fresh weight, Cr from 13.1 to 79.6 µg/kg fresh weight, Mo from 6.69 to 196 µg/kg fresh weight, Pb from 11.9 to 125 µg/kg fresh weight, Co from 1.64 to 36.0 µg/kg fresh weight, As from 0.245 to 11.32 µg/kg fresh weight, Cd from 0.816 to 26.1 µg/kg fresh weight, and Hg from 0.62 to 0.759 µg/kg fresh weight.

3.2 Health risk assessment

3.2.1. Non-carcinogenic risk

The non-carcinogenic risk indicated that consumption of peppers and pepper products does not pose a risk to human health when considering four regions in Serbia (1 - Belgrade region, 2 - The region Vojvodina, 3 - The region of Šumadija and Western Serbia and 4 - Region of Southern and Eastern Serbia). THQ values for all elements were lower than 1, therefore it can be concluded that peppers and pepper products are safe for consumption.

Contribution of analysed PTEs to non-carcinogenic risk, based on average pepper consumption in four regions in Serbia is shown in Figure 2. The highest mean value of non-carcinogenic risk (THQ value) was found for Co, while the lowest mean value was found for Al. People from the region of Southern and Eastern Serbia are at the highest risk of non-carcinogenic risk due to highest consumption of peppers compared to other three regions.

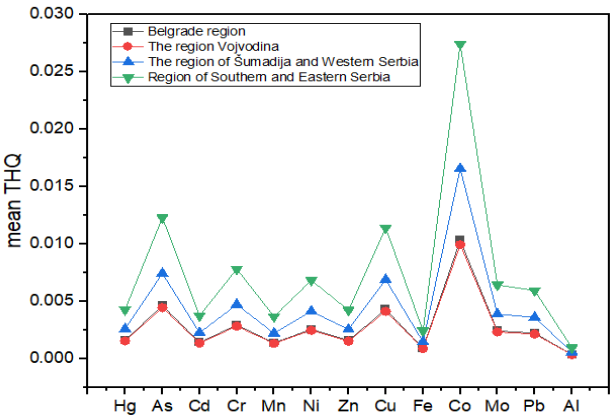

Figure 2. Contribution of analysed PTEs to non-carcinogenic risk due to pepper consumption in four regions in Serbia

Total target hazard quotient (TTHQ) that combine effect of all toxic elements showed that all samples had TTHQ<1 and were safe for consumption both for adults and children. Comparing results between regions, it was found that Southern and Eastern Serbia's people are at the highest risk.

3.2.2. Carcinogenic risk

The evaluation of carcinogenic risk indicated that consumption of peppers and pepper products do not pose a risk to children and adults when considering individual elements in one sample. However, consumption of some peppers does pose a risk when all five potentially carcinogenic elements are observed at the same time (As, Pb, Cd, Cr and Ni). Incremental life time cancer risk (ILCR) that combine effect of five toxic elements showed that same samples had ILCR value higher than 1×10^{-4}. For adults in Belgrade region and region of Vojvodina, ILCR>1×10^{-4} was found for one sample of yellow bell pepper. For adults in region of Šumadija and Western Serbia, ILCR>1×10^{-4} was found for three samples (one yellow bell pepper, and two green peppers), while for children ILCR higher than 1×10^{-4} was in one yellow bell pepper. As in the case of non-carcinogenic risk, the greatest carcinogenic risk exists for residents of Southern and Eastern Serbia where for adults ILCR>1×10^{-4} was found in six samples (one yellow bell pepper, one red pepper and four green peppers). For children ILCR higher than 1×10^{-4} was in three samples (one yellow bell pepper, and two green peppers).

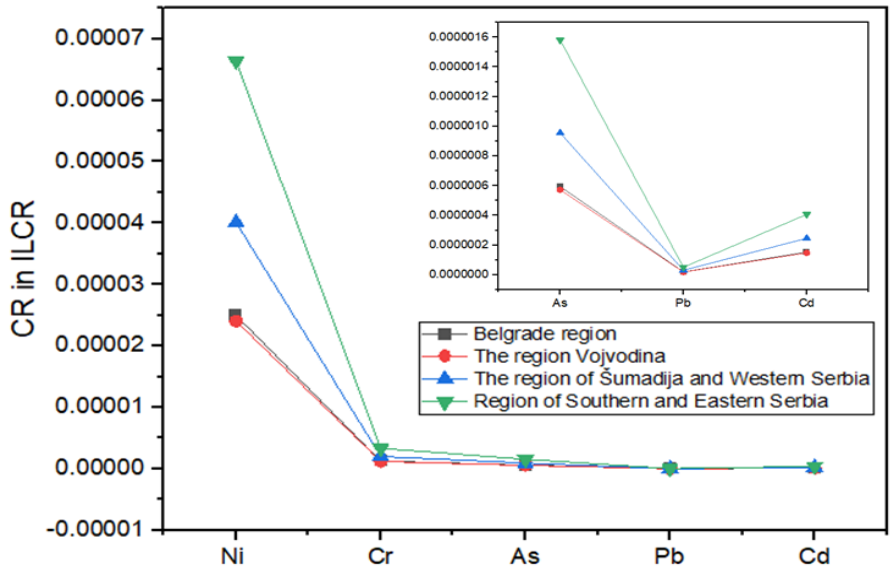

Figure 3. Contribution of analysed PTEs to carcinogenic risk due to pepper consumption in four regions in Serbia.

4. CONCLUSION

This study revealed that concentrations of potentially toxic elements (PTEs) varied significantly in peppers and pepper products. Estimation of non-carcinogenic risk indicated that peppers are safe for consumption by adults and children. On the other hand, the carcinogenic risk assessment showed that some samples of fresh peppers may pose a risk to adults and children due to the incremental lifetime risk (ILCR) values higher than 1×10^{-4}. People from the Southern and Eastern Serbia region are most at risk since in this region people consume greater quantities of these vegetables. In both cases (non-carcinogenic and carcinogenic risk) children are at the lowest risk because children consume smaller quantities of peppers than adults according to their body weight.

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IDENTIFICATION OF THE OPTIMAL CO-SUBSTRATE FOR CO-COMPOSTING WITH GRAPE POMACE BY USING MULTIPLE CRITERIA ANALYSIS

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Abstract: *Composting is a biological aerobic process and the second most used treatment for organic waste (OW). The main observed component in this paper is the grape pomace (GP) which consists of Grape marc (GM) and grape stalks (GS) as a by-product of the wine production process. In addition to GM and GS, food waste (FW) and poultry manure (PM) were observed. The aim of this paper was to determine which co-substrate is better for composting with GM and GS using a previously developed mathematical model. By applying a mathematical model, it was obtained that the optimal mixture includes 65.00% GM, 15.00% GS and 20.00% co-substrate. The obtained results showed that the presence of FW in the optimal mixture contributes to increasing the content of C and N, while the presence of PM contributes to achive the higer pH value and a lower content of lignin. Also, the results showed that there are sufficient amounts of the observed OW fractions if the entire amount of GM was treated. From the aspect of nutrient content, the mixture when the co-substrate is PM has a higher content of* NH_4^+ *and* P_2O_5 *which makes this co-substrate more favourable.*
Keywords: grape marc, composting, optimization, nutrients

1. INTRODUCTION

The wine industry, viticulture, as the agricultural branch, have traditionally has been among the most represented economic activities in the world. It is estimated that the annual quantities of grape production are higher than 77.8 million tons [1]. The most significant cultivation of grapes is in Europe, namely, Italy, France and Spain, amounting to about 40.00% of the total production globally, followed by America and Asia [2]. A significant amount of grape pomace (GP) waste is released during the winemaking process, representing about 25.00% of the total processed grapes [3], which can amount to tens of millions of tons of GP annually. The main components of GP are skins, seeds, stalks and a small amount of pulp formed during the winemaking process. Some GP parts are used to obtain other products in the food and pharmaceutical industries, such as grape seed oil or phenolic compounds. After grape fermentation in wine production, GP is used to obtain alcohol or cellulose-based compounds. After that, it remains a solid residue with altered characteristics, which in most cases is rejected [4]. However, this type of organic waste (OW) should not be dismissed primarily because of the significant content of essential nutrients, especially P and K. Some negative properties of this OW, such as low pH value and the content of polyphenolic compounds, can be eliminated by using biological treatment. The problem of the presence of polyphenol compounds that have a phytotoxic and antimicrobial effect for use as an organic fertilizer is solved by treating the GP by composting [5]. The insufficiently good initial composition of GP can be solved by co-composting.

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Composting is a biological treatment where mesophilic and thermophilic microorganisms are used to decompose complex compounds to obtain a stable end product that can be used as a organic fertilizer [6]. During the composting process, easily degradable components such as proteins and sugars are first broken down and provide the necessary energy for the reproduction and physiological activities of microorganisms and the transition to the next phase. The second phase of the composting process is accompanied by high temperatures at which more complex compounds from OW decompose. In the last stage, the decomposition of more difficult to decompose compounds is completed, and after that, the process of maturing the product begins and at the end a stable product is obitining [7].
Due to its favourable properties, many studies have focused on monitoring the process of co-composting GP with additional co-substrates. Research that has investigated the advantages and disadvantages of composting GP and organic fraction of municipal waste (OFMSW) has shown that the presence of OFMSW contributes to increasing the content of P and N and reducing the acidity of the mixture [8]. A study conducted in Brazil examining the use of compost obtained from GP showed that the final product contains a high content of nutrients. Due to the presence of metals, it is necessary to include an additional fraction of OW in composting [9]. A similar study was conducted in Chile, where the parameters of quality and stability of compost obtained from GP and animal manure were examined. The results showed that the obtained compost satisfies the quality criteria through phytotoxicity, and the absence of pathogens, and can be used as an organic fertilizer [10]. Research that has been conducted with composting certain parts of GP has shown that in the treatment of GS and sludge, GS contribute to achieving higher temperatures, and C/N ratio at the end and beginning of the process. These results were obtained for the case when the GS were chopped [11].
In this paper, a previously developed mathematical model was applied to obtain the optimal mixture for the composting process using multi-criteria optimization (MO) with the application of the global criterion method. Three different fractions of OW were taken into consideration: GP, which is divided into GM and GS, FW and PM. Two cases were observed, the first one when the composition of the mixture includes the GM, GS and FW as a co-substrate and the other when the composition of the mixture includes the GM, GS and PM as a co-substrate. The goal of this paper was to obtain an optimal mixture for composting and to select a favourable co-substrate that is necessary to included in the mixture with GM and GS, while meeting the boundary conditions and criteria set by the mathematical model.

2. EXPERIMENTAL RESEARCH

2.1 Mathematical model description and study area

In this research, a previously developed mathematical model was used to obtain the optimal mixture for the beginning of the co-composting process. During the formation of the model according to the rules of MO, boundary conditions were set and criteria were defined to obtain an optimal solution. The boundary conditions predicted by the model are that the C/N ratio should be between 25:1 - 35:1, the moisture content 40.00% - 60.00%, and the criteria is to achieve the maximum pH value and C content in the mixture, as well as minimum content of lignin and N [12]. The mathematical model was applied to the area that includes the territory of the Republic of Serbia (RS). According to the population census, RS has 7,041,599.00 inhabitants and the annual production of FW is 0.1045 [13, 14]. The average yield of grapes is 8t/ha, and assuming that GP represents 25.00% of the total amount of grapes and that GS are one-quarter of GP, the amount of waste generated during grape processing was calculated [15]. The average amount of excrement of poultry is 0.065 t/year [16]. Based on the number of inhabitants, the area under vineyards and the number of poultry, the amounts of OW that are generated on an annual level in the territory belonging to the RS were calculated, table 1.

Table 1. Amounts of organic mass on the territory of the Republic of Serbia
Source: (orig.)

Type of organic mass			
Vineyards	The area under vineyards [ha]	GP per area [t/area]	The total amount of GP [t/year]
Grape pomace	22,082.44	2.00	44,164.880
Animal excrements	Number of heads	Amount of excrement per head [t/head]	Total amount of excrement [t/year]
PM	26,710,921.00	0.065	1,736,209.865
Municipal waste	Number of inhabitants	Quantity of MW per capita [t/inh]	The total amount of MW [t/yrar]
FW	7,041,599.00	0.1045	736,055.90

2.2 Optimization of the co-somposting process

When optimizing the co-composting process, the main goal is to use the available OW fractions to obtain an optimal mixture, with which composition the necessary conditions for the begining and flow of the co-composting process is achiving. The mathematical model was formed with three fractions OW. The GP was taken as the main component, while the GM and GS were considered as separate fractions, and the other fractions of OW were changed during the experiment. In each part of the experiment, one fraction was taken, in the first case FW and in the second case PM.
For the modelling of the co-composting process, the basic characteristics of the substrates was used, table 2.

Table 2. Substrate characteristics
Source: [17-24]

Component Parameter	GM	GS	FW	PM
C [%][a]	52.49	46.42	56.57	33.31
N [%][a]	1.76	1.23	4.00	3.20
OM [%][a]	96.49	94.77	97.06	65.41
Moisture [%][b]	56.60	10.80	70.00	71.10
pH [%][b]	3.94	7.30	6.70	8.17
Lignin [%][b]	11.10	32.30	12.03	2.00
NO_3^-[mg/kg][a]	22.80	9.10	4.00	10.80
NH_4^+[mg/kg][a]	641.00	2,326.00	484.00	670.00
P_2O_5 [mg/kg][a]	1140.00	901.98	534.68	1,544.00
K_2O [mg/kg][a]	41,483.00	49,240.00	33,021.00	11,438.00

a - Determined by measurement, b - taken from the literature

3. RESULTS AND DISCUSSION

3.1 Physical-chemical characteristics of the mixture

After applying the developed mathematical model, the values of the share of individual components included in the composition of the optimal mixture were obtained for both observed cases, in the first case when the co-substrate is FW and in the second case when the co-substrate is PM. The obtained

results showed that by applying the mathematical model it is possible to satisfy the set boundary conditions and criteria.
In table 3 results are shown, the shares of individual components that enter in the optimal mixture as well as the obtained parameter values, namely: C, N content, C/N ratio, moisture, pH value and nutrient concentration.

Table 3. Composition of optimal mixtures after the mathematical model
Source: (orig.)

Mixture composition Mixture characteristic	Mixture 1 64.40 % GM 20.59 % FW 15.00 % GS	Mixture 2 64.61 % GM 20.38 % PM 15.00 % GS
Max C [%]	52.41	47.66
Max pH	5.01	5.30
Min N [%]	2.14	1.97
Min Lignin [%]	14.46	12.61
C/N	26.97	27.03
Moisture [%]	52.48	52.68
NO_3^- [mg/kg]	51.30	43.50
NH_4^+[[mg/kg]	49.00	177,00
P_2O_5 [mg/kg]	2018.00	2334,00
K_2O [mg/kg]	21268.00	18627.00

Based on the results shown in table 3, it can be seen that when the co-substrate is FW, the content of C, N and lignin is higher, and a lower value of pH value is achieved. On the other hand, in the second case when the co-substrate is PM, the obtained results showed that their presence in the optimal mixture contributes to the reduction of C, N and lignin content, while the pH value is higher compared to the first mixture. The values obtained in this way for the content of C, N, C/N ratio and lignin content can be related to the structure and properties of the observed OW fractions, i.e. FW contain more lignocellulosic components and have a lower pH, while PM has high pH and low lignocellulose content. Also, the obtained results show that in both cases the pH value is above 5, which is in the optimal range for the start of the process [25]. Based on the obtained results for the physical-chemical properties of the obtained mixtures, it can be concluded that the mixture has more favourable characteristics when the co-substrate is PM, namely a higher pH value and a lower lignin content.

3.2 Degree of utilization of fractions OW

If the developed mathematical model were applied to the available amounts of OW and assuming that the obtained share of the GM in the optimal mixture represents the available amounts in the territory of the RS, 33,123.66 t/year and if it were treated with the composting process, then it would be necessary to add 7,715.13 tons of GS and 10,580.31 tons of FW, in the first case. Since the proportions of the components included in the composition of the optimal mixture are the same in the second case when the co-substrate is PM, it is necessary to add the same amounts of observed fractions of OW. In this way, the problem of GM would be solved, and 69.88% of the available amount of GS, 1.44% of FW, would be used, while in the second case, the same share of GM and GS (100% and 69.88%) and a small part of PM, 0.60% of the total amount generated on the territory of RS would be used.
Based on the obtained results, it can be concluded that the utilization of larger available amounts occurs when the co-substrate is FW, and somewhat lower when the co-substrate is PM.

3.3 Amount of compost and nutrient content

Based on the obtained shares of individual OW fractions entering in the optimal mixture and their amounts, it was obtained that the mass of the optimal mixture would be 51,419.10 tons. Starting from the mass of the OW optimal mixture at the beginning of the process and assuming that after the composting process, the mass of the initial mixture is reduced by 75.00%, the amount of compost at the end of the process for both cases was obtained. The amount of compost if the process was carried out under controlled conditions would amount to 12,854.77t/year [26]. Based on the share of nutrients at the beginning of the process (table 2) and at the end of the process (table 3), the amounts of nutrients that would be obtained after the composting process for both mixtures were determined. Thus, in the first case when the co-substrate is FW, in the compost that would be obtained after applying the composting process, the amount of nutrients would be: 659.459 kg NO_3^-, 629.893 kg NH_4^+, 25,941.32 kg P_2O_5 and 273,399.50 kg K_2O. In the second case, when the co/substrate was PM, the amount of nutrient will be 559.191 kg NO_3^-, 2,275.32 kg NH_4^+, 28,718.00 kg P_2O_5 and 239,449.52 kg K_2O.
By comparing the mixtures, it can be seen that the content of NO_3^- and K_2O is higher when the co-substrate is FW, while the content of NH_4^+ and P_2O_5 is when the co-substrate is PM.
Based on the obtained results, it can be concluded that the presence of PM as a co-substrate contributes to an increase in the content of nutrients, especially NH_4^+ and P_2O_5which makes this mixture more favourable.

4. CONCLUSION

The development of the composting process is quite complex because it depends on many factors, such as the characteristics of the treated substrate and the physical parameters that are monitored. In this paper, a previously developed mathematical model was applied to obtain the optimal mixture for the composting process and the maximum proportion of GM in the mixture. It was shown that all criteria are satisfied when the proportion of GM in the optimal mixture is 65.00%, 15.00% and 20.00% of co-substrate. By applying the previously developed mathematical model for obtaining the optimal mixture, it was shown that it is possible to eliminate GM completely when observing both cases. If we look at the use of OW fractions, it was shown that in the first case, the GM is eliminated completely, i.e. 100%, the GS 69.88% and FW with 1.44%. In the second case, the utilization of the GM is 100%, the GS is 69.88%, and the PM is about 0.60%. Based on the obtained results, it can be seen that it is possible to eliminate the GM completely, and that there are also sufficient amounts of other fractions of OW, which would replace certain components. Also, the results showed that the content of nutrients in both cases is high, especially the content of phosphorus and potassium. A slightly higher content of NH_4^+ (72.38%) and P_2O_5 (9.66%) was achieved when the co-substrate was PM. It can be concluded that PM represents the optimal co-substrate that is necessary to be added to the GM and GS during co-composting.

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PERSPECTIVES AND CHALLENGES IN COGNITIVE ENHANCEMENT BASED ON THE NEUROTECHNOLOGY APPROACH

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Abstract: *Cognitive enhancement or neuroenhancement implies any action or intervention that improves performance related to cognitive abilities such as learning, memory, attention, or vigilance. The whole approach is based on an understanding of the underlying neurobiology of cognitive functions and interventions through conventional methods (environmental enrichment, adequate sleep, optimized diet, physical activity, etc.), pharmacological methods (nootropics and drugs used for treating patients with neurological disorders) and neurostimulation.*
Due to the latest developments in the field of technology, the possibility to enhance cognitive function using computer chip implants in the brain is opened. Such devices that interface with the neural system are presently in development and engaged only for those with a therapeutic requirement. On the other hand, as for all methods of cognitive enhancement, it is really hard to draw the line between their approved and non-approved usage. Therefore, the upcoming application of brain chip implants could expand brain performance for individuals even without therapeutic prerequisite, although both the public and scientists already anticipate some negative impacts.
This paper discusses perspectives and challenges in the latest development of the neurotechnology approach used to improve cognitive performance.
Keywords: Cognitive Enhancement, Neurotechnology, Brain Chip Implants.

1. INTRODUCTION

Cognition refers to mental processes that comprise attention, memory, making decisions, solving problems, producing and understanding language, reasoning, etc. Demand for memorising facts, learning new operations and skills, and performing complex analytics is on a constant rise in contemporary society. Modern humans are facing a huge amount of information on a daily basis, especially in certain technology-based professions. Keeping and improving mental capabilities might be crucial in daily life, but especially in some professions. For example, enhancing procedural memory may upgrade task competency in many job positions. Besides the high demand for improving cognitive skills of healthy population several disorders, for instance, attention deficit hyperactivity disorder (ADHD), Alzheimer's, Parkinson's and Huntington's diseases, schizophrenia, etc. are characterized by cognitive impairments. Such patients regularly fight with numerous everyday activities demanding focusing, memory, problem-solving and planning. The probable public health benefit of improving treatments for such patients is more than obvious. Cognitive skills are regularly and traditionally acquired through slow, step by step, effortful, and expensive procedures of education and training. Therefore, several approaches to augment brain function have been proposed. These different strategies of brain functioning improvement are usually termed cognitive enhancement or neuroenhancement (Table 1). Cognitive enhancement techniques are classified whether they are

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conventional or unconventional, but also if they are external or internal to the user, and whether they are hardware/software based [1]. Unconventional techniques of direct nervous system stimulation are here presented as a special category known as neurostimulation.

Table 1. Different approaches to cognitive enhancement
Source: presented data are acquired through literature review and appropriate references cited in the table

COGNITIVE ENHANCEMENT	**Conventional methods**	**Education**: formal, informal and non-formal types [1]; **Enriched Environment**: physical stimulation (nutrition, sleep, exercise…), social stimulation and cognitive challenges [2]; **Mental Training**: learning strategies, general mental activity, rhyming, recalling colourful or emotional scenes, recalling number series or letters, yoga, martial arts, meditation, video gaming [2]; **Use of external information processing devices**: cognitive training, neurofeedback [3].
	Pharmacological methods	**Nootropics**: classical nootropic compounds, substances increasing brain metabolism, cholinergic drugs, plants and their extracts with nootropic effects [4]; **Drugs for treating neurological disorders** [5].
	Neurostimulation	**Transcranial electric stimulation** (i.e., tDCS, tACS, tRNS) [6]; **Transcranial magnetic stimulation** (i.e., single, dual pulse, and rTMS) [6]; **Focused ultrasound** [7]; **Electrical vestibular stimulation (EVS)** [6]; **Vagus nerve stimulation (VNS)** [6].

Cognitive enhancement embraces three steps [1]. Assessment of cognitive abilities is the first step. It is followed by intervention aimed at cognitive abilities improvement. Final step is the validation of improvement that takes place by evaluating the cognitive abilities upon intervention. If the intervention is used to correct a certain pathological conditions or impairments of cognition, then it is stated as a therapy. However, drawing the line between intervention and therapy is not that easy in certain cases.

Conventional means of enhancing cognition embrace education, enriched environment, mental training, and the use of external information processing devices (Table 1). Education could be defined as any experience that has effects on the way one thinks, feels, or acts. Clearly, education is approached through formal and unformal programs and forms and affects how our "biological software" in the brain collects, preserves, and analyse information. Enriched environment is the stimulus for the brain by its social and physical surroundings, or by cognitive challenges [2]. Any stimulus which represents positive experience enhance cognitive flexibility through the process of neuroplasticity. Neuroplasticity is biological capability of the brain to constantly modifies in concordant to stimuli from the environment. In addition, there is a huge number of different forms of mental trainings through which cognitive enhancement is possible to achieve. Usually, these are learning strategies to memorize information, methods for general mental activity, use of rhyming, recalling colourful or emotional scenes, recalling number series or letters, yoga, martial arts, meditation, video gaming, etc. The list of mental trainings is constantly expanding. External information processing devices are applied in modern versions of "mental gym programs". They are often used in conjunction, such as neurofeedback and cognitive training. Cognitive training is a conventional method transformed into modern virtual game-like format of mental exercises. Neurofeedback is a technique to monitor brain signals with either visual or auditory feedback [3].

The use of pharmacological methods in cognitive enhancement is associated with the treatment of medical disorders such as dementia and ADHD, but there are considerations that certain medicines are also taken in non-clinically prescribed circumstances. Nootropics, also known as "smart drugs" are an assorted collection of medicinal substances whose action advances human mental activities, particularly in cases where these functions are impaired [4]. A heterogeneous group of nootropics has been divided into four subgroups according to their nature and effects: classical nootropic compounds, substances increasing brain metabolism, cholinergic drugs, and plants and their extracts

with nootropic effects. Nootropics are used in acute or subacute conditions for treating memory, consciousness, and learning disorders.
Neurostimulation embraces group of non-invasive technologies such as; transcranial electric stimulation (tES), transcranial magnetic stimulation (tMS), electrical vestibular stimulation, vagus nerve stimulation (VNS), and focused ultrasound; as well as invasive technologies as deep brain stimulation. All neurostimulation technologies are all grounded on the usage of electrical or magnetic stimuli to alter the electrophysiology of the central and peripheral nervous systems. Transcranial direct-current stimulation (tDCS) is a movable, wearable electric brain stimulation technique that delivers a low electric current to the scalp. In transcranial alternating current stimulation (tACS) a low-intensity sinusoidal electrical current is applied to the brain through electrodes on the scalp. Transcranial random noise stimulation (tRNS) is a method that involves the application of a low-intensity alternating current whose intensity and frequency change in a randomised way. Deep brain stimulation involves inserting neuro-stimulators in precise fragments of the brain, which direct electrical pulses that interfere with neural activity at the target sites. This technology is mainly used for the treatment of movement and memory disorders [7].

2. NEUROTECHNOLOGY IN COGNITIVE ENHANCEMENT

Until recently, deep brain stimulation and other invasive technologies based on the insertion of electrodes and devices were used in humans only due to medical interventions (e.g. epilepsy and Parkinson's disease). Research on cognitive augmentation in humans was limited to medically approved cases as learning enhancement and visual prosthesis. The development of brain-computer interfaces (BCIs) opened a new era for the implementation of technologies for brain recording and brain stimulation. Brain-computer interfaces obtain brain signals, analyse them, and decode them into instructions that are transmitted to output devices that perform wanted actions. The BCI includes hardware that records brain signals (electrical or magnetic signals made by brain neurons) and software that analyses and converts them into specific commands. The brain comprises of almost 100 billion neurons, each making thousands of synapses (connections) with other neurons. Therefore, interpreting the collected signals is quite a complex problem. Hopefully, it is expected that machine-learning algorithms will increase the capacity of BCIs to interpret brain activity in real time.
The main goal of BCI in medicine is to replace or restore useful functions to disabled people. BCI technology may permit individuals unable to speak or use their limbs to once again communicate or operate devices for walking and object manipulation. In other words, brain-computer interfaces are systems that allow communication between the brain and various machines like a computer, smartphone, or robotic limb. Looking from more general view, BCI might be used as an approach to cognitive enhancement not only in patients with medical diagnosis but also in healthy populations.
The term brain-machine interface is commonly used as a synonym to the described term brain-computer interface. Anyway, brain-machine interface (BMI) refers to the definite interface between nervous system tissue and a device (usually an electrode); accordingly, BMI is invasive. Many researchers assume that BCI encompasses the entire BMI field since brain-machine interface is focused on refining the electrodes themselves for recording or stimulating brain activity. The term neurotechnology is another term often used as a synonym, but more precisely it includes any method or electronic device which interfaces with the nervous system to screen or control neural activity [8]. Neurotechnology incorporates the use of brain chips, neural implants, and BCI technology.

2.1 Brain Implants

In April 2021, Neuralink, the tech startup co-founded by Elon Musk, demonstrated how a chip-implanted monkey could play the video game Pong with its mind. This demonstration opened the possibility for human brain implants. Neuralink announced in May 2023 approval from the USA Food and Drug Administration to begin trials to implant brain chips into humans. Most probably, many years will pass before patients get the Neuralink treatment, but that isn't stopping investors from

boosting the company. Neuralink aims to ultimately enable a patient suffering from paralysis to use devices such as computers or phones with their brain activity alone. It is presumed that their implant contains multiple chips, a wireless battery, and other electronics that are hermetically closed inside a small device (the size of a large coin). Ultra-thin threads will protrude from the implant directly into the brain tissue, and signals will be sent via Bluetooth to, and decoded by, BCI. As a result, a patient will be able to, for example, control an onscreen cursor or move a robotic limb. Neuralink already created a surgical robot to embed the implant and its 64 ultra-thin flexible connected threads upon which are 1,024 electrodes that record neural activity. The robot uses optical coherence tomography for non-invasive imaging of the brain and the needle as thin as a human hair to insert the "threads.
Neuralnik is not the only company in the field of inserting brain implants into humans. Synchron is a company financially supported by Bill Gates and Jeff Bezos and they already tested brain-computer interface (BCI) in humans. The same company also reported the insertion of Stentrode through the blood vessels into the brain's motor cortex.
According to some sources, more than 150,000 people from the USA have a type of brain implant known as a deep brain stimulator to treat tremors caused by movement disorders such as Parkinson's. One forthcoming practice of brain chip implants could be to expand brain functioning for people even without therapeutic requirements. A brain implant might work by transferring pulses of electricity straight into neurons that help rule a particular skill of interest or to improve memorizing facts. The chip might also give the brain some extra memory and subsequently knowledge could be kept externally.

3. PERSPECTIVES

Practically, neurotechnology can be applied to permit mind-controlled prostheses, improve cognitive abilities, and cure neurological dysfunction. The use of BCIs to enhance motor and cognitive recovery within neurorehabilitation settings is more than expected and approved by scientists and by public. In research published in 2019 Widge and associates determined that electrical stimulation of the ventral internal capsule/ventral striatum brain areas enhances cognitive control. They also found that upon deep brain stimulation of this area, specific neural biomarkers that correspond with clinical improvements could be observed and followed [10]. The almost identical framework could also be applied to further cognitive or emotional difficulties, for example, monitoring and enhancement of learning or emotion dysregulation, thus opening the possibility for some type of “cosmetical cognitive enhancement” approach.
In both cases from the point of technology, there are several critical segments to be improved. Implanting electrodes into brain tissue comes with certain risks. Therefore, it would be ideal to attach them outside of the brain entirely and specifically outside of the dura mater, the brain’s protective membrane. Currently, chip arrays record data from maybe a couple of hundred neurons at a time. Expanding this feature to record electrical signals instead from hundreds to hundred thousand of neurons opens much bigger possibilities around the type of fidelity keeping in mind almost 100 billion brain neurons, each having a couple of thousand synapses. Furthermore, an open question is do we need chip technology that is limited concerning the size of the implant and invasive surgical approach? The next step in brain chip development could be the creation of nanomaterials that move through the body and specifically through the bran. Injecting nano-sensors that would be deployed throughout the brain could be followed by their control by magnets or radio signals. Additionally, the technology of nanoparticles could be combined with genetic and molecular engineering. Huge number of such nanoparticles would substitute one or a few implants. As a result, instead of sensing broad signal from multiple neurons nanoparticles would detect specific signals from single cells of various cell types finally allowing us to associate them with specific neurological diseases or specific cognitive domains and functions. Another additional step in improving the usage of neurotechnology

in cognitive enhancement could be refining the connection between brains and machines. This would beef up our senses and allow us to control robots from a distance.

Neurotechnology that is based on non-invasive neurostimulation is at certain preference compared to invasive technology that uses brain implants. For example, transcranial direct current stimulation works by sending electricity through the scalp. Some scientists believe that this method could be further improved thus helping in the enhancement of skills such as learning and memory. Similarly, the transfer of electrical signals through the vagus and other nerves may prompt the brain to release neurotransmitters and metabolites that alter connections between different neural cells. The natural process of memorizing and learning is based on the same neurobiological mechanism. Thus, further stimulation and direction of the same neurobiological process via electrical stimulation of the vagus may "tune" the brain to recognize important details with less practice which might be of interest to both, patients and healthy population. Moreover, recent studies have revealed the prospect of using neurotechnological methods to assess the cognitive processes associated with individual and group decision making, memory enhancement, attention enhancement, different aspects of perception and awareness, and social interaction [7].

Lately, scientists have started exploring the option of brain-to-brain communication. This would be possibility to physically and directly connect two or more brains permitting straight and shortest exchanges of information between people. In several studies combination of electroencephalography and transcranial magnetic stimulation was used in brain-to-brain communication to spread information between individuals in a collaborative task [7]. Although described brain-to brain communication is currently characterized with lot of limitations achievements in this field represent an important proof-of-concept, and further development might potentially lead to future upgraded and more functional systems of brain-to-brain communication.

4. CHALLANGES

The usage of neurotechnology raises concerns in first place about free will and privacy of individuals. The potential ability to "read" or "assess" someone's thoughts, emotions, states, or attitudes opens the possibility of its misuse. Nowadays, many neuroscientists are worried about the latest consent for insertion of brain chips into humans that Food and Drug Administration approved. A logical question is whether the private company Neuralink will have admission to the neuro data of the people that they implant devices in.

As expected, different investigations on public attitudes demonstrated negative views across the whole population about using brain chip implants for enhancement. Most the people recognize usage of brain chip implants to improve cognitive processing as interfering with nature and passing a line. In this line, they are mostly bothered about potential economic inequality in brain implants application and cybersecurity. Most people claim higher standard to guarantee the safety of brain chip implants, especially if they are used in the cosmetic cognitive enhancement practice. In contrast, most people support the use of brain chips for medically approved therapeutic purposes in patients [11].

Neuroscientists are afraid that the application of BCI technology in humans will cause mental changes that are unpredictable and little understood. Most probably some changes might entirely modify someone's identity and sense of self. In some particular cases, patients have stated back feelings of estrangement, or even that the implant makes them feel unlike themselves. Consequently, the main questions are what kinds of changes does BCI-based cognitive enhancement cause, and how much changes matter to individuals and whole human society? Clearly, notions of personality, individuality, independence, and self are quite compact, obscure, and opaque dimensions. Therefore, all criticisms are well based and reasonable.

5. CONCLUSION

At present time, methods of cognitive enhancement based on neurotechnology approach look quite promising, but at the same time frightening. That is the step that all new technology passes on their path to approval and usage. Helping other people in their fight against neurodegenerative diseases and other types of handicaps is beyond any doubt something we should persist. Opening the gates for cosmetic neurology that will allow anyone with enough money in the pocket to "expand mind" is something different. Both practices are based on the same neurotechnology approach. In both cases at the moment, we are not able to predict all side effects, particularly ones that may affect someone's personality. Consequently, our attitude towards cognitive enhancement must be carefully determined and balanced.

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PRESCRIBING WELLNESS IN PRIMARY CARE: INTEGRATING HEALTH AND HEALTHCARE

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Abstract: *The integration of wellness promotion in primary healthcare settings, emphasizing the concept of prescribing wellness is needed. Recognizing the significant impact of lifestyle on health outcomes, healthcare providers are increasingly incorporating wellness interventions into their practice. By prescribing and encouraging healthy behaviors, such as exercise, nutrition, stress management, and sleep hygiene, primary healthcare providers can prevent and manage chronic diseases more effectively. This proactive approach improves individual health, reduces healthcare costs, and enhances overall well-being. Research indicates that patients respond positively to wellness prescriptions, leading to increased engagement and adherence to healthy behaviors. Integrating wellness into primary healthcare involves educating providers on evidence-based interventions, and utilizing community resources to support behavior change. Collaborative care models that involve multidisciplinary teams and shared decision-making further enhance the integration of wellness in healthcare settings. Prescribing wellness in primary healthcare has the potential to address the root causes of many chronic conditions and promote holistic approaches to healthcare. By focusing on prevention and lifestyle modifications, primary healthcare providers play a critical role in empowering patients to take control of their health. However, challenges such as limited time, reimbursement constraints, and patient readiness for change need to be addressed for effective implementation.*
Keywords: Wellness, Primary healthcare, Lifestyle, Holistic approaches

1. INTRODUCTION

The idea of well-being, a healthy lifestyle, and wellness have as their common denominator the preservation and promotion of health. Achieving well-being refers to how individuals meet emotional, social, and spiritual needs [1]. Integrating wellness promotion into primary healthcare settings and emphasizing the concept of prescribing wellness is a pivotal strategy that aims to elevate the overall state of public health [2,3]. This approach departs from the traditional healthcare model centered solely around treating illnesses and places substantial emphasis on holistic well-being [3]. At its core, this approach recognizes that health extends beyond the absence of disease. It encourages a proactive stance by prioritizing prevention through education, screenings, and interventions. Healthcare providers take on the role of educators, equipping patients with knowledge about healthy lifestyle choices, the significance of regular check-ups, and the benefits of early detection [2,3]. By

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doing so, they empower patients to make informed decisions that positively impact their long-term health outcomes.

One of the key principles of this approach is the idea of "prescribing wellness" [2,3,4]. This means that, just as a physician might prescribe medication, they also prescribe personalized wellness activities tailored to each patient's needs. These activities could encompass physical exercise routines, stress management techniques, dietary guidelines, mental health practices, and more [4,5]. By integrating these recommendations into patients' lives, healthcare professionals help individuals adopt healthier habits, potentially averting the development of chronic conditions and enhancing their overall quality of life. Furthermore, this approach promotes a shift in patient-provider dynamics. Patients are encouraged to actively engage in their healthcare journey, moving from a passive recipient of medical treatment to an empowered participant in their well-being [3,5]. The collaboration between healthcare experts from various fields, such as doctors, nurses, dietitians, psychologists, and fitness trainers, is crucial in devising comprehensive wellness plans that cater to individual needs.

2. LIFESTYLE BEHAVIORS, HABITS, AND CHOICES

The Mueller and Kaufmann wellness model serves as the foundation for the idea of wellness-related lifestyles, which emphasizes social interaction, diet, travel, fitness, a holistic approach to life, and environmental protection [1]. This model highlights a range of factors that collectively contribute to fostering holistic well-being and a high quality of life. Central to this model are elements such as social interaction, dietary choices, travel experiences, physical fitness, adopting a holistic life perspective, and prioritizing environmental preservation. Social interaction holds a key role in the wellness-related lifestyle [1]. It recognizes the inherent human need for social connections and relationships, as they contribute significantly to mental and emotional well-being [1]. Engaging in meaningful interactions, nurturing friendships, and fostering a sense of belonging all contribute to a balanced and fulfilling life. Recognizing the profound impact of nutrition on overall health, the model underscores the importance of making informed dietary choices [1]. Prioritizing balanced and nourishing diet rich in vitamins, minerals, and nutrients not only supports physical health but also contributes to mental clarity and vitality. Travel experiences are emphasized as an integral part of wellness-related lifestyles [1]. The model acknowledges the benefits of exploring new places, cultures, and environments for personal growth, relaxation, and rejuvenation. Travel provides opportunities to step out of daily routines, gain new perspectives, and engage in activities that enhance physical and mental well-being. Physical fitness is a central component, emphasizing the significance of regular exercise and physical activity [1]. The model advocates incorporating movement into daily routines to promote cardiovascular health, flexibility, strength, and overall vitality. Exercise contributes to stress reduction, improved mood, and enhanced overall quality of life. A holistic approach to life is an essential tenet of the wellness-related lifestyle model [1]. It encourages individuals to view their well-being as an interconnected whole, encompassing physical, mental, emotional, and spiritual dimensions. By recognizing the interplay of these elements, individuals can strive for a balanced and harmonious life. Lastly, environmental protection is a vital consideration within this model [1]. Recognizing the symbiotic relationship between human well-being and the health of the planet, the model promotes responsible and sustainable practices that contribute to environmental preservation. This includes reducing waste, conserving resources, and making choices that minimize negative impacts on the environment.

By embracing these factors, individuals can cultivate well-rounded and fulfilling lives that prioritize not only their health but also the well-being of their communities and the planet. Healthcare providers today are increasingly recognizing the profound influence that lifestyle factors have on health outcomes [5,6]. Lifestyle, encompassing behaviors, habits, and choices that individuals make in their daily lives, plays a pivotal role in determining one's health trajectory [6]. These choices can either contribute to the development of chronic diseases or act as protective factors that promote long-term well-being. To address this, healthcare providers are integrating wellness interventions into their

practices. Rather than solely focusing on treating illnesses after they have manifested, these providers are adopting a proactive approach that emphasizes prevention and lifestyle modifications. By "prescribing" and encouraging healthy behaviors, primary healthcare providers are equipping patients with tools to take control of their health and make informed choices that lead to better outcomes.

3. WELLNESS-RELATED LIFESTYLE

Wellness-related lifestyle encompasses a multifaceted approach to health, addressing not only physical well-being but also psychological, social, and spiritual dimensions [7]. This comprehensive perspective recognizes that true wellness goes beyond the absence of illness; it embraces happiness, personal growth, purposeful living, and meaningful connections with others. Within the framework of wellness, individuals strive to achieve a balanced and harmonious life across various domains. Happiness and contentment are fundamental components of well-being [8]. Wellness encourages individuals to pursue activities and make choices that bring joy and satisfaction [7,8]. This could range from engaging in hobbies and spending time with loved ones to exploring new experiences that foster a sense of happiness and fulfillment. Personal development is another integral facet [7,8]. Wellness-related lifestyle emphasizes continuous learning and self-improvement [7,8]. Individuals are encouraged to set goals, challenge themselves, and engage in activities that promote personal growth and skill enhancement. This contributes to a sense of accomplishment and overall well-being. Finding one's life purpose is deeply intertwined with wellness. Having a sense of purpose gives life meaning and direction. Individuals are motivated to identify their passions, values, and goals, aligning their actions with their inner sense of purpose. This connection fosters a strong sense of well-being and fulfillment. Relationships play a crucial role in wellness-related lifestyle [5,6]. Nurturing social connections and building a supportive network contribute significantly to overall well-being. Meaningful relationships provide emotional support, a sense of belonging, and opportunities for shared experiences, all of which are vital for psychological and emotional health.

Spa and wellness centers are pivotal in the pursuit of well-being [1,6]. Visitors to these centers seek experiences that cater to various dimensions of wellness. Their perceptions of well-being are influenced by the relaxation, rejuvenation, and self-care practices offered [1]. Such centers provide environments that promote mental and spiritual wellness, often through practices like meditation, mindfulness, and stress reduction techniques [1]. Travel motives are also linked to healthy lifestyles and well-being [7,8]. Many individuals choose travel experiences that align with their wellness goals, seeking destinations and activities that support physical, mental, and emotional well-being. Wellness-focused travel provides opportunities for individuals to explore new cultures, engage in physical activities, and indulge in relaxation practices that contribute to their overall sense of well-being. In wellness centers, the concept of well-being is deeply rooted in psychological, spiritual, and social effects [1,8]. These centers provide a holistic approach to wellness, offering services and activities that address mental clarity, inner peace, and a sense of connection with oneself and others. This approach recognizes that a state of well-being involves harmony between mind, body, and spirit.

3.1. Spas and wellness centers

Modern spas and wellness centers have evolved into havens where visitors are encouraged to prioritize their enjoyment, enhance relaxation skills, find solace, and equip themselves to manage the stressors of everyday life [8]. These establishments serve as settings for self-discovery and self-improvement, providing a retreat from the demands of modern life. Spas offer a sanctuary for individuals to focus on their health and well-being, positioning themselves as oases of rejuvenation and holistic wellness. The realm of wellness tourism has witnessed substantial global growth, driven by evolving healthcare trends that emphasize proactive, comprehensive, and preventive approaches to health. This shift entails fostering behaviors that fortify personal, physical, emotional, and spiritual well-being [7,8]. Notable examples include the surging popularity of training programs tailored to individual needs, as well as the widespread adoption of practices such as yoga, tai chi, and meditative

exercises [8]. These trends reflect a broader recognition of the benefits of nurturing one's overall well-being holistically. Numerous entities, including healthcare facilities and corporations, have recognized the profound advantages of promoting a healthy lifestyle. This realization stems from an understanding that well-being significantly impacts productivity and quality of life. As a result, wellness is not only considered from a medical perspective but also as a strategic investment that enhances performance and fosters a balanced, fulfilling existence [1,8]. The contemporary approach to wellness acknowledges the multifaceted nature of well-being, integrating physical health with mental, emotional, and spiritual dimensions. Spas and wellness centers align with this philosophy by offering diverse programs and activities that cater to the whole individual. Guests can engage in relaxation therapies, treatments, mindfulness sessions, and educational workshops that collectively contribute to their overall wellness journey [7,8]. Furthermore, these establishments recognize the importance of personalized experiences. Each individual's well-being journey is unique, and spas have responded by providing tailored services that address specific needs and goals. From stress reduction and rejuvenation to personal growth and self-care, spas serve as platforms for self-discovery, learning, and empowerment. Modern spas and wellness centers have evolved into spaces that encourage individuals to prioritize their well-being, offering environments conducive to relaxation, self-improvement, and stress management [7,8]. The growth of wellness tourism reflects a broader shift towards proactive health practices that encompass various dimensions of well-being. As society increasingly recognizes the interplay between well-being, productivity, and overall quality of life, the role of wellness establishments in promoting holistic health becomes even more vital.

3.2. The role of general practitioners in Wellness and health tourism

Wellness and health tourism have emerged as transformative approaches to nurturing holistic well-being. These forms of tourism encompass journeys that prioritize health enhancement and self-improvement through a range of activities tailored to promote physical, mental, and emotional vitality [2,4]. From immersive spa retreats and rejuvenating yoga getaways to fitness-focused vacations and mindfulness workshops, these experiences are designed to empower individuals on their wellness journeys. Central to the effectiveness of wellness and health tourism is the role of general practitioners (GPs) in shaping patient perspectives and decisions. GPs serve as trusted sources of medical guidance, offering patients valuable insights into how such travel experiences can contribute to their overall health [2,3,4]. GPs can elaborate on the potential advantages, including stress reduction, improved mental health, enhanced physical fitness, and opportunities for relaxation and self-discovery [2]. Crucially, GPs are equipped to provide personalized recommendations that consider patients' individual medical backgrounds and specific health goals. By tailoring advice, GPs help patients select activities and destinations that align with their well-being needs, ensuring safety and effectiveness. They can also educate patients about potential risks and considerations, helping them make informed choices that foster positive outcomes. GPs play a vital role in preventive care by discussing vaccinations, safety precautions, and health considerations before embarking on wellness and health tourism journeys [2,3,4]. Post-trip, GPs can engage in follow-up consultations to monitor patients' well-being, address any concerns, and assess the impact of the experience on their health. This holistic approach to post-travel care supports a seamless transition back to daily life while maintaining the benefits gained from the wellness journey [4]. Furthermore, collaboration between GPs and wellness tourism providers is essential to ensure comprehensive care. GPs can share medical insights with providers, ensuring that activities are adapted to accommodate any medical conditions or specific requirements. This collaboration fosters a seamless integration of medical expertise into the design and execution of wellness experiences, enhancing safety and patient satisfaction. GPs serve as informed advocates for wellness and health tourism, guiding patients toward experiences that align with their health objectives and cater to their overall well-being. By fostering an open dialogue, offering personalized advice, and ensuring safety, GPs empower patients to embark on wellness journeys that can lead to transformative improvements in their physical, mental, and emotional health.

3.3. The concept of "prescribing wellness" within primary healthcare

Integrating wellness into primary healthcare entails a multifaceted approach aimed at fostering comprehensive well-being [3,4]. This process begins with educating healthcare providers about evidence-based interventions that extend beyond traditional medical practices. By equipping providers with knowledge about nutrition, exercise, stress management, and other wellness-related strategies, they become better positioned to address the broader determinants of health [4]. This integration also hinges on leveraging community resources as catalysts for behavior change. Collaborating with local organizations, fitness centers, mental health professionals, and nutritionists allows healthcare providers to extend their reach beyond clinical settings. Patients are not only informed about healthy choices but also empowered with accessible resources that facilitate sustainable lifestyle changes [3,4]. Central to successful integration is the adoption of collaborative care models. These models emphasize the importance of multidisciplinary teams comprising healthcare professionals from diverse fields. This inclusive approach encourages shared decision-making, where patients actively participate in their care plans, making them more likely to adhere to wellness recommendations. Collaboration also ensures that healthcare interventions are holistic and tailored to each patient's unique needs.

The concept of "prescribing wellness" within primary healthcare represents a paradigm shift [3]. By treating lifestyle changes as prescriptions, healthcare providers underscore the significance of wellness in disease prevention and management. This approach acknowledges that many chronic conditions stem from modifiable behaviors and lifestyle choices [3,4]. As a result, addressing these root causes becomes a pivotal strategy in achieving improved health outcomes. Moreover, this approach promotes holistic healthcare by recognizing that physical health is intertwined with mental, emotional, and social well-being. Prescribing wellness encompasses personalized plans that incorporate exercise routines, stress reduction techniques, dietary adjustments, and other self-care practices. Patients are empowered to take charge of their health, not only addressing current health issues but also preventing future ones. Integrating wellness into primary healthcare involves educating providers, harnessing community resources, and embracing collaborative care models [5]. By prescribing wellness, healthcare professionals target the underlying factors contributing to chronic conditions and emphasize a holistic approach to well-being. This integration not only improves patient outcomes but also lays the foundation for a healthcare system that prioritizes prevention, education, and the empowerment of individuals to lead healthier lives.

3.4. Challenges for effective "prescribing wellness" within primary healthcare

Primary healthcare providers assume a pivotal role in empowering patients to proactively manage their health through prevention and lifestyle adjustments. This approach emphasizes addressing health concerns before they escalate, fostering a culture of well-being, and minimizing the burden of chronic diseases. Nonetheless, several challenges must be navigated to ensure the effective implementation of this approach. The significance of prevention and lifestyle modifications cannot be overstated. Primary healthcare providers offer patients the tools and guidance needed to make informed choices that impact their long-term health outcomes [3,5]. By imparting knowledge about healthy behaviors, risk factors, and the benefits of proactive measures, providers inspire individuals to assume an active role in safeguarding their well-being. Yet, these efforts encounter obstacles that necessitate attention. Time constraints pose a significant challenge, as primary care appointments are often limited in duration. Effectively discussing preventive strategies and facilitating behavior change within these time frames can be demanding. Providers must balance addressing immediate health concerns while allocating sufficient time to educate patients about wellness practices [5,6]. Reimbursement constraints further complicate matters. In many healthcare systems, financial incentives might be skewed toward reactive treatments rather than preventive services [3,5,6]. This can discourage primary healthcare providers from dedicating ample time to wellness education and behavior change discussions. Recognizing and rectifying these financial disparities is vital to

encourage a more proactive healthcare approach. Additionally, patient readiness for change is a complex factor [6]. While primary healthcare providers offer guidance, patients' willingness and capacity to adopt lifestyle modifications play a crucial role. Some individuals might already be motivated to make positive changes, while others might require more time and support to initiate shifts in their behaviors. Tailoring interventions to individual needs and preferences is essential for effective engagement.

3. CONCLUSION

By fostering an integrated and proactive healthcare model, primary care settings become hubs for addressing health concerns and cultivating enduring well-being. Emphasizing preventive measures, behavior change, patient education, and collaborative care reduces the burden of preventable diseases, improves public health outcomes, and enhances individuals' resilience against health challenges. The inclusion of wellness interventions underscores the vital role of lifestyle in health outcomes. Through prescribing and promoting healthy behaviors, healthcare providers nurture a culture of prevention, empowering patients to make positive choices and contributing to a healthier society with reduced disease burden and enhanced well-being. This wellness-related lifestyle encompasses elements like happiness, personal development, purposeful living, relationships, and experiences from wellness centers and travel. This holistic approach acknowledges health as encompassing physical vitality, fulfillment, belonging, and balance across various life dimensions. Primary healthcare providers empower patients through prevention and lifestyle adjustments, equipping them with knowledge and strategies to be active participants in their health journey. Overcoming challenges like time constraints and reimbursement structures is essential for successful implementation. This ensures that primary care catalyzes improved well-being and is a cornerstone of holistic health management.

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LIFESTYLE MEDICINE: EMPOWERING HEALTH THROUGH BEHAVIOR MODIFICATIONS

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Abstract: *Lifestyle medicine utilizes evidence-based behavior modifications in diet, exercise, sleep, stress management, positive social connections, and substance use to prevent, treat, and potentially reverse lifestyle-related chronic diseases. By adopting and maintaining healthy behaviors, individuals can improve their health and overall quality of life. Healthy lifestyle recommendations have the potential to prevent over 80% of chronic conditions. Lifestyle-related diseases, influenced by misinformation and poor choices, are the leading cause of death in the modern world. To address this challenge, lifestyle medicine provides essential recommendations to extend life, enhance health, and promote well-being. Key interventions include healthy eating, active living, maintaining a healthy weight, and building emotional resilience. Integrating lifestyle practices into medical care helps reduce risk factors for chronic diseases and complements traditional therapy. By utilizing scientific evidence from various health-related fields, lifestyle medicine supports clinicians in promoting disease treatment and overall health. Transforming medical culture to prioritize lifestyle education empowers individuals to take control of their health, leading to longer, healthier lives with improved quality and reduced disability. While not all healthcare practitioners may fully incorporate lifestyle goals into their practice, having access to information and tools is a significant step forward.*
Keywords: Lifestyle, Well-being, Evidence, Healthcare

1. LIFESTYLE MEDICINE

Lifestyle medicine is a multidisciplinary field focused on utilizing evidence-based lifestyle interventions to prevent, treat, and manage various chronic diseases and health conditions [1,2]. This emerging discipline involves a spectrum of researchers and experts delving into various aspects encompassed within its purview, including but not limited to nutrition, physical activity, weight management, and smoking cessation. While these individual elements hold significance on their own, their collective exploration converges under the umbrella of lifestyle medicine, where the synthesis of these modalities highlights the interplay between human behaviour and health outcomes. Through an integrative approach that considers the cumulative effects of lifestyle choices, lifestyle medicine strives to empower individuals with knowledge and tools to optimize their health and foster a higher quality of life [2].

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2. THE EVOLUTION OF LIFESTYLE MEDICINE

The evolution of lifestyle medicine traces a progressive path marked by the growing understanding of how daily habits influence health outcomes. It began in the early 20th century with a shift towards preventive medicine, emphasizing underlying causes over symptoms. As chronic diseases like heart disease and obesity surged in the latter 20th century, the role of lifestyle choices gained prominence. The 1960s and 1970s linked risk factors like poor diet and sedentary behaviour to chronic diseases [1,2]. Organizations like the American College of Lifestyle Medicine (founded in 2004) advanced the field. Scientific research increasingly supported lifestyle's impact on health, leading to its integration into medical education. Lifestyle medicine views health holistically, spanning physical, mental, and emotional well-being [3]. Collaboration among experts in various fields furthered understanding. Public interest grew, promoting lifestyle's role in disease prevention. This approach is globally recognized for its potential to alleviate chronic diseases and enhance overall health. Lifestyle medicine evolves, advocating proactive, holistic well-being approaches in modern healthcare.

3. HEALTHY LIFESTYLE RECOMMENDATIONS

Lifestyle medicine encompasses a range of practices that individuals can adopt to promote good health and prevent the onset of various diseases [1,2]. These practices focus on optimizing key aspects of daily life to create a foundation for overall well-being. Some essential practices of lifestyle medicine to promote good health are given in the text. Lifestyle medicine represents a paradigm shift in healthcare, acknowledging the profound impact of daily habits and practices on disease prevention and treatment. This multidisciplinary field investigates the interactions between human behavior and health outcomes, emphasizing the role of lifestyle modifications as integral components of comprehensive healthcare strategies [3]. The following review synthesizes key practices within lifestyle medicine that have gained recognition for their potential to promote good health and enhance overall well-being.

3.1. Nutrition and Balanced Diet

A cornerstone of lifestyle medicine, nutrition plays a pivotal role in preventing chronic diseases. The research underscores the significance of a balanced diet rich in whole foods, emphasizing fruits, vegetables, whole grains, lean proteins, and healthy fats. The Mediterranean and Dietary Approaches to Stop Hypertension diets, characterized by high fiber content, moderate fat intake, and abundant antioxidants, have demonstrated favorable outcomes in reducing cardiovascular risk factors. Mounting evidence also highlights the impact of nutrition on gut microbiota composition, implicating dietary choices in immune regulation and metabolic health [1,2,4].

3.2. Physical Activity and Exercise

Regular physical activity is fundamental to maintaining cardiovascular health, metabolic balance, and mental well-being. Incorporating aerobic exercises, strength training, and flexibility routines contributes to improved muscle mass, bone density, and insulin sensitivity [1,2,4]. Moreover, exercise influences neuroplasticity, with cognitive benefits observed in individuals engaging in routine physical activity. The role of exercise in enhancing mitochondrial function, promoting anti-inflammatory responses, and modulating hormonal profiles underscores its significance within lifestyle medicine.

3.3. Stress Management and Psychological Health

Psychological well-being is intrinsically linked to physical health. Stress management techniques such as mindfulness, meditation, and relaxation exercises are recognized for their capacity to mitigate the detrimental effects of chronic stress on immune function, cardiovascular health, and neuroendocrine systems. Mind-body interventions have demonstrated measurable effects on stress

hormone levels, neurotransmitter balance, and autonomic nervous system regulation, affirming their relevance in lifestyle medicine interventions [2,4,5].

3.4. Weight Management and Metabolic Health

Addressing weight-related concerns is pivotal in preventing and managing metabolic disorders. Lifestyle medicine advocates for sustainable weight loss strategies grounded in caloric balance, nutrient-dense food choices, and increased physical activity. Evidence supports the efficacy of behaviour modification interventions in promoting lasting weight reduction, with emphasis on setting realistic goals, monitoring progress, and cultivating intrinsic motivation [2,4].

3.5. Social Connections and Community Engagement

A growing body of research underscores the health benefits of social connections and community engagement. Robust social networks contribute to emotional resilience, reduced risk of mental health disorders, and improved cardiovascular outcomes. Lifestyle medicine interventions leverage the potential of group-based programs, highlighting the synergistic effects of social support in fostering adherence to healthy behaviours and sustaining positive lifestyle changes [2,4].

3.6. Personalization and Holistic Approach

Central to lifestyle medicine is the recognition of individualized interventions tailored to unique needs, preferences, and cultural backgrounds. Personalized approaches acknowledge the intricate interplay between genetic predisposition and lifestyle factors, emphasizing the importance of patient-centered care. A holistic perspective acknowledges the interconnectedness of physical, mental, and emotional well-being, promoting a comprehensive understanding of health that extends beyond disease prevention to encompass overall vitality [2,4].

4. INTEGRATING LIFESTYLE PRACTICES INTO MEDICAL CARE

In recent years, the integration of lifestyle practices into medical care has gained prominence as a transformative approach to health management. This paradigm shift recognizes that addressing the complex interplay between individual behaviours, environmental factors, and disease risk can significantly impact patient outcomes. By bridging the gap between conventional medical interventions and proactive lifestyle modifications, this integration holds the potential to revolutionize healthcare delivery and improve overall population health [6,7].

4.1. Rationale for Integration

Traditional medical models often focus on reactive interventions targeting specific diseases or symptoms. However, an increasing body of evidence highlights the pivotal role that lifestyle factors play in disease prevention, progression, and even treatment response. Lifestyle practices encompass a spectrum of behaviours, including nutrition, physical activity, stress management, sleep hygiene, and substance use, that collectively influence physiological processes and health trajectories. Recognizing this intricate relationship, healthcare systems are embracing a more holistic approach that encompasses lifestyle medicine as an integral component of patient care [6].

4.2. Benefits and Impact

The integration of lifestyle practices into medical care offers a range of benefits that extend beyond disease management. By empowering patients to take an active role in their health journey, this approach fosters a sense of agency and autonomy, leading to higher adherence rates and sustainable behavioral changes. Moreover, comprehensive lifestyle interventions have been shown to address multiple risk factors simultaneously, yielding synergistic effects on health outcomes. For instance,

lifestyle modifications can enhance medication efficacy, reduce the need for pharmaceutical interventions, and minimize the occurrence of adverse events. Additionally, the incorporation of lifestyle medicine aligns with the principles of patient-centered care, emphasizing personalized strategies that resonate with individual preferences and cultural contexts [6,7,8].

4.3. Clinical Implementation and Challenges

Integrating lifestyle practices into medical care requires a multidisciplinary collaboration among healthcare providers, including physicians, dietitians, physical therapists, psychologists, and nurses. This collaborative approach enables the development of tailored interventions that encompass diverse aspects of a patient's life. However, challenges arise in terms of time constraints within clinical encounters and the need for comprehensive training for healthcare professionals to effectively guide patients through behavior change. Overcoming these obstacles necessitates innovative strategies such as telehealth platforms, wearable technology, and group-based interventions that extend patient-provider interactions beyond the clinic walls [8,9].

4.4. Shifting Healthcare Culture

The integration of lifestyle practices into medical care necessitates a cultural shift within healthcare systems. Education and training must emphasize the significance of lifestyle factors, equipping medical professionals with the knowledge and skills to engage patients in meaningful conversations about behavior change [1,2,9]. Additionally, reimbursement structures should evolve to incentivize preventive measures and lifestyle interventions, reflecting their potential to mitigate the long-term burden of chronic diseases. The integration of lifestyle practices into medical care heralds a new era of healthcare delivery characterized by proactive, holistic, and patient-centered approaches [10,11]. By recognizing the interconnectedness of lifestyle choices and health outcomes, this paradigm shift has the potential to enhance preventive strategies, optimize treatment efficacy, and ultimately elevate the overall well-being of individuals and communities. As healthcare systems navigate this transition, collaboration among healthcare providers, policymakers, and patients is crucial to realize the transformative impact of lifestyle medicine on the landscape of modern medicine.

5. TRANSFORMING MEDICAL CULTURE TO PRIORITIZE LIFESTYLE EDUCATION

To transform medical culture to prioritize lifestyle education, a multifaceted approach is essential. One key aspect involves incorporating comprehensive lifestyle medicine education into medical school curricula and continuing education programs for healthcare professionals. By ensuring that both current and future practitioners are well-versed in the significance of lifestyle factors in health outcomes, a solid foundation is laid for the integration of lifestyle education [8,9]. Equally important is the development of evidence-based clinical guidelines that underscore the importance of lifestyle interventions alongside traditional medical treatments [11]. These guidelines can serve as a point of reference for healthcare practitioners when addressing patient needs. Interdisciplinary collaboration is another critical element. Encouraging teamwork among healthcare providers, including physicians, nutritionists, psychologists, and physical therapists, ensures that patients receive holistic and well-rounded care that takes into account various aspects of their well-being. Adopting a patient-centered approach is vital [2]. This entails involving patients in decision-making and goal-setting regarding their lifestyle choices, empowering them to be active participants in their health journey. To effectively guide patients toward making sustainable lifestyle changes, healthcare providers should also receive training in behavior change techniques and motivational interviewing. Institutional support is equally crucial. Healthcare institutions must provide the necessary resources, tools, and time for healthcare providers to engage in meaningful discussions with patients about lifestyle choices. Public awareness campaigns play a role in educating individuals about the role of diet, exercise, stress management, and other lifestyle elements in preventing and managing chronic

diseases [2,11]. Modifying reimbursement structures can incentivize healthcare providers to incorporate lifestyle interventions into their practice, acknowledging the value of addressing lifestyle factors. Robust research that highlights the impact of lifestyle interventions on health outcomes is paramount, reinforcing the importance of lifestyle education within the medical culture [11]. Leadership and advocacy within the medical community are powerful drivers of change. Encouraging influential figures to champion the integration of lifestyle education can lead to policy shifts and cultural transformations within healthcare institutions. Regular assessment and refinement of strategies are necessary as new research emerges and best practices evolve. Through this concerted effort, the medical culture can undergo a transformative shift, placing lifestyle education at the forefront. This approach ultimately leads to improved patient outcomes, elevated quality of care, and a more comprehensive understanding of health that extends beyond conventional medical paradigms.

6. MULTIDISCIPLINARY COLLABORATIONS IN THE CONTEXT OF LIFESTYLE PRACTICES

Multidisciplinary collaborations in the context of lifestyle practices extend beyond healthcare and can encompass various sectors to create comprehensive and impactful approaches to well-being. Some examples include the following [1,2,7,11]. Collaborations between educators, psychologists, nutritionists, and physical activity experts can lead to the development of comprehensive wellness programs for schools and universities. These programs can address students' physical and mental well-being through educational initiatives, stress management techniques, physical activity promotion, and healthy eating campaigns. Bringing together professionals from human resources, nutrition, fitness, and mental health fields can result in workplace wellness programs [12]. These programs focus on creating healthier work environments through initiatives such as ergonomic improvements, stress reduction workshops, healthy cafeteria options, and physical activity incentives. Collaboration between technology developers, healthcare providers, and fitness experts can lead to the creation of wearable devices and health apps that provide personalized recommendations for nutrition, exercise, and stress management. These technologies can help individuals track their progress and make informed lifestyle choices. Urban planners, architects, public health experts, and policymakers can collaborate to design cities and communities that promote physical activity, access to healthy food, and green spaces. This approach aims to create environments that naturally encourage healthier lifestyle choices [13].

Collaboration between chefs, nutritionists, and culinary experts can result in the development of culinary programs that focus on preparing nutritious meals that are also delicious [14]. These programs can be integrated into schools, restaurants, and community centers to promote healthy eating habits. Collaboration between social workers, healthcare providers, and community organizations can lead to programs that address social determinants of health, such as access to housing, food, and transportation. These collaborations aim to improve overall well-being by addressing broader societal factors [12]. Partnerships between fitness professionals, entertainment venues, and media outlets can promote active lifestyles through events, TV shows, and interactive experiences that encourage physical activity while providing entertainment. Collaboration between museums, cultural centers, and health experts can result in initiatives that combine cultural experiences with health promotion. Exhibits, workshops, and events can highlight the connections between cultural engagement and overall well-being. Collaboration between environmental scientists, health experts, and policymakers can result in initiatives that promote sustainable practices for the benefit of both human health and the environment [15]. Encouraging activities like walking or biking instead of driving can have positive effects on both personal health and the planet. Collaboration between farmers, nutritionists, and policymakers can result in initiatives that promote locally sourced, fresh produce and educate communities about the benefits of seasonal eating and sustainable agriculture. These multidisciplinary collaborations acknowledge that health and well-being are influenced by a wide range of factors and environments, and by working together across sectors, we can create more holistic and effective approaches to promoting healthier lifestyles.

7. CONCLUSION

Lifestyle medicine embodies a holistic approach to health by incorporating evidence-based practices that enhance well-being through behavior modifications. Integrating lifestyle practices into healthcare aligns with patient-centered and preventive approaches, with the potential to improve treatment outcomes. While the adoption of lifestyle goals varies, progress through information and tools signifies a promising path forward. As this integration advances, patient outcomes will likely improve, expanding the definition of health beyond traditional medical confines.

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ENVIRONMENT AND SUSTAINABLE DEVELOPMENT. MECHATRONICS. OCCUPATIONAL SAFETY AND HEALTH AND FIRE SAFETY. SMART MANAGEMENT SYSTEMS. GRAPHIC ENGINEERING. DESIGN. TRAFFIC ENGINEERING. BIOTECHNOLOGY AND HEALTHCARE. MECHANICAL ENGINEERING. ECOTOURISM AND RURAL DEVELOPMENT.

COMPLICATIONS OF PERTUSSIS INFECTION IN NEONATE: A CASE REPORT

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***Abstract**: Pertussis can cause serious and sometimes deadly complications in babies and young children. Babies who have not had all recommended pertussis vaccines are more likely to get serious complications. About one third of babies younger than one year old who get whooping cough need care in the hospital. Of those babies about: 68% will have apnea (life-threating pauses in breathing), 22% get pneumonia, 2% will have convulsions, 0,6% encephalopathy, and 1% will die. Case presentation: Neonates and infants are more likely to develop severe pertussis. The authors report a malignant pertussis case in not vaccinated 23-days-old girl with respiratory failure, severe pneumonia and convulsions. Bordetella pertussis was detected from nasopharyngeal secretions by polymerase chain reaction. The child was treated for 6 weeks in the neonatal intensive care unit, either on mechanical ventilation, then depending on additional oxygen. The patients symptoms completely resolved after 8 weeks.*
Keywords: pertussis, complications, neonate, pneumonia

1. BACKGROUND

Pertussis, commonly known as whooping cough is highly contagious acute respiratory illness caused by Bordetella pertussis. Pertussis usually starts as an undifferentiated respiratory syndrome and, than, progresses to produce severe and paroxysmal attacks of “whooping” cough. Vomiting, cyanosis and apnea can occur as a result of these episodes of cough and, in infants and young children, complications have been described and may be life threatening, as impaired cerebral oxygenation may occur [1].
Therefore, effective vaccines against pertussis have been developed and have been included in national immunization programmes worldwide for several decades. The first dose of vaccine is at the age of 3 months, according to the Serbian immunisation schedule.
A precise estimate of the burden of pertussis is difficult, as under-recognition and/or under-reporting probably occur, as physicians, including pediatricians, have not been used to deal with such a disease in children for a long time [2]. Here, authors report the clinical case of a unvaccinated neonate diagnosed with pertussis.

2. CASE PRESENTATION

A 23-days-old girl was admitted to the Pediatric Department on the request of her general pediatrician, because of 5-6 days lasting cough, with cyanosis during of some episodes, fever (37.8C) and malaise on the day of admission. On admission the patients body temperature was

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37.3C, heart rate was 156 beats per minute, respiratory rate was 64 breaths per minute, the oxygen saturation was 92% on room air. She presented with puffy nose, pharynx was slightly injected. Pulmonary auscultation presented diffuse crakles. The rest of the physical examination was unremarkable. The blood analysis revealed an increased peripheral white blood cell count (24.8, than $46.5x10^9$) with lymphocitosis (67.3, than 48.6%) and a normal biochemistry, including normal C-reactive protein. The chest radiography showed a reinforcement of the perihilar bronchovascular reticulum and heterogeneus infiltrates on the inferior third of right lung. Echocardiography revealed no abnormalities. At this point, the differential diagnosis included viral respiratory infection and pertussis. The patient received azithromycin per os, inhalation of fenoterol/ipratropium-bromide and budesonide. On Day 3 of hospitalization, the patient worsened, developed more frequent paroxysms-rapid, violent and uncontrolled coughing fits, apnea and crises of cyanosis. Oxygen saturation dropped to 82% on room air. Patient developed a GTC convulsion that lasted about one minute and stopped spontaneosly. The patient was referred to a University clinic on the Day 3 for further diagnosis and treatment. On admission to the clinic patient was febrile (38.8C), tachypneic (50/min), with retraction of the intercostal spaces, tachycardic (150/min), the oxygen saturation was 92% on room air. The blood analysis revealed an increased peripheral white blood cell count ($65.14x10^9$) with lymphocitosis (45%), and a normal biochemistry, including normal C-reactive protein. The chest radiography showed homogeneosly reduced transparency of the upper right lobe; the left lung as a whole had reduced tranparency.
Bordetella pertussis was detected from nasopharyngeal secretions by polymerase chain reaction. Nasopharyngeal aspirate for RSV was negative. A bronchoscopy was performed, during which a large amount of secretion was aspirated. Fiber aspirate was sterile. Blood culture was sterile. Parenteral antibiotic therapy with ampicillin, amikacin and azithromycin was applied. On Day 3 of admission, during bronchoscopy, cyanosis and desaturation developed, for which the newborn was intubated and mechanical ventilation was started. In the further course, due to febrility and the increase in the laboratory parameters of the infection, the microbiological analyses were repeated and the antimicrobial therapy was corrected on two occasions. From 11^{th} day of admission, the child is afebrile, there is an improvement in the general condition and auscultatory findings over the lungs. On the eleventh day the patient was extubated, supplemental oxygen therapy via nasal cannula was continued. Application of inhaled bronchodilators and percussion drainage were continued. On the 35^{th} day of hospitalization the use of antimicrobial therapy and oxygen therapy was stopped. The child was discharged on the 40^{th} day after admission.

3. DISCUSSION

Such a short clinical report highlighted that the occurrence of pertussis must be suspected and investigated in infants presenting persistent cough, both in unvaccinated children in the first two months of life, and in children whose vaccination has not yet been completed. In addition to pointing the attention on a diagnosis of pertussis, this case report further raised the issue of modifying and/or implementing the immunisation strategy. Lowering the time points of the three vaccine doses during the first year of life could help to improve the coverage in infants, but it is nod enough, as evidenced by the model of disease prevalence provided by Bento et al in USA [3]. Indeed, an important window of susceptibility persists during the first year of life and, in particular, in the first two months, if the environmental circulation of the bacterium is not interrupted by minimizing also the number of susceptible adults, representing the weakest link in the “prevention chain”. However, pertussis can be mitigated and manifest through an atypical course of disease in infants, if the infection occurs when the immunisation schedule has started regularly, but not completed yet. [4,1]. It is well known that there is a lack

of long-term persistence of pertussis immunity after the completion of the scheduled immunisations in the pediatric age and, therefore, the protection against pertussis wanes if booster doses are not administrated every 10 years. Vaccination strategy which consists of immunising family members and close contacts of the neonate, and mothers prenatal vaccination should be proposed in order to reduce the risk of pertussis in neonates and younger infants [5].

4. CONCLUSIONS

Pertussis is a highly contagious disease that can have very serious complications, especially in unvaccinated newborns and incompletely vaccinated infants in the first year of life. Pediatricians should be aware of invasive B. pertussis infection and severe complications in children with pertussis. Also, it is necessary to consider a new vaccination strategy that would include mothers prenatal vaccination and immunising family members and persons who come into close contact with newborns.

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SPORT RELATED INJURIES IN BRAZILIAN JIU JITSU

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Abstract: *Brazilian jiu-jitsu (BJJ) is a combat sport which relies mostly on ground combat, emphasizing grappling skill over strength and submission over striking. Given the main goal of the BJJ fight, which is to "tap out" or submit sparring partner by a vast spectrum of different levers on the joints of the arms, legs, and spine, as well as applying suffocation and strangulation without striking, many injuries can occur among BJJ fighters. We conducted a study on 162 BJJ fighters from the BJJ club ViN in Belgrade, Serbia regarding sports related injury-specific information. We found that most common injuries related to BJJ are minor in severity and predominantly located in the extremities, e.g. legs and arms. Loss of consciousness is common injury, but usually without any consequences. The results are discussed with small literature review.*
Keywords: Brazilian jiu jitsu, sport injuries.

1. ITRODUCTION

Brazilian jiu-jitsu (BJJ) is a martial art and combat sport which relies mostly on ground combat, emphasizing grappling skill over strength and submission over striking. BJJ is based on grappling, ground fighting and submission holds. It was developed in the early 19th century and instantly gained popularity all over the world with the creation of the Ultimate Fighting Championship (UFC) in 1993 when Royce Gracie, a famous BJJ practitioner won the first two UFC tournaments [1]. BJJ is still evolving and growing as one of the best combat sports for professional athletes as well as for amateur practitioners. BJJ fighters wear a belt that denotes their skill and rank. The belts for people older than 16 years of age in increasing order are white, blue, purple, brown, and black. Belts graduation is dependent on skill and duration of BJJ practice. Combining belts, weight class and age, competition groups are formed for BJJ tournaments [2]. The first BJJ team in Serbia was founded by master Jovan Žerjal in 1997. Since then, BJJ community in Serbia is constantly rising.

Given the substantial variability in ranking, skill and age of BJJ practitioners, as well as main goal of the BJJ fight, which is to "tap out" or submit sparring partner by a vast spectrum of different levers on the joints of the arms, legs, and spine, as well as applying suffocation and strangulation without striking, many injuries can occur in this population if the rules of the fight are not respected, which mostly depends on the coach.

While other combat sports such as mixed martial arts (MMA), judo and wrestling have been the focus of many studies regarding injuries, BJJ has not received many attention [3, 4]. According to our knowledge, there is little research on injuries in BJJ community, manly focusing on injuries

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that occur during training sessions and no research regarding injuries sustained during BJJ-specific conditioning [5, 6]. Searching the internet and relevant medical databases, we did not find data on injuries among Serbian BJJ fighters and practitioners, even though it is now a relatively mass sport in this country with several thousand active practitioners. The main goal of this pilot study was to obtain and analyze basic data on sport related injuries among Serbian BJJ fighters, with the aim of better prevention of these injuries.

2. MATERIAL AND METHODS

The online survey was created to collect demographic and injury-specific information among Serbian BJJ fighters and practitioners. This survey was distributed to the 162 BJJ fighters from the BJJ club ViN in Belgrade. The study was approved by 5 coaches of the ViN team. The survey was anonymous in order to protect the health information and privacy of participants. Only athletes over the age of 18 were included, and regardless of a past injury history. Survey was conducted in January 2023. Basic demographic statistic was performed.
Basic demographic characteristics were collected about: age, gender, years of training, belt rang, weekly training schedule, weight class, and body mass index (BMI). Weight class was divided into standardized categories: feather, light, middle, heavy, medium heavy and super heavy. Injury-specific information were separated by "body parts" as follows: head, arm, leg, spine, other. Injury severity was self-assessed and classified as: no injury, minimal, moderate or severe injury. Explanation and example was given for each severity of injury (e.g. minimal – does not lead to an absence from training, like scratch; moderate – maximum of 2 weeks absence from training, like tendon stain; severe – over 2 weeks absence from training, like bone fracture). If the same BJJ fighter had several different injuries, he chosen only the most severe form of injury. Data on chronic diseases were also collected. As a dichotomous variable (yes/no), it was investigated whether a BJJ fighter ever lost consciousness after being choked or strangled. Similarly, the interviewed BJJ fighters answer the question whether they use protective equipment (yes/no) and what kind.

3. RESULTS

The results were obtained from 162 respondents in total. The majority of participants were male (n=146; 90,12%), while there was only 16 female BJJ fighters (9,88%). Regardless of gender, the average age was 28,58 years, ranging from 18 to 44. Since all fighters were from the same BJJ club, they all had same environment and training schedule with maximum of 10 training sessions per week. However, the majority of BJJ fighters (n=132; 81,48%) had 3 training sessions per week. About one third of BJJ fighters use protective equipment (n=61; 37,65%). The most common protective gear was a mouth guard which was worn by 45 BJJ fighters (27,7% of all fighters). Second most common protective equipment was crotch protector worn by 22 fighters (13,58%). Belt ranking is showed in the figure 1.

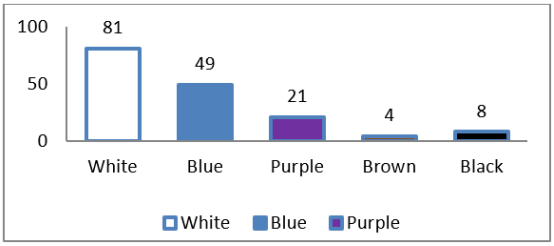

Figure 1. Belt ranking of all 162 BJJ fighters enrolled in the study.

Years of training are presented in the figure 2. This data are in linear connection with belt ranking.

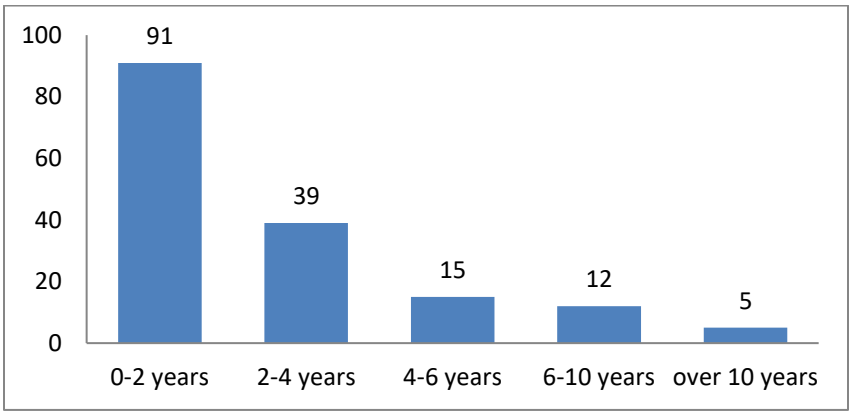

Figure 2. Years of training of all 162 BJJ fighters.

Body mass index as a measure of body fat indicated that majority of fighters had healthy weight with average body mass index (BMI) of 25,66. Weight class distribution of responders is showed in Table 1.

Table 1. Distribution of weight classes.

Weight class	Number	Percent (%)
Feather (≤62kg)	21	12,96
Light (62-69kg)	42	25,92
Middle (69-77kg)	36	22,22
Heavy (77-85kg)	22	13,58
Medium heavy (85-94kg)	28	17,28
Super heavy (≥94kg)	13	8,02

Data on which part of the body is injured are given in the figure 3.

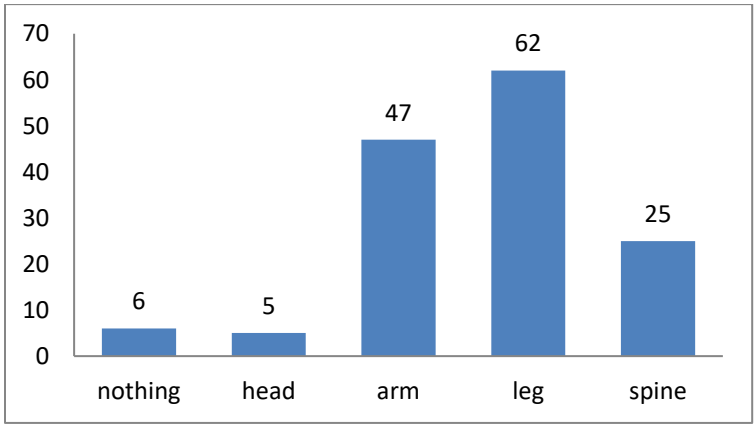

Figure 3. Injuries distribution concerning body parts.

The severity of injuries suffered by BJJ fighters during training or competition according to their own assessment, but after giving them above mentioned explanation and example of all types of injuries is shown in the figure 4.

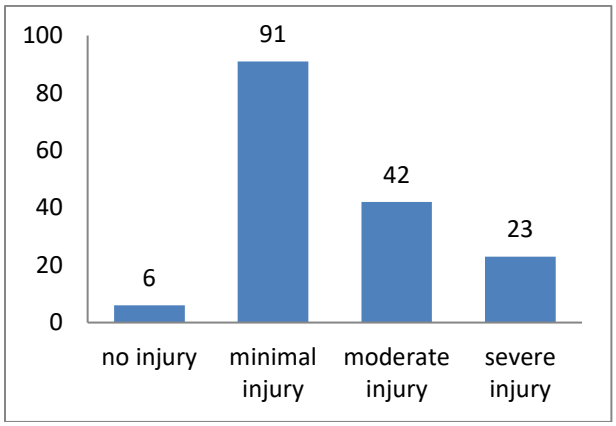

Figure 4. The severity of injuries in BJJ fighter from the study.

As a specific form of injury, lost of consciousness that can be consequence of applied choke or strangulation was also investigated, and results show that 35 BJJ fighters have lost consciousness (22%), and 127 BJJ fighters or 78% have not had a loss of consciousness.
Medical data on chronic diseases was collected for another pilot study, but since it can have influence on sport related injuries it was questioned whether BJJ fighters have or does not have chronic medical conditions. Results show that majority of BJJ fighters are chronic disease free, and only 7 out of 162 BJJ fighters have chronic medical conditions or 4,32%.

4. DISCUSSION

Brazilian jiu-jitsu (BJJ) is rapidly becoming a widely popular sport, with an estimation of nearly 3 million fighters worldwide [7]. Despite this, there is a paucity of literature investigating the injury profile of BJJ fighters during training or competition. Recently Hunker et al. and Petrisor et al. conducted studies about this topic [7, 8]. According to our knowledge, our study is first study of sports injuries in BJJ fighters in Serbia population, which now has several thousands practitioners. The average age of BJJ fighters in our study was 28,58 years, ranging from 18 to 44 years. This findings are in accordance with results of similar studies such as study of McDonald et al. in which an average age of BJJ practitioners was 30.3 years ranging from 18 to 55 years. This is the expected result considering that no minors were included in the study, as well as the fact that BJJ is a sport that is mostly practiced by young healthy people. This is supported by the fact that more than 95% of our fighters did not had any chronical medical condition. Our study showed male predominance of BJJ fighters, which is in accordance with similar studies [5]. Results obtained in our survey show that all demographic data, such as age, gender, years of training, belt rang, weekly training schedule, weight class, and body mass index (BMI) are similar to other studies with same goal of investigation [7-10].
However, since BJJ is a grappling-based martial art whose central goal is the skill of controlling a resisting opponent in ways that force him to submit or “tap-out” without using striking, but rather controlling opponents body or applying different techniques of strangulation, choking and using levers on the different body joints, a certain number of sports injuries is expected, but with the help of well-educated coaches it must be minimized. Examples of the most common techniques used in BJJ are given in the picture 1.

Picture 1. Most common techniques used in BJJ. (A) Choking that can lead to neck muscle injury or loss of consciousness if the opponent does not submit in time or the trainer/referee does not stop the fight. (B) A lever on the leg ("toe hold") that can lead to a sprained ankle if the fight is not stopped in time. (C) Suffocation ("rear naked choke – RNC") which may lead to loss of consciousness. (D) lever on the arm ("armbar") that can cause a elbow fracture if not stopped in time.

Recent studies show that more then 90% of BJJ practitioners suffered at least one injury during training or competition, but all studies show that injuries are much more common during training period then in competition, and this figure appears to be consistent with the studies available for other types of combat sports such as taekwondo, karate, and judo [5, 9]. In our study only 6 BJJ fighter out of 162 had no injury during training. Likely, most of the injuries were minimal, and did not require medical assistance or absence from training (91 BJJ fighter or 56,17%). On the other hand, 65 BJJ fighters from our study had moderate (n=42 or 25,92%) or severe (n=23 or 14,19%) injury which required medical assistance or intervention or absence from training due to recovery. In Hunker et al study, 91% of fighter had some kind of injury during training, and nearly two-thirds of those fighters required some form of medical intervention. In our study similar finding were obtained, with 40,15% of BJJ fighters having some sort of injury that required medical attention.
Literature review showed that most commonly affected locations of injury in BJJ practitioners included the hand and fingers (37% of injuries), and on the second place is led or knee. In a 2014 research by Scoggin et al. use of the leaver on the arm during competition was the most common mechanism of injury, leading to elbow injury [7]. Similarly, McDonald et al. found arm injuries to occur most frequently during competition [5]. Hunker at al also showed that injury type and location of injury vary in incidence by setting, e.g. out of the 11 reported neck injuries, all occurred in training whereas, of the 12 reported arm injuries, only 58.3% occurred in training with the remaining injuries occurring during competition [7]. The neck represents a particularly vulnerable area of injury and literature results show that 90% of injuries to the neck require a break in training and 70% of those disruptions in training lasted longer than two weeks [7]. In our study most frequent injuries were located in the leg and arm with a combined frequency of 67,28%, with slight predominance of leg injuries.
In the study about the safety of sportive chokes, conducted on 4307 BJJ fighters, 1443 (33.5%) reported being choked over 500 times during training, 3257 (75.7%) have been choked to near-syncope, and 1198 (27.8%) have been choked unconscious. Only 2 fighters of the 4307 (0.05%) reported ongoing symptoms from chokes 24 hours after training and which were likely not related to ischemia of the brain [11]. In our study lost of consciousness that can be consequence of applied

choke was positive in 35 BJJ fighters or 22% which is similarly to mentioned results of Stellpflug et al. Likely, no fighters had prolonged symptoms or complications due to applied choke leading to loos of consciousness.

Although injuries in BJJ are relatively common, most injuries are of minimal severity and do not require time off training or medical attention. The role of the coach in the club, i.e. the referee at the competition, is especially important in order to stop the fight in time. Also, the use of protective equipment significantly reduces the possibility of injuries.

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MECHANICAL ENGINEERING

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ENERGY SAVINGS AND CO_2 EMISSION REDUCTION POTENTIAL THROUGH THE EXISTING BUILDING RENOVATION

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Abstract: *The Republic of Serbia has more than 2.2 millions of buildings built before 2011. when the Rulebook on energy efficiency of buildings was adopted. Which further implies that more than 289 millions of square meters of dwellings in Serbia have lower thermal envelop properties than it is recommended and thus much higher energy consumption for heating than it is the case in new buildings. This makes an opportunity for deep building renovation of Serbian building stock and potential energy savings. In this manner, it is possible to save up to 6.76·10^9 kWh/a of energy for heating yearly just by the renovation of the existing building stock built in a period from 1971-1980. If this calculation is extended to all Serbian dwellings, it is possible to save up to 2.68·10^10 kWh/a of final energy for heating yearly. Similarly, CO_2 emission reduction for the existing buildings can be accomplished up to 40% just by the refurbishment of the building envelope.*
Keywords: Deep Building Renovation, Energy Savings, CO_2 Emission Reduction, Existing Building Stock

1. INTRODUCTION

It is considered that building sector is the one of the biggest energy consumers in the European Union (EU), using about 40% of total energy consumption and 36% of global greenhouse gas emissions [1]. More, it is considered that about 75% of buildings in EU is energy inefficient, so the European Commission proposed a revision of Directive on Energy performance of buildings 2018/844 [2] in 2021. Further, new targets by 2050 include achieving zero-emission and full decarbonisation of building stock. Being at the road for accession to the EU, Serbia is following the European goals in building energy performances as well and prepares a long-term strategy for deep building stock renovation. Currently, there is no unique deep building renovation integrated strategy towards Directive's goals, but different single attempts such as: renovation of existing facades by adding internal or external insulation, windows replacement, roof renovation, replacement of heat sources etc [3]. Thus, the long term strategy for integrated and planed deep building renovation is mandatory in order to decrease building energy consumption and global greenhouse gas emissions.

1.1 Energy sources used in households in Serbia and worldwide

According to the data obtained through the research of the Statistical Office of the Republic of Serbia, the most commonly used fuel for heating in the Republic of Serbia is wood and wooden biomass, with a share of 48%, followed by district heating in a percentage of 20.7%, electrical energy 14.6%, natural gas 10%, coal 4.6% and the rest of the share goes on LPG, geothermal energy, fuel oil and other types of biomass [4]. On the other hand, in the EU, the biggest share of fuels in final energy consumption in households in 2021 goes on natural gas 33%, then electricity 25%, followed by renewables and biofuels with a share of 21% (Fig. 1) [5]. Looking at the USA energy consumption, it varies within the different countries due to the different climate conditions, but in overall, according

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to the data from the year 2020, the most used fuel in new housing was natural gas with a share of 55%, followed by electricity with 45% and the rest of 1% goes on all other fuels [5].

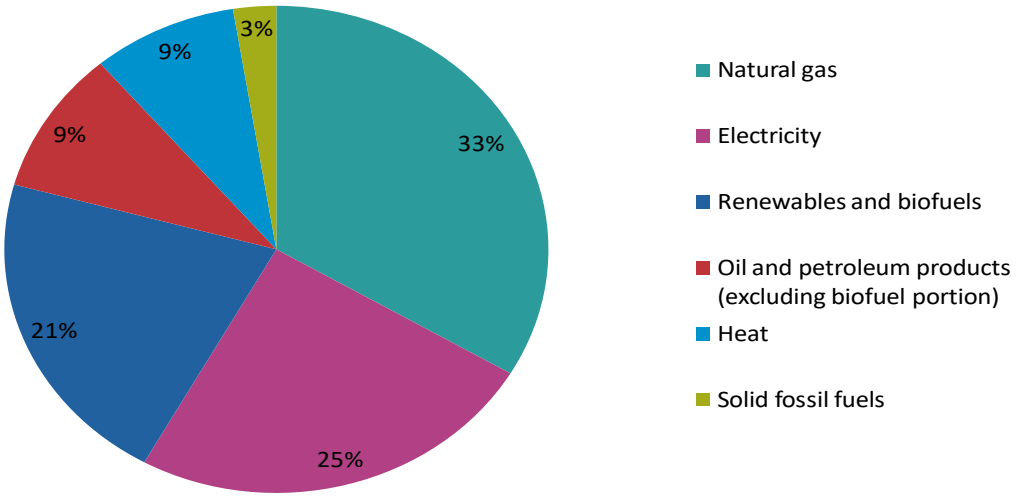

Figure 1. The share of fuels in final energy consumption in households in EU in 2021
Source: Eurostat [5]

The shares of fuels in the final energy consumption in the residential sector for space heating for 2020 for various countries are shown in Figure 2. It can be noted that the countries which are using the large quantities of wood for heating are considered to use a renewable energy sources, which could be discussed from the various points. For example, it is considered that the wood is a biomass, but on the other hand, it should be precisely defined by the legislation which type of wood can be used for heating purposes, since some of the developing countries do not have a defined strategies for planed timber harvests. More precisely, looking at the conversion factors for calculations of primary energy needs for heating in Rulebook of energy efficiency of buildings [6] for biomass for example for the Republic of Serbia, it can be seen that the all types of biomass has the same conversion factor 0.1. Obviously, it is necessary to reconsider this and introduce some weight factors which give a higher value to the biomass obtained as a waste from the wooden industry production, agriculture and fast growing seedlings. In this manner, it is possible to define a better strategy for future fuels usage for the heating purposes in households.

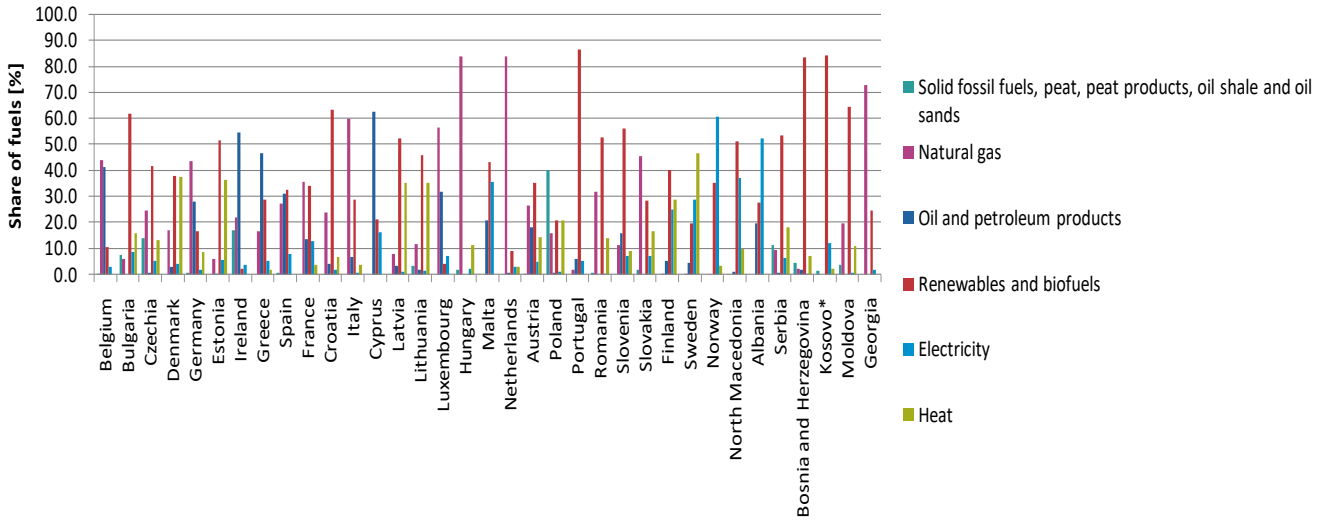

Figure 2. The share of fuels in the final energy consumption in the residential sector for space heating for 2020 ((*) This designation is without prejudice to positions on status, and is in line with UNSCR 1244.)
Source: Eurostat [5]

2. ANALYSIS OF EXISTING BUILIDNG STOCK IN THE REPUBLIC OF SERBIA.

According to the literature [7], there are more than 289 millions of square meters of dwellings in Serbia built before 2011, when the Rulebook on energy efficiency of buildings was adopted. A modest part of old building stock was under some type of the reconstruction, either the insulation was added or windows were replaced, but a large number of buildings still has the same thermal properties as when they were built. Looking at the period of last 20 years, 64% of Serbian inhabitants live in households which are not renovated. If the partial renovation was conducted, usually it was windows replacement with a share of 66,7% in existing buildings and adding the insulation in 47% [4].

If it is considered that more than 2.2 millions of buildings in Serbia are build before 2011, it is obvious that there is a large potential of building stock renovation. The share of number of buildings built before 2011 by the year of construction in Serbia is given in Figure 3. It can be noted that about 12% of buildings were built before the Second World War, while all the other buildings were built in a period after 1945, with the biggest share of buildings built in a period from 1971-1980.

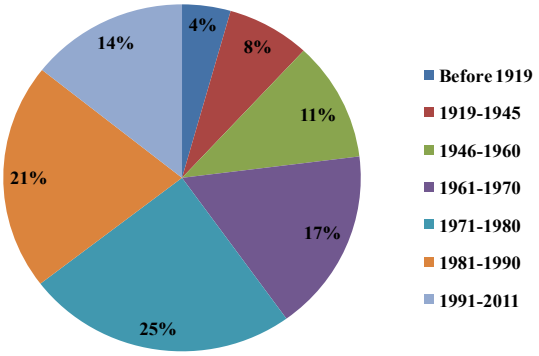

Figure 3. The share of buildings by the year of construction
Source: National Typology of Residential Buildings in Serbia [7]

The typical U-values for external walls and windows for existing building stock is given in Table 1.

Table 1. The typical U-values for external walls and windows for existing building stock
Source: [7]

Year of construction	Type of dwelling	Type of element	U-value
Before 1919	Free-standing residential building	External wall	1.12
		Windows	3.5
From 1919 to 1945	Free-standing residential building	External wall	1.67
		Windows	3.5
From 1946 to 1960	Free-standing residential, Residential buildings-lamella, Residential buildings in row	External wall	1.26
		Windows	3.5
From 1961 to 1970	Free-standing residential building	External wall	3.31
	Residential building – lamela	External wall	1.74
	Residential building in a row	External wall	1.26
		Windows	3.5
From 1971 to 1980	Free-standing residential building	External wall	1.68
		Windows	3.3

Comparing these U-values from the Table 1. to the maximum allowed values from the actual Rulebook on the energy efficiency of buildings [6], it is obvious that values for the existing buildings built before 2011 are far away from the prescribed ones.

3. POTENTIALS FOR THE ENERGY SAVINGS AND CO_2 EMISSIONS REDUCTION ON THE EXAMPLES OF THE EXISTING BUILDINGS.

3.1 Example of the energy consumption of buildings from 1980s and possible savings.

Since the biggest percentage of buildings in Serbia was built in a period of 1971-1980 (Fig. 3), the example of energy consumption of such a type of buildings will be presented on a building of total heating area about 2690 m^2 and climate conditions of Belgrade, the capital of Serbia. As a typical representative of these type of buildings, the thermal envelope layers are adopted according to the literature [7] and U-values are calculated and shown in Table 2.

Table 2. U-values for thermal envelop of the example building before the refurbishment
Source: [8]

Type of the envelope element	U-value [W/(m2K)
External wall	1.74
Ceiling	1.66
Internal wall	1.61
Windows and balcony doors	3.3
Floor construction	0.56

According to the U-values and methodology of calculation of building energy needs for heating prescribed in a Rulebook on energy efficiency of buildings [6], the final, delivered and primary energy needs are calculated and given in [8]. Using these data, the calculation was done per square meter of heated area before the reconstruction and with the various possibilities of energy efficiency improvement (Figure 4).

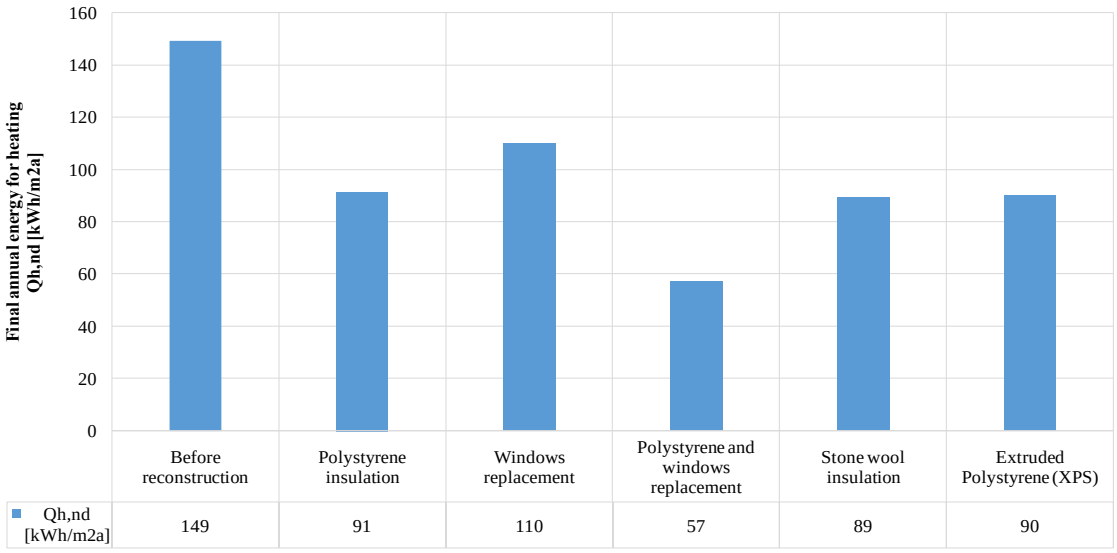

Figure 4. Final annual energy needs for heating per square meter for example building before and after renovation

Further, the analysed options from the energy point of view took into a consideration following measures: insulation of thermal envelope with polystyrene to fulfil the requirements from the Rulebook for existing buildings renovation, then windows replacement, combination of these two measures, insulation of thermal envelope with stone wool and insulation of thermal envelope with extruded polystyrene. The results are shown in Figure 4 for final energy needs for heating per square meter for these five options of building renovation. From the results, it can be seen that the building renovation with polystyrene insulation of thermal envelope and windows replacement provides energy savings of 62% of final energy needs for heating of the building.

3.2 Example of the CO_2 emission of buildings from 1980s and possible emission reductions.

Similarly, if it is assumed that the heating is provided using electrical boiler, using electrical energy as a source for heating and domestic hot water preparation (DHW), the CO_2 emission can be calculated as well, with a respect to the methodology given in [6]. The results of the comparison before and after the various possibilities of building envelope renovations are shown in Figure 5.

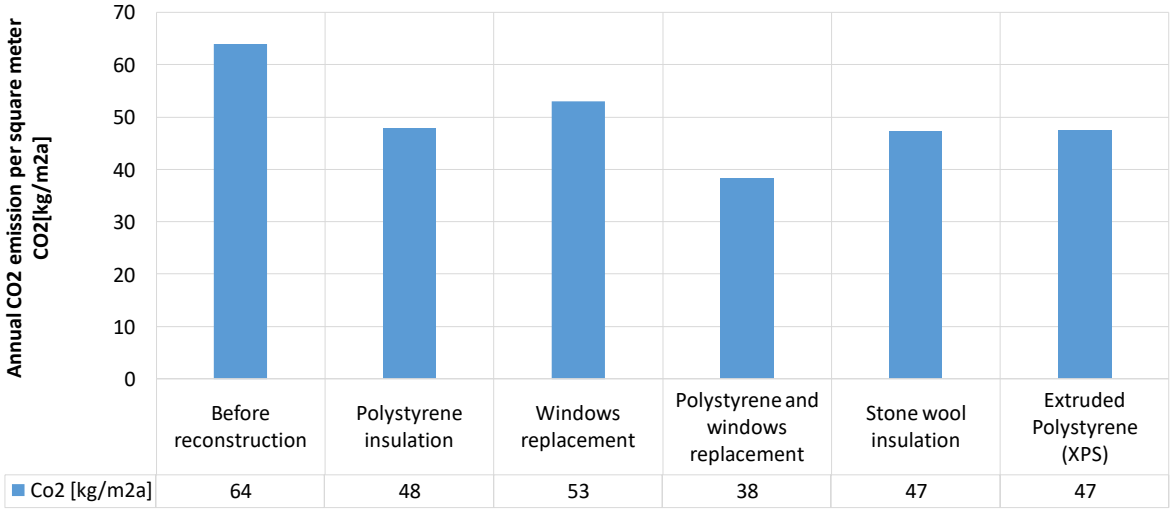

Figure 5. CO_2 emission per square meter for example building before and after renovation

If the deep renovation of thermal envelope is performed, it is possible to reduce up to 40% of CO_2 emission of the building for heating and DHW. This percentage can be even higher if the heating source is replaced as well. With other words, in the case of deep thermal envelope refurbishment and replacement of the electrical boiler with a boiler on biomass (conversion factor 0.1 is given in [6]), as well, it is possible to reduce up to 80% of CO_2 emission for heating needs of building.

3.3 Discussion on the potentials of energy savings and CO2 emission reduction.

Looking at the number of square meters of buildings 73173360 m^2 (25.26% of total square meters built before 2011) [7] built in a period from 1971-1980, and the results of final energy consumption per square meter showed in section 3.1., it is possible to calculate the overall final energy consumption of total building stock in Serbia built in this period. Further, if the overall final energy need for heating is 149 kWh/m^2a, the overall total final energy needs for heating of buildings in Serbia built in a period from 1971-1980 is 1.09·10^10 kWh/a yearly, which further implies with a possibility of 62% of the final energy savings for heating with renovation of thermal envelope (polystyrene insulation of thermal envelope and windows replacement), which is 6.76·10^9 kWh/a of saved energy yearly. Furthermore, looking at the characteristics of the thermal envelope of all buildings built before 2011 from the Table 1. it is notable that the overall values for windows are pretty much the same for all categories of buildings (U-value for windows is from 3.3. to 3.5 W/(m^2K)), while external wall values are in the range from 0.77-1.67 W/(m^2K). Moreover, if it is considered that all existing building stock needs before the refurbishment are about 149 kWh/m^2a of final energy for heating, multiplied by 289687720 m^2 of existing dwellings, gives 4.31·10^10 kWh/a yearly and if this dwellings are refurbishment as it is previously described, it is possible to save 2.68·10^10 kWh/a of final energy for heating yearly. Knowing that the prescribed maximum allowed amount of energy for new buildings heating by Rulebook on the conditions, content and manner of issuance of certificates of energy performance of buildings [9] is less than 65 kWh/m^2a, the saved amount of energy for heating is enough to fulfil the requirements of more than 4.12·10^8 square meters of new buildings in Serbia. Similarly, looking at the CO_2 emission from existing buildings obtained in Section 3.2. which is calculated based on assumption that the electricity is used for heating, and the share of used electricity

for heating in Serbia of 14.6%, it can be obtained that the 6.84·10^8 kg/a of CO_2 is emitted for buildings heating on electricity, built in a period from 1971-1980. This amount can be reduced to 2.73·10^8 kg/a of CO_2 just by the refurbishment of thermal envelope of this category of buildings.

CONCLUSION

This paper deals with a study of possibilities of refurbishment of the Serbian building stock and potential savings of energy and CO_2 reduction. The results are obtained based on the calculations for the example building, built in Belgrade in a period from 1971 to 1980, since the biggest share of existing buildings in Serbia (about 25%) was built in this period. Calculations showed that by reconstruction of all existing buildings built before 2011, adding the external insulation and replacing the external windows and doors could implies with 62% of final energy savings for heating in Serbia, which allows a more than 4.12·10^8 square meters of new buildings in Serbia to be heated on the same amount of energy that is currently wasted. Similar calculation showed potential in CO_2 emission reduction in between 40% to 80% depending on the type of refurbishment (only envelope or envelope and source). These figures implies with a huge potentials for energy savings and cleaner and more sustainable environment in the Republic of Serbia.

Acknowledgement: This research was supported by the Ministry of Science, Technological Development and Innovation of the Republic of Serbia [contract number 451-03-47/2023-01/ 200105 from 03.02.2023. year].

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INTERNATIONAL SCIENTIFIC AND PROFESSIONAL CONFERENCE
POLITEHNIKA 2023
Belgrade, 15th December 2023

ENVIRONMENT AND SUSTAINABLE DEVELOPMENT. MECHATRONICS. OCCUPATIONAL SAFETY AND HEALTH AND FIRE SAFETY. SMART MANAGEMENT SYSTEMS. GRAPHIC ENGINEERING. DESIGN. TRAFFIC ENGINEERING. BIOTECHNOLOGY AND HEALTHCARE. MECHANICAL ENGINEERING. ECOTOURISM AND RURAL DEVELOPMENT.

ANALYSIS OF REMEDIATION OF HORIZONTAL CYLINDRICAL TANK FOR OIL STORAGE

Marko Jarić[1], Innovation Centre of Faculty of Mechanical engineering in Belgrade

Abstract: *The paper deals with the problems related to the horizontal cylindrical tank with capacity 52m^3 for oil storage, which is in long time continual service. Before planned change of location necessary planned cleaning and inspection activities were performed. During inspection process cracks were observed in base metal and on internal side at reinforcement plates. Cracks were analysed and confirmed by detail visual and dye penetrant tests. Appropriate remediation documentation was prepared before starting of cracks excavation process. All cracks were fully removed which was confirmed by relevant NDT-tests. Repairing welding activities and appropriate NDE-examination tests after repairing welding process were performed. After successfully leak test, tank was transferred on the new location and put in service.*
Key words: Horizontal tank, Cracks, Suction, WPS

1. INTRODUCTION

Storage tanks are projected to operate with internal gas and vapour spaces at pressures close to atmospheric pressure and hence often they hold the name atmospheric tanks. Such tanks are usually made from carbon steel, alloy steel, aluminium or other metal depending on service. Also some tanks have been fabricated from non-metallic materials such as reinforced concrete, reinforced thermoset plastics and wood. Nowadays some wooden tanks, some riveted tanks and some bolted tanks can be found still in service.

Usually storage tanks in oil & gas (petroleum industry) are normally used for liquids having a true vapour pressure which is less than atmospheric pressure. Vapour pressure is the pressure on the surface of a confined liquid caused by the vapours of that liquid. Vapour pressure grows up with growing-up of temperature. Crude oil, heavy oils, gas oils furnace oils, naphtha, gasoline and non-volatile chemicals are usually stored in atmospheric storage tanks. Many of these tanks are protected by pressure-vacuum vents that limit the pressure difference between the tank vapour space and the outside atmosphere to a few ounces per square inch. Non-petroleum industry uses atmospheric tanks include storage of a variety of chemicals and other substances operated in closed-loop systems not vented to atmosphere and with pressure control and relief devices as required. These tanks may be designed and operated as low-pressure storage tanks. Additional uses for atmospheric storage tanks can include liquid (both hydrocarbon and non-hydrocarbon) storage in horizontal vessels, storage of process liquids or granular solids in skirt supported or column-supported tanks with elevated cone bottoms (non-flat bottom) and process water/liquids in open-top tanks.

In general exist many classifications of the storage tanks while the most common classification is classification according to their construction characteristics. According to this classification storage tanks can be classified into the following types: fixed cone roof tank, umbrella roof tank, geodesic dome roof tank, different constructions of storage tanks with floating roofs, tank with vapour dome

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roof, welded horizontal tank supported on saddles, figure 1, plan hemispheroids tanks, nodded hemispheroid tanks, plain spheroid tanks, plan hemispheroid tanks with knuckle radius and nodded spheroid tanks. Although welded horizontal tank supported on saddles are very often in long time service for oil storage critical places of cracks are not fully explored so the main goal of these paper will be analysis of the most critical places of formation and growth of cracks at these types of storage tanks [1,2]. Here should be mentioned that the horizontal tank, which was analysed in this paper, was made from carbon steel and it was capacity of $52m^3$ and that due planned plant modification its location was changed when was used opportunity for performing detail inspection on it.

Figure 1. Common construction of the horizontal tank which was supported on the saddles

2. DETERIORATION OF THE WELDED HORIZONTAL TANK SUPPORTED ON SADDLES DUE CORROSION

The prime cause of deterioration of the steel storage tanks and their accompanying equipment is corrosion. Locating and measuring the extent of corrosion is a major reason for storage tank examination. If left unchecked, tank deterioration can progressively lead to failure which may have adverse effects such as endangering personnel, environmental and property damage and business interruptions. Corrosion in general case can be divided on external corrosion and internal corrosion. On all external parts of a tank, atmospheric corrosion like a type of external corrosion can appear. The type of tank, construction details, and environmental conditions can all affect the location, extent and severity of external corrosion. For example a sulphurous, acidic or marine atmosphere can damage protective coatings and increase the rate of corrosion. External surfaces of the tank and auxiliary equipment if they are not protected with paint or other coatings where surfaces are in contact with moisture or the ground. Extended contact with water is likely to cause localized corrosion. Such susceptible areas should be protected with coatings designed to withstand long time immersion. Inspections should target areas where tank details cause water or sediment to accumulate. Beside external corrosion of tank shell, external corrosion of tank bottom can appear. The foundation material used for forming a pad that is directly in contact with the steel bottom plates may contain material that promote corrosion. For example, cinder may contain sulphur compounds that become very corrosive in the presence of moisture. The presence of clay, wood, gravel or crushed stone as contaminants in a sand pad may cause pitting corrosion at each point of contact. Faulty pad preparation or poor drainage may allow water to remain in contact with the tank bottom. If a tank previously leaked corrosive fluid through its bottom, accumulation of the fluid underneath the tank can cause external corrosion of the bottom plates. For tanks that are supported above grade, an improperly sealed ring wall may allow moisture to accumulate between the tank and the support, thereby accelerating corrosion. Asphalt-impregnated fibreboard is not a recommended sealant for tanks sitting on concrete ring wall foundations. The lower tank shell can become severely externally corroded near the grade line where soil movement has raised the grade level to cover the lower portion of the shell. External corrosion also occurs when insulation absorbs ground of surface water by wicking action, or when damaged or improperly sealed openings around nozzles and attachments allow water behind insulation.

Unlike of external corrosion internal corrosion in a storage tank depends on the contents of the tank and its materials of construction. Usually tanks which are using for storage crude oil and petroleum are made from carbon steel. Internal corrosion of these tanks in the vapour space can be caused by hydrogen sulphide vapour, water vapour, oxygen or any combination of these. In the areas in contact with the stored liquid, corrosion is commonly caused by acid salts, hydrogen sulphide or other sulphur compounds, dew point corrosion, or contaminated water that settles out and mixes with solids on the bottom of the tank, typically referred to as BS&W. Issues of SCC can be of particular concern when the product is known to be corrosive to welds and other heat-affected zones. Ethanol, di ethanolamine (DEA), and caustic products are just a few of the products that can be contribute to this condition when in contact with bare metal [1,3,4].

3. OTHER TYPE DETERIORATIONS OF THE WELDED HORIZONTAL TANKS

In the other types of deteriorations that most often appear at the tanks, include brittle fracture, leaks, cracks, mechanical deterioration and settlement of the equipment. The short explanations of these damage mechanisms will be show in the next lines.

Brittle fracture and sudden loses of the contents of a tank can result in injuries to personnel and extensive damage to equipment in surrounding areas. Pollution of streams or waterways can result when such a tank failure occurs near a waterway or is connected to one by a sewer or other flow channel. Probability of brittle fracture can be minimized by proper design, fabrication, operation and maintenance [5].

Leaks are primarily the result of corrosion but can occur at improperly welded or riveted joints, at pipe thread or gasket connections or cover plates, or at crack-like flaws (including arc strikes on plates) in welds or in plate material. Three-plate laps in lap-welded tank bottoms are particularly prone to defects that can lead to leaks. Cracks-like flaws can result from a number of causes including deficiencies in design, fabrication, and maintenance. The most likely points for crack-like flaws to occur are at the bottom-to-shell details, around nozzle connections, at manholes around river holes or around rivet heads, at welded brackets or supports and at weld seams. The lower shell-to-sketch plate or shell-to-bottom weld is especially critical because in relatively hot tanks there is a higher likelihood for this detail to develop a crack-like flaw due to high stresses. Potential for this occurrence can be minimized by the use of thicker, butt-welded annular bottom plates for higher design stress tanks and for larger elevated temperature tanks [1, 6, 7].

Many other type of mechanical deterioration can over the service life of a storage tank. If such deterioration is discovered, permit cost-effective maintenance and repair to be done on scheduled basis, the risk of failure. Examples of conditions that cause other types of mechanical deterioration can include severe service conditions like frequent fill/withdrawal cycling or elevated affecting the integrity of the shell-to-bottom weld, bulging, peaking, denting, overpressure, etc. [1,7].

Settlement of tank due to soil movement under the tank or tank foundation can also cause mechanical deterioration. Uniform settlement of the tank entire would not necessarily cause structural damage or be or be considered a serious issue. Large or uneven amounts of settlement can cause nozzles with attached piping to become overstressed and possibly deformed or cracked or interfere with nominal operation of a floating roof. Significant amounts of uneven settlement should be cause for concern and for further investigation. Edge settlement in tanks with cone-down bottom can trap BS&W, resulting in bottom and lower shell corrosion in this area. Soil and water can be retained against the external when such settlement is present [8,9].

4. ESTABLISHING OF INSPECTION PLANS

An inspection plan is often developed and implemented for tanks through the collaborative activities of the inspector, engineer, corrosion specialist, and operations personnel. An inspection plan should contain the inspection tasks, scope of inspection, and schedule required to monitor damage mechanisms and assure the mechanical integrity of the tank. Knowledge of the capabilities and

limitations of NDE techniques allow the proper choice of examination techniques(s) to identify particular damage mechanisms in specific locations. The plan should typically:

- define the type(s) of inspection needed, e.g. external, internal thickness measurements, NDE, associated piping, etc.;
- identify the regulatory intervals for seal or other component inspection needs, any applicable jurisdictional requirement, and the date for each inspection type;
- describe the inspection and NDE techniques, extent and locations;
- describe any surface cleaning requirements for needed for inspection and examinations;
- describe the requirements of any needed pressure of tightness test, e.g. type of test, test pressure and duration; and
- describe any required repairs.

Thus prepared inspection plans should consider information such as operating temperature ranges, process fluid corrosive contaminant levels, material of construction, tank design and configuration, service changes since the last inspection, and inspection/maintenance history. Ongoing communication with operating personnel when process changes or upsets occur that could affect damage mechanisms and rates are critical to keeping an inspection plan updated. Other common issues in an inspection plan include:

- describing the types damage mechanisms anticipated or experienced in the tank;
- defining the location of the damage;
- defining any special access requirements [10];

4. PLANNED CLEANING AND INSPECTION ACTIVITIES BEFORE TANK TRANSFERRING ON NEW LOCATION

Horizontal tank, which that presented in this paper, was long time in continual service in process plant and due planned modifications in the process after performed few surveys, and conducted discussions it was adopted new location and function of the previously mentioned tank. In addition, it was planned installation of the new ladders and new instrument equipment. Considering the previously facts before installation the tank on new location it was used opportunity for performing appropriate cleaning and inspection activities. On that occasion, it was conducted the following activities: preliminary visual inspection before cleaning process, full drainage of tank, venting, full inspection after cleaning process. Here should be mentioned that usually in all process plants preliminary inspection report and final inspection report should be prepared with that relevant department before put equipment in the service should approve final inspection report. In case of some repairing also repairing plans should be prepared and approved. Repairing plans should be mentioned in the final inspection report.

6. FINDINGS OBSERVED DURING FINAL INSPECTION

Full inspection was performed after finishing cleaning activities on the tank which was made from carbon steel and which capacity was $52m^3$. On that, occasion it were performed visual inspection of external and internal surfaces and ultrasonic thickness testing of metal elements such as penetrant tests of the suspected areas and weld joints. Here should be mentioned that focal points of the visual inspection were directed on the areas, which were considered as critically such as areas where tank was supported on the saddles, weld joints that connecting heads and shell welds around the nozzles [10]. On the other side ultrasonic thickness, testing was performed according to the relevant international standards in this area that are recommended measuring of thickness of metal elements in all four quadrants for the cylindrical part of the equipment while for the heads minimum one measuring point is recommended in the centre of the heads, figure 2. Penetrant tests were performed in the random basis and it was take into consideration of the connections between cylindrical shell and heads [11].

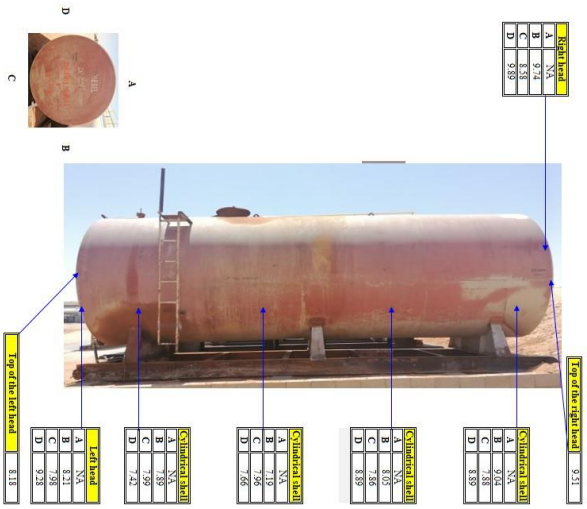


Figure 2. Scheme of performing ultrasonic thicknesses testing

During performed detail visual inspection of the interior of the tank, cracks observed at the area where tank has supported on the saddles, figure 3. Detected cracks also were confirmed by conducted additional penetrant test in these suspected areas.

Figure 3. Observed cracks in the suspected areas

Here should be mentioned that most of the cracks were individual while some cracks were found with branch.

7. PERFORMING OF REPAIR WELDING ACTIVITIES ON THE HORIZONTAL TANK

After detail examination of the tank and detecting defects (cracks) it was make a decision that before transferring the tank on new location and put in service its repairing should be detail performed. First step in repairing process is include removing of the all cracks from the tanks and performing adequate NDE examinations in sense of confirming that all cracks were fully removed, figure 4 and figure 5. Here should be mentioned that penetrant tests of affected areas in the tank were repeated up to the moment when it was established that cracks were fully removed. Also on assessable places together with penetrant tests, ultrasonic tests for defects were performed, [11].

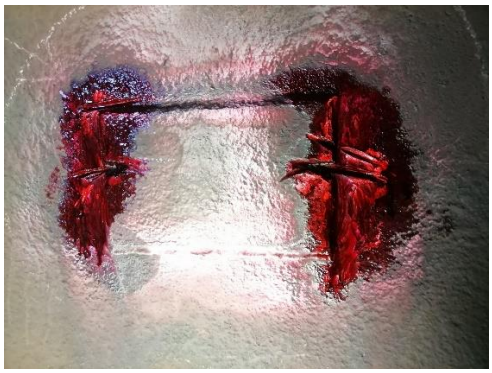


Figure 4. Penetrant tests for needs of confirmation of cracks removing-after spraying penetrant

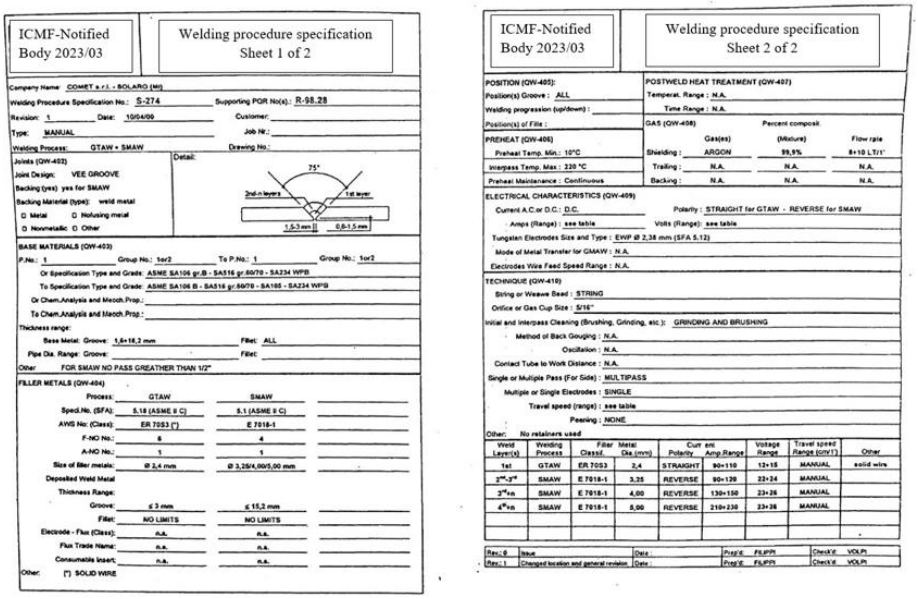
Second phase is including of providing skilled welders for needs of performing repair-welding activities and creating and approving welding procedure specification for needs of this activity [12]. Creating of WPSs is of exceptional meaning for integrity of apparatus and safety of workers, which are doing maintenance of apparatus during its required working life. This phase is usually carried out in one of two possible ways, either a suitable WPSs are created which are checked and approved, or it is provided appropriate approved WPSs (or standardized WPS-SWPS) from renowned Welding houses.

Figure 5. Penetrant tests for needs of confirmation of cracks removing-after spraying developer

For some urgent welding operation often is cheaper and more reliable buying of appropriate WPSs than preparing and approving of their own especially when fabrication companies does not have experienced Welding engineers especially trained for preparation specific WPSs and also when are requiring to performing of destructive examinations of welding samples for needs of qualifying these WPSs, [13,14].

For needs of sanation of this tank, appropriate approved WPSs have provided with GTAW+SMAW welding processes with direct current, figure 6. After finishing of repair welding activities detail visual inspection, penetrant test of the new fabricated weld joints was performed as well as leak test of the tank [10]. Hence visual inspection has performed by using visual inspection tools. Generally visual inspection was performed before, during and after finishing sanation activities [12].

Review of the performed activities has presented on the figure 7 below. Since finishing all repairing activities and inspection activities, the tank was transferred on the new position where has also been performed one more additional visual inspection in sense of avoiding possible damages which could produce be transferring process. Since finishing all repairing activities and inspection activities, the tank was transferred on the new position, where has been also performed one more additional visual inspection in sense of avoiding possible damages which could happen during transferring process. This additional inspection was shown that transferred was performed in a proper way. After that, it was started painting of this tank and it has put in service on the new location.


ICMF-Notified Body 2023/03

Welding procedure specification Sheet 1 of 2

Company Name: COMET s.r.l. - SOLARO (MI)

Welding Procedure Specification No.: S-274 Supporting PQR No(s).: R-98.28

Revision: 1 Date: 19/04/09 Customer:

Type: MANUAL Job Nr.:

Welding Process: GTAW + SMAW Drawing No.:

Joints (QW-402)

Joint Design: VEE GROOVE

Backing (yes) yes for SMAW

Backing Material (type): weld metal

☐ Metal ☐ Nofusing metal

☐ Nonmetallic ☐ Other:

Detail:

BASE MATERIALS (QW-403)

P.No.: 1 Group No.: 1or2 To P.No.: 1 Group No.: 1or2

Or Specification Type and Grade: ASME SA106 gr.B - SA516 gr.60/70 - SA234 WPB

To Specification Type and Grade: ASME SA106 B - SA516 gr.60/70 - SA105 - SA234 WPB

Or Chem.Analysis and Mech.Prop.:

To Chem.Analysis and Mech.Prop.:

Thickness range:

Base Metal: Groove: 1,6÷16,2 mm Fillet: ALL

Pipe Dia. Range: Groove: Fillet:

Other: FOR SMAW NO PASS GREATHER THAN 1/2"

FILLER METALS (QW-404)

Process:	GTAW	SMAW
Spec.No. (SFA):	5.18 (ASME II C)	5.1 (ASME II C)
AWS No. (Class):	ER 70S3 (*)	E 7018-1
F-NO No.:	6	4
A-NO No.:	1	1
Size of filler metals:	Ø 2,4 mm	Ø 3,25/4,00/5,00 mm
Deposited Weld Metal Thickness Range:		
Groove:	≤ 3 mm	≤ 15,2 mm
Fillet:	NO LIMITS	NO LIMITS
Electrode - Flux (Class):	n.a.	n.a.
Flux Trade Name:	n.a.	n.a.
Consumable Insert:	n.a.	n.a.

Other: (*) SOLID WIRE

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Welding procedure specification Sheet 2 of 2

POSITION (QW-405):

Position(s) Groove: ALL

Welding progression (up/down):

Position(s) of Fillet:

POSTWELD HEAT TREATMENT (QW-407)

Temperat. Range: N.A.

Time Range: N.A.

GAS (QW-408) Percent composit.

	Gas(es)	(Mixture)	Flow rate
Shielding:	ARGON	99,9%	8÷10 Lt/1'
Trailing:	N.A.	N.A.	N.A.
Backing:	N.A.	N.A.	N.A.

PREHEAT (QW-406)

Preheat Temp. Min.: 10°C

Interpass Temp. Max.: 220 °C

Preheat Maintenance: Continuous

ELECTRICAL CHARACTERISTICS (QW-409)

Current A.C.or D.C.: D.C. Polarity: STRAIGHT for GTAW - REVERSE for SMAW

Amps (Range): see table Volts (Range): see table

Tungsten Electrodes Size and Type: EWP Ø 2,38 mm (SFA 5.12)

Mode of Metal Transfer for GMAW: N.A.

Electrodes Wire Feed Speed Range: N.A.

TECHNIQUE (QW-410)

String or Weave Bead: STRING

Orifice or Gas Cup Size: 5/16"

Initial and Interpass Cleaning (Brushing, Grinding, etc.): GRINDING AND BRUSHING

Method of Back Gouging: N.A.

Oscillation: N.A.

Contact Tube to Work Distance: N.A.

Single or Multiple Pass (For Side): MULTIPASS

Multiple or Single Electrodes: SINGLE

Travel speed (range): see table

Peening: NONE

Other: No retainers used

Weld Layer(s)	Welding Process	Filler Classif.	Metal Dia.(mm)	Curr.ent Polarity	Curr.ent Amp.Range	Voltage Range	Travel speed Range (cm/1')	Other
1st	GTAW	ER 70S3	2,4	STRAIGHT	90÷110	12÷15	MANUAL	solid wire
2nd-3rd	SMAW	E 7018-1	3,25	REVERSE	90÷120	22÷24	MANUAL	
3rd+n	SMAW	E 7018-1	4,00	REVERSE	130÷150	23÷26	MANUAL	
4th+n	SMAW	E 7018-1	5,00	REVERSE	210÷230	23÷26	MANUAL	

Rev.:	Issue	Date:	Prep'd: FILIPPI	Check'd: VOLPI
Rev.: 1	Changed location and general revision	Date:	Prep'd: FILIPPI	Check'd: VOLPI

Figure 6. Used WPS for needs of sanation horizontal oil tank

Figure 7. Visual inspection, penetrant test and leak test after all repair welding activities

|**Figure 8.** Horizontal tank after painting and transferring on new location

8. CONCLUSION

The paper has shown one of the tanks classification in the process industry according their construction properties and also the problems, which can appear after made decision of transferring horizontal tank supported on the saddles (capacity-52 m^3) on new location which regular maintenance is non-clear followed. During preparation process before transferring on new location, which in generally case include detail cleaning and external and internal inspection of tank, was observed many individual and branched cracks in area of supporting the tank on the saddles. Taking into account the fact that during normal operation of the process equipment present of the cracks of any type is not allowed, it was make decision regarding of the fully horizontal tank remediation. At the first sanation phase cracks were removed by grinding and base metal around the cracks were continuously inspected for needs of checking possible residues of cracks. Confirmation in sense of fully clean metal was obtained by penetrant test and ultrasonic examination. Repair welding process was performed by procured approved welding process specification because it was cheaper and more reliable solution at that moment. After repairing relevant non-destructive examinations performed and on that basis, it has established that the equipment was repaired on a proper way. Since the horizontal tank was transferred on new location one additional visual inspection was performed in sense of checking possible damages during transportation process. After all mentioned equipment was put in service, properly painted and maintenance plan has been set according to the relevant standards from this area.

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STUDY OF POROSITY AND OIL CAPACITY OF COATINGS FORMED BY ELECTRIC ARC METALLIZATION METHOD

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Abstract: *The results of studies of porosity and oil capacity of coatings formed by electric arc metallization with the use of aerosol fluxing and introduction of alloying elements from its composition into the combustion zone of electric arc are presented. Welding wire Cv-08G2C, flux components: Na_2CO_3, Na_3AlF_6, $Na_2B_4O_7$ and distilled water were used as materials. The characteristics of the coatings were investigated according to the generally accepted methods. The use of aerosol fluxing at electric arc metallization reduces porosity and oil capacity of formed coatings in 1.5-1.6 and 1.7-1.8 times, respectively, in comparison with coatings obtained without aerosol fluxing. When using aerosol fluxing, due to deoxidation of iron, the content of its oxide decreases, which contributes to an increase in the density and quality of the formed coatings.*
Keywords: electric arc metallization, coating, porosity, oil capacity, flux.

1. INTRODUCTION

Various methods of gas-thermal spraying of coatings are widely used in the restoration of worn machine parts: gas-flame, plasma, detonation, electric-arc metallization [1-5]. Electric arc metallization (EAM) is of particular interest for the repair industry. EAM is the process of melting two wires by burning an electric arc between them, dispersing the melt and transporting the particles with compressed air [3,5-7]. The scheme of realization of this process is shown in Figure 1. Electric arc metallization can restore machine parts of a wide range of nomenclature in various industries and agriculture, obtain coatings of pseudo-alloys, as well as decorative coatings of non-ferrous metals (copper, bronze, brass, aluminum) [4-6, 8-9].
The Electric Arc Metallization ("EAM") method is quite simple, productive and cheap [3-5, 9-11]. For example, coatings formed by the electric arc metallization ("EAM") are 3-10 times cheaper than coatings formed by plasma and detonation sputtering [7-10,12,13]. EAM allows to obtain coatings on machine parts from solid wire for metallization or cored wire with sufficient physical-mechanical and operational characteristics [7-12].

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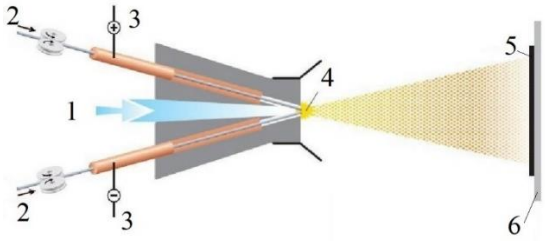
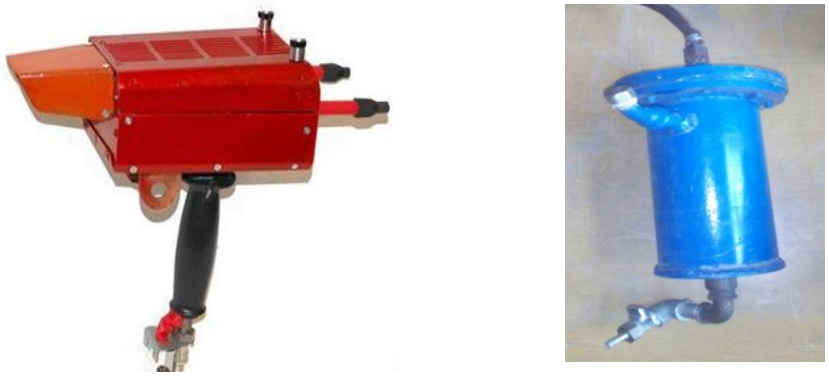


Figure 1. Schematic diagram of the process implementation at electric arc metallization:
1 - compressed air flow, *2* – spraying wire, *3* – current supply,
4 – electric arc, *5* – coating to be formed, *6* – sprayed surface

To improve the physical and mechanical properties of formed electrometallization coatings, as well as to neutralize the negative effect of oxidation on the quality of the applied metal, it is possible through the use of aerosol fluxing (AF) and the introduction of alloying elements from its composition into the combustion zone of the electric arc [10-14].
The essence of the proposed method of AF, designed for deoxidizing and alloying of metal at electric arc metallization, is that in the flame of dispersed dispersed molten metal by electric arc is introduced together with compressed air aerosol, which is an aqueous solution of chemical inorganic materials, which when dissolved in water have passed the stage of electrolytic dissociation [14-16].
The essence of the proposed method of AF, designed for deoxidizing and alloying of metal at electric arc metallization, is that in the flame of dispersed dispersed molten metal by electric arc is introduced together with compressed air aerosol, which is an aqueous solution of chemical inorganic materials, which when dissolved in water have passed the stage of electrolytic dissociation Na_2CO_3, Na_3AlF_6, $Na_2B_4O_7$.

2. MATERIALS AND METHODS

Samples for research were made of steel 45. When forming the coatings, an electric arc metallizer "EAM-9ShD" (Russia) (figure 2a), a welding rectifier VDU-506 and a hydrodisperser (figure 2b) were used. Welding wire Cv-08G2C, flux components: Na_2CO_3, Na_3AlF_6, $Na_2B_4O_7$ and distilled water were used as materials.

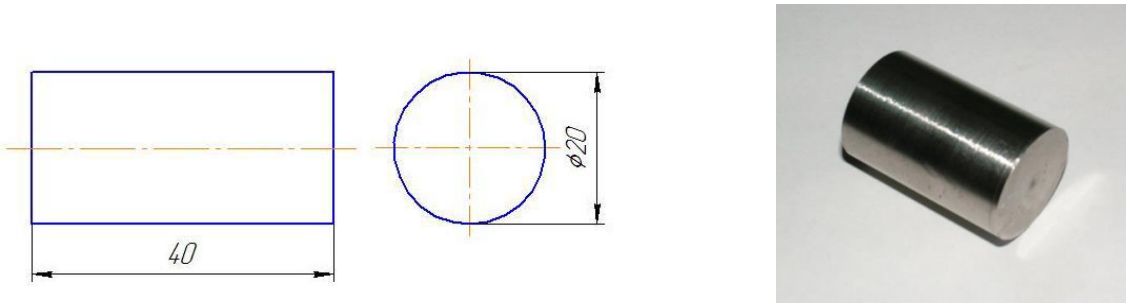


a) b)

Figure 2 Equipment for coating:
a – metallizer "EAM-9ShD", b – hydrodisperser

Coating formation modes: current intensity – 200 A, tension – 27V, wire feed rate – 13 m/min, air pressure – 0,60 MPa, metallization distance – 130 mm, part rotation frequency – 170 min^{-1}, solution flow rate for AF – 13 ml/min.
The porosity of the obtained coatings was determined by color defectoscopy. After grinding the coatings to Ra = 0.63-0.64 μm, the samples (Fig. 3) were washed in cold running water, then immersed for 30 s in a warm (35-40°C) solution of sodium hydroxide (20 g/l) and for 1 min in a

clarification solution (nitric and hydrofluoric acids in a ratio of 1:1). To stain the pores, the samples were placed for 5 min in a solution containing 20 g/L copper sulfoxide and 20 ml/L hydrochloric acid. Washed and dried samples with areas of pink spots of released copper on the coating were examined under a microscope (20x). The porosity of the coatings was determined as a percentage ratio of the areas of stained spots to the area of the considered area.



a) b)

Figure 3. Sample for the study of porosity and oil capacity of coatings:
a) scheme; b) general view

The oil capacity of the coatings was evaluated using a method based on determining the amount of oil penetrating into the pores of the coating. Samples were weighed, then immersed in Shell HF-E ISO 15 oil heated in an electric furnace SNOL-1,6.2,5.1/11 (СНОЛ-1,6.2,5.1/11) (*Russia*) to a temperature of 100-110°C and kept in it for at least 1.5-2.0 hours. Then the container with oil together with the immersed sample was cooled in air to temperature 20±5^{0}C. After extraction, the sample was washed in benzene for 10 min and dried in a SNOL-3.5 (СНОЛ-3.5) desiccator for 40 min at 40-50°C. After cooling in air, the sample was weighed. Oil capacity of coatings (M) in mg/mm^2 was calculated according to the formula (1):

$$O = \frac{m-m_1}{s}, \quad (1)$$

where m – sample mass after immersion in oil, *mg*;
m_1 – sample mass before immersion in oil, *mg*;
S – sample surface area, *mm*^{2}.

3. RESULTS AND DISCUSION

The results of studies of porosity of coatings obtained by electric arc metallization using aerosol fluxing depending on the content of flux components are presented in figure 4. Figure 5 shows a general view of the sample with colored pores marked on the coating. It is established that the use of aerosol fluxing at electric arc metallization allows reducing the porosity of the formed coatings by 1.5-1.6 times. This is due to the fact that due to deoxidation of iron the content of its oxide decreases, which contributes to an increase in the density and quality of the applied metal layer. Obviously, the high rate of the process also contributes to the increase of kinetic energy, which provides a more dense and low-porosity coating.
The oil capacity of coatings is related to the porosity formed during their application. For parts operating under conditions of changing lubrication from liquid to boundary lubrication, the oil capacity of coatings is one of the most important properties that can improve self-lubrication of interacting surfaces and reduce the coefficient of friction in a moving joint. This results in reduced wear rate and increased life of parts in the assembly unit.
The conducted studies have shown that the values of oil capacity of coatings applied without application of AF (65 mg/mm^2), are higher than with AF (36-39 mg/mm^2) by 1.7-1.8 times (Fig. 6). Obviously, the reduction in oil content of coatings is associated with a decrease in their porosity.

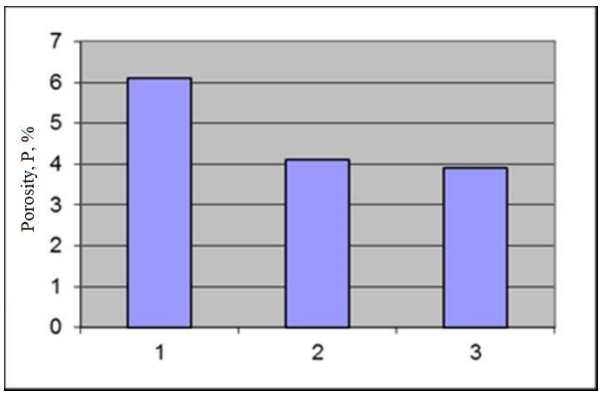


Figure 4. Change in porosity of formed coatings:
1 – Cv-08G2C (without AF); 2 – Cv-08G2C + AF (flux №1); №3 – Cv-08G2C + AF (flux №2)

Figure 5. General view with characteristic areas of released copper in pore locations, 20^x

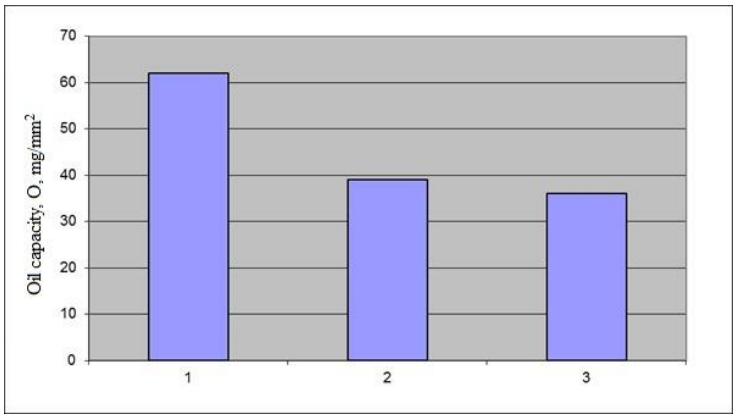


Figure 6. Results of studies on the oil capacity of coatings:
1 – Cv-08G2C (without AF); 2 – Cv-08G2C + AF (flux №1); №3 – Cv-08G2C + AF (flux №2)

4. CONCLUSIONS

The use of aerosol fluxing during electric arc metallization reduces porosity and oil capacity of the formed coatings by 1.5-1.6 and 1.7-1.8 times, respectively, compared to coatings obtained without aerosol fluxing. This should be taken into account when predicting the service life of moving joints, which will use parts with coatings obtained by electric arc metallization and using AF.

To achieve rational operational properties of the formed coatings it is recommended to use hydroflux of the following composition: $C_{Na_2CO_3} = 42$ g/l, $C_{Na_3AlF_6} = 6$ g/l, $C_{Na_2B_4O_7} = 12$ g/l.

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EFFECT OF THE VOLTAGE AND THE MAGNETIC FIELD VARIATIONS ON THE VELOCITY FIELD IN A MHD PUMP - SIMULATION AND EXPERIMENTAL ANALYSIS

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Abstract*: Magnetohydrodynamics (MHD) is a field of study that takes into account the interaction of the magnetic field, the electric field represented by its current density and the characteristics of the medium involved. It was initiated by the Nobel Prize winner Hannes Alfven in the sixties. In this work, we conducted a three-dimensional and time dependent simulation of a magnetohydrodynamic (MHD) pump using COMSOLMULTIPHYSICS software. Additionally, a series of laboratory experiments were performed testing both the pumping mechanism and the MHD propulsion principle. The results obtained show that the performance of the proposed applications (MHD pump and MHD propulsion) is directly linked to the electrical conductivity of the liquids, to the electrical voltage applied and to the intensity of the magnetic field adopted. The simulation and the experimental results show that the flow velocity increases when the applied voltage is varied from 0V to 15V with a fixed magnetic field of 0.45T. The same conclusion is derived if the applied voltage is constant (V=2 V) and the magnetic field is varied from 0 T to 0.5T. The experimental observation of the performance of the prototypes shows bubble generation at the electrodes as well as thermal and electrochemical phenomena, which should be taken into consideration in future works.*

Keywords: MHD Pump, Voltage, Magnetic field, Velocity Field, Electrical Conductivity.

1. INTRODUCTION

With the energy crisis of the seventies and the new concern of the environmental issue of the beginning of the twenty first century, researchers are now looking for new clean solutions to the world's energy shortage. The interest in the MHD field is developing both as an energy source or as a propulsion method to compete with electrical vehicles [1-5]. New research results in desalination of seawater using portable apparatus shows a growing attention to the numerous applications of the MHD especially when combined with the solar energy [6-8]. In this paper, to test the performance of the proposed model, a series of experiments were conducted and a Comsol Multiphysics simulation was carried out to predict velocity field variations. The model for the MHD pump consists of a canal (8x3x1) cm placed in a magnetic field and subject to a current in the shown directions(figure 1). The fluid considered in the experiments and the simulation is a NaCl solution. When the ions present in the solution are subject to a magnetic field and an electric field, they are accelerated in the channel due to the Lorentz Force. This force either pumps the liquid or propels the channel. The analysis of such a model combines the electromagnetic model and the fluid flow model.

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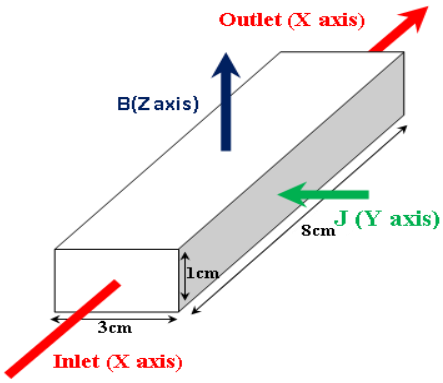

Figure 1. Proposed model
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Characteristics of the solution used in the simulation:

- Density: 1020 kg/m3
- Dynamic Viscosity : 0.007 Pa.s
- Relative Permeability : 1
- Electric Conductivity : 1 S/m

2. MATHEMATICAL MODELS

The proposed system uses the coupling of two phenomenon: the magnetic field and the electric field as to produce the Lorentz Force. This force puts into movement the conducting fluid according to the Navier-Stokes Law [9-12].

2.1 The electromagnetic model

When electrical charges Q are present in an electric field $\vec{E}$ and a magnetic field $\vec{B}$, the Maxwell Equations show that they will be put into movement with a velocity $\vec{V}$ thanks to the electric force $\vec{F}_e$ and the magnetic force $\vec{F}_m$:

$$\vec{F}_e = Q.\vec{E} \text{ and } \vec{F}_m = Q.\left(\vec{J} \times \vec{B}\right) \quad (1)$$

With:

$$\vec{J} = \sigma.\vec{E} + \sigma.\left(\vec{J} \times \vec{B}\right) \quad (2)$$

Based on Maxwell's Equations, the reduced magnetic potential $\vec{A}$ verifies the following equation:

$$r\vec{o}t\left(\frac{1}{\mu} r\vec{o}t\vec{A}\right) + \sigma\left(\frac{\partial \vec{A}}{\partial t} - gr\vec{a}dU\right) - \sigma\left(\vec{V} \times \vec{B}\right) = 0 \quad (3)$$

Where σ , U , μ and J are respectively the electrical conductivity of the solution, the electrical potential, the permeability and the current density.

2.2 The Fluid Flow model

When a fluid of density ρ and viscosity υ is put into motion by a force $\vec{F}$ under a pressure p , the obtained velocity $\vec{V}$ is given by the Navier-Stokes equations which express the conservation of the momentum and mass according to:

$$\frac{\partial \vec{V}}{\partial t} + \left(\vec{V}.\vec{\nabla}\right)\vec{V} = -\frac{1}{\rho} gr\vec{a}dp + \left(\upsilon\vec{\nabla}.\vec{V}\right) + \vec{F} \quad (4)$$

$$\frac{\partial \rho}{\partial t} + div\left(\rho.\vec{V}\right) = 0 \tag{5}$$

The main driving force acting on the fluid is the Lorentz Force given by:

$$\vec{F} = \vec{J} \times \vec{B} \tag{6}$$

3. SIMULATION AND EXPERIMENTAL RESULTS

Considering all these parameters and applying the appropriate boundary conditions, a simulation is carried out to predict the flow velocity [13].A first simulation is carried out for a magnetic field of 0.15T and a potential of 2V. Figure 2 represents the velocity Field, The interaction between the magnetic flux density and induced current density applied on the channel yields the Lorentz force which puts the solution into motion.Figure 3 represents the variations of the fluid velocity at the exit of the channel (x=8cm) along the y-axis. The overall shape takes a parabolic form with a maximum value of 0.028 m/s at the middle and decreases progressively to reach its lowest value at the surface of the channel.

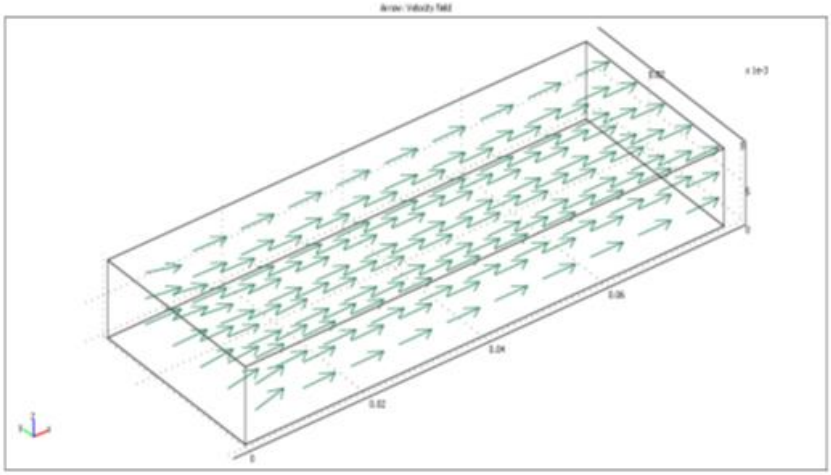

Figure 2. Velocity Field
Source: original copyright

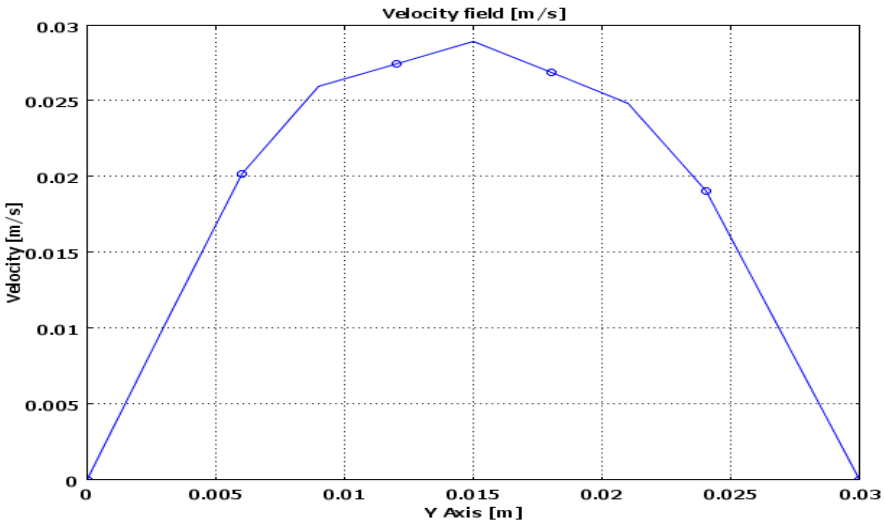

Figure 3. Velocity Field at the exit of the channel along the y-axis
Source: original copyright

The experimental setup is mainly designed to observe and measure the performances of the proposed design as shown in figures 4 and 5.

Figure 4. Experiment conducted to test the MHD pumping performance
Source: original copyright

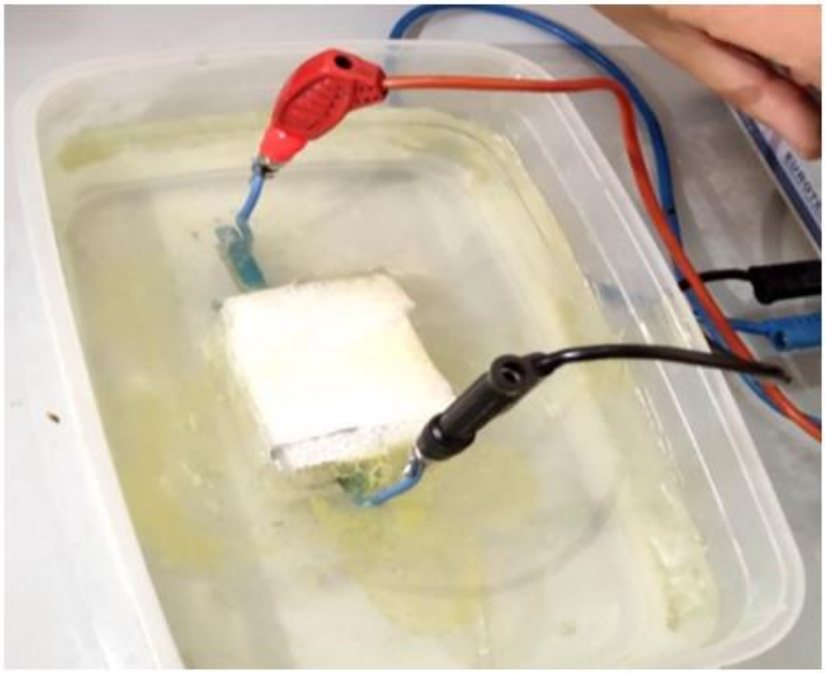

Figure 5. MHD pump exhibiting bubbles at electrodes
Source: original copyright

To analyze the effect of the magnetic field for a specific voltage and the effect of the applied voltage for a given magnetic field, few simulations and experimental tests are performed.The Matlab computer tool is used to plot the evolution of the velocity field using the numerical values obtained in both the simulation and the experimental data[15, 16]. The results are summarized in tables 1 & 2 and figures 6&7. According to the shown results, we notice that the flow velocity increases as either the voltage or the magnetic field is increased. When we compare between simulations analysis and experimental tests, we notice a larger increase in the velocity field in the experimental results as the voltage goes beyond 08 volts. The reason for this difference is the fact that, as the voltage is increased, the conductivity of the solution is also increased due to an increase in the temperature of the solution [17]. As voltages are increased, bubbles at the electrodes were observed due to the electrolysis phenomenon.

Table 1. Obtained simulation and experimental results for B=0.45T
Source: original copyright

	Applied voltage [V]			
	3	5	10	15
Average velocity [m/s]	Simulation results			
	0.062	0.104	0.260	0.364
	Experimental results			
	0.064	0.110	0.270	0.0380

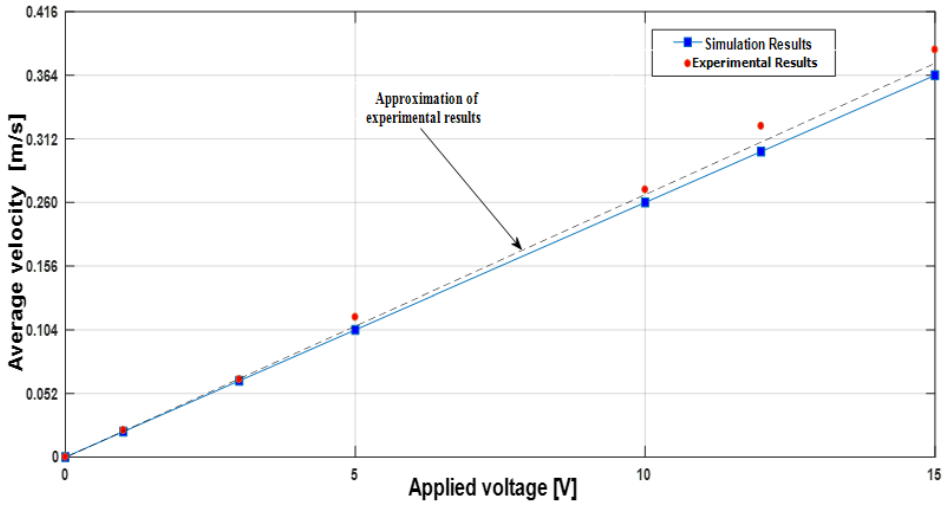

Figure 6. Variations of the velocity in terms of the applied voltage
Source: original copyright

Table 2. Obtained simulation and experimental results for V=2V
Source: original copyright

	Magnetic field[T]			
	0.1	0.2	0.3	0.4
Average velocity [m/s]	Simulation results			
	0.017	0.034	0.051	0.068
	Experimental results			
	0.02	0.037	0.05	0.065

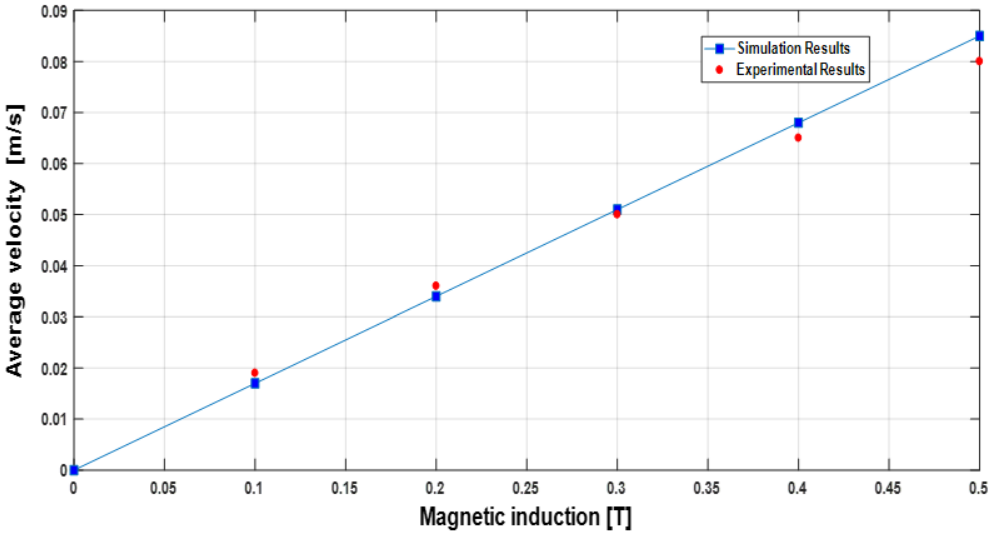

Figure 7. Variations of the velocity in terms of the magnetic field
Source: original copyright

4. CONCLUSION

In this paper, we have presented a simulation of a MHD pump using Comsol Multiphysics and experimental tests to analyse the effect on the velocity field of the variations of the applied voltage and magnetic field. As the power supply or the magnetic field is increased, the fluid flow tends to increase. The comparison between the two methods show that the values obtained for the velocity field are relatively close and in the experimental tests, bubbles are observed for high voltages due to the increase in the temperature of the conducting solution.

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ENVIRONMENT AND SUSTAINABLE DEVELOPMENT. MECHATRONICS. OCCUPATIONAL SAFETY AND HEALTH AND FIRE SAFETY. SMART MANAGEMENT SYSTEMS. GRAPHIC ENGINEERING. DESIGN. TRAFFIC ENGINEERING. BIOTECHNOLOGY AND HEALTHCARE. MECHANICAL ENGINEERING. ECOTOURISM AND RURAL DEVELOPMENT.

THE EFFECTS OF TOOL WEAR ON CUTTING FORCES DURING THE TURNING OPERATION OF WORKPIECE WITH COATINGS

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Abstract: *The development and application of cutting tools made of super hard materials as a precondition for increasing the productivity of machining requires higher costs of tools. Since tool life is closely related to tool wear, it can be influenced by the knowledge about the tool – workpiece interaction mechanism. Practical application of amorphous-crystalline coatings are limited by lack of scientific facts in terms of their mechanical machining. In engineering literature are not sufficiently represented papers related to cutting operations of the workpiece with coatings – coatings. Lack of information regarding the effects of the coatings with amorphous-crystalline structure on tool wear and tool life. This paper presents the influence of cutting conditions and structural composition of coatings on tool wear. Tools are based on hard metal P10, polycrystalline cubic boron nitride (PCBN)-kiborite and composite 10. On the other hand starting from the Merchant's model of orthogonal cutting and by introducing the effects of the tool flank wear height* B_L *and the concentrated force on the cutting edge, it is arrived at the novel concept of consideration of the forces acting in the chip formation process. The increase of the radial force developed as a consequence of tool flank wear is taken for the tool wear criterion.*
Keywords: Tool life, Tool wear, Merchant's model, Cutting forces

1. INTRODUCTION

Tool wear is an important factor that directly affects the productivity and surface quality. Traditionally, at the production environment, a tool change was based on experience or the quality of machined surface. In the early nineties of the last century there was a transition from traditional to automated tool change with the idea that implies possibility of monitoring the amount of wear on the cutting tool edges during the cutting process. With the development of computer this on-line monitoring of the tool wear is gaining more importance [4, 5]. Previous studies in the field of monitoring tool wear in a metal cutting process where based on measurement of the: cutting forces, stress/strain measurement, work piece dimensions, spindle motor torque and the surface finish quality. The paper shows the influence of the flank wear height at the clearance face on tool life and the forces that appear with a special review of the morphology of the flank wear. The starting point is basic Merchants model of chip formation in orthogonal cutting. As the cutting forces increase with increasing of the flank wear height it is necessary to complete Merchants model that would include: flank wear, forces caused by flank wear and force for chip formation. The presence of wearland has been found to have no effect on the basic model of chip formation and basic cutting quantities such as: shear angle, shear stress on the shear plane and friction angle. Existence of flank wear in the vicinity of the cutting edge resulting in an additional force of rubbing or ploughing at the clearance face results in increased radial force. Based on completed Merchant's model and predominant adhesion wear mechanism it is possible to define tool life using cutting speed, feed and

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flank wear height, which is the efficient mathematical model that predicts tool life in production environment.

2. REGIONS OF THE TOOL WEAR OCCURRING DURING TURNING.

When mating surfaces of the tool and workpiece are brought together as the result of their contact the following forms of tool wear occur: adhesion, abrasion, diffusion and oxidant wear. Process of tool wear is related with adhesion and abrasion processes and depends of the cutting parameters: workpiece material, tool material, tool insert geometry etc. For a given workpiece and tool material, tool wear form may depend on the cutting parameters, cutting speed and un-deformed chip thickness. In the cutting process, as a result of chip formation, tool wear occurs on the rake and clearance face of the tool, Figure 1a. Tool wear on the clearance face is defined with flank wear height B_L, Figure 1b., while tool wear on the rake face is defined with crater depth B_{dk} and width B_{sk}, Figure 1b and 1c, where the length of the crater does not change significantly. During the cutting process tool wear, on rake and clearance face, is increased until the width of crater B_{sk} reaches the cutting edge and destroy it, Figure 1c. Tools that have cutting edge radius can wear on the clearance face in the area of the major cutting edge which represents nose wear or edge rounding, figure 1d. Flank wear arises due to both adhesive and abrasive wear mechanism from the intense rubbing action of the two surfaces in contact, i.e. the clearance face of the cutting tool and the newly formed surface of the workpiece. Increasing the height of the flank wear leads to deterioration of the surface finish and to increased heat generation, Figure 1a. In this paper are presented experimental results of turinig-tool wear with hard metal and cubic boron nitride inserts and their impact on cutting forces and Merchant's model of orthogonal cutting.

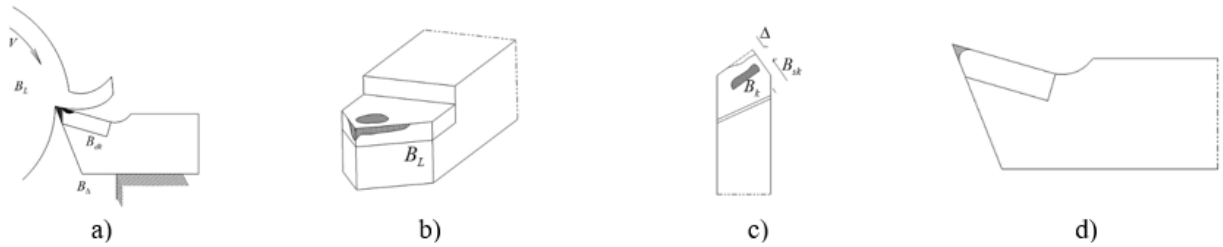


Figure 1. Regions of the lathe tool wear.
Source: original copyright

3. EXPERIMENTAL SETUP

The orthogonal machining tests were conducted on PH-42 CNC Lathe with variable spindle speed from 16 to 5200 rpm, spindle power 16 kw. Turning tools are used with hard metal P10, composite 10 and PCBN-kiborit inserts (Institute of superhard materials Kiev-Ukraine). Material of the workpiece with coatings are given in table 1. Cutting conditions: feed-rate $s = 0.05 - 0.38\ mm/rev$, depth of cut $a = 0.2 - 0.4\ mm$, rake angle $\gamma = -2^O - 18^O$ The cutting forces are measured using two-component piezoelectric dynamometer Kistler 9257B. Flank wear heights are measured using microscope (Carl Zeiss-LSM 510).

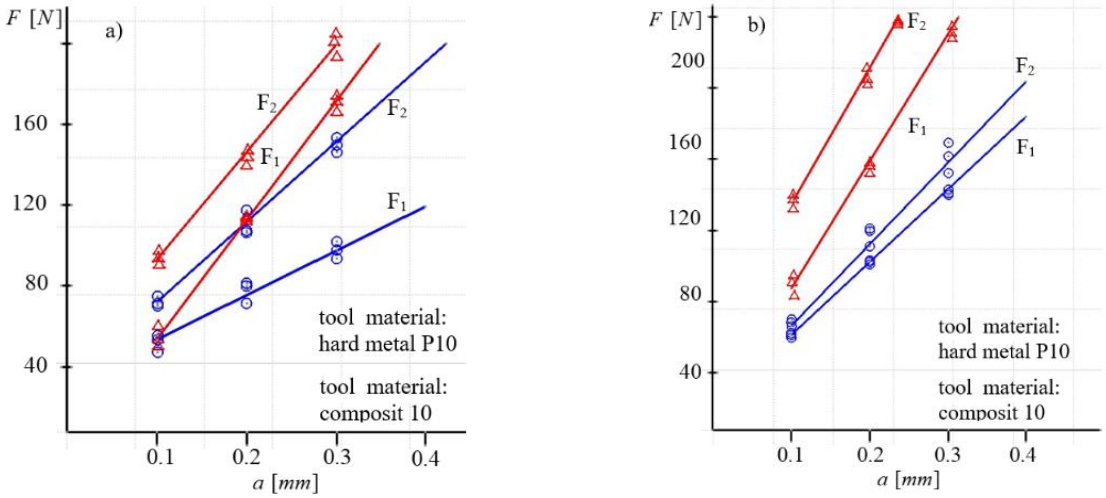
4. CUTTING FORCES AND TOOL WEAR-RESULTS AND DISCUSSIONS

Turning of the workpiece with amorphous-crystalline coatings with PCBN and P10 inserts are performing during the high cutting speed and small depth of cut (due to limitation of the coating thickness $a = 0.1 - 0.6\ mm$). Tools are working in the condition of fine turning characterized by small contact area between tool and chip but with very high specific load at the contact surface. Figure 2 shows the changes of components F_1 and F_2 as a function of the cutting depth during the turning operation of coatings 30HGSA and 65G with Composite10 and P10 inserts.

Table 1. Chemical composition of the workpiece with coatings

Source: original copyright

	Chemical composition %										
Workpiece material	C	Si	Mn	Cr	W	Mo	Ni	Cu	Fe	B	Hardness [HRC]
5H4V3MFS	0.9	0.7	0.7	5	3.5	1	-	-	basic	-	45-48
30HGSA	0.3	1.1	1	1	-	-	0.4	-	basic	-	20-30
65G	0.65	0.3	1.1	0.3	-	-	0.3	-	basic	-	45-48
SH15	1	0.27	0.3	1.45	-	-	0.3	0.25	basic	-	36-38
$Fe_{80}B_{20}$	-	-	-	-	-	-		-	80	20	56-58



a) b)

Figure 2. The effects of depth of cut on cutting forces F_1 and F_2 during the turning of: a) 30HGSA coating ($v = 30 m/s$, $s = 0.1 mm/rev$, $a = 0.25 mm$);b)65G coating ($v = 30 m/s$, $s = 0.1 mm/rev$, $a = 0.25 mm$)

Source: original copyright

From Figure 2 can be seen that cutting forces caused by turning of 65G coating are higher than cutting forces caused by turning of 30HGSA coating due to higher hardness. Force/resistance component in radial direction F_2 is higher than cutting force/resistance component F_1 which is characteristic of hard turning materials. Figures 3-6 shows the effects of flank wear height on cutting force components F_1 and F_2 during the turning operation of several coatings (30HGSA, 5H4V3MFS and Fe80B20) with hard metal P10, PCBN-kiborit and composite 10 inserts.

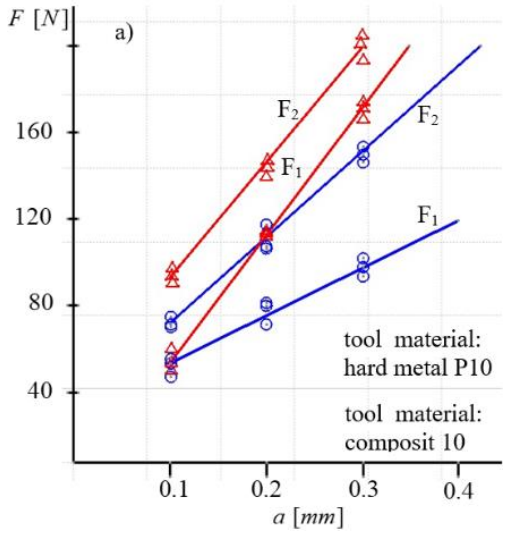


Figure 3. The effects of flank wear height B_L on cutting force components during the turning of coating 30HGSA

$v = 30 m/s$, $s = 0.1 mm/rev$, $a = 0.25 mm$

Source: original copyright

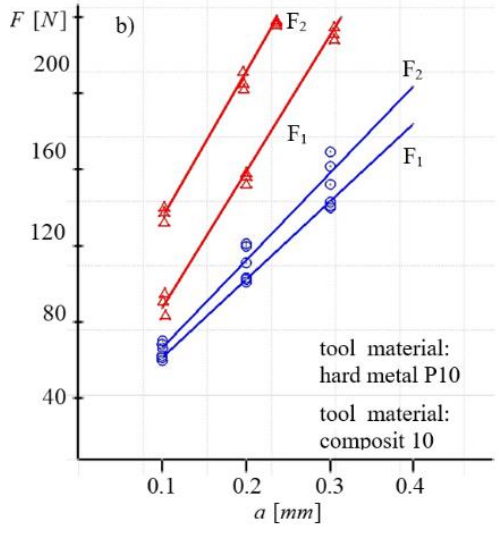
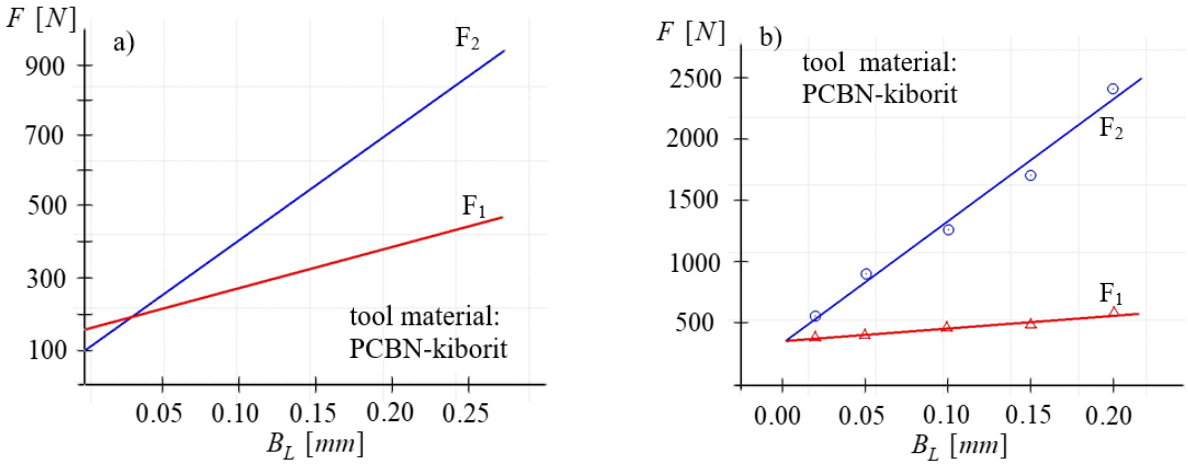


Figure 4. The effects of flank wear height B_L on cutting force components during the turning of coating 5H4V3MFS

$v = 2.4 m/s$, $s = 0.2 mm/rev$, $a = 1 mm$)

Source: original copyright



a) b)

Figure 5. The effects of flank wear height B_L on cutting force components during the turning of coatings: a) SH15 33-38 HRC ($s = 0.38 mm/rev$, $a = 0.1 mm$);
b) SH15 60-62 HRC ($s = 0.38 mm/rev$, $a = 0.1 mm$)

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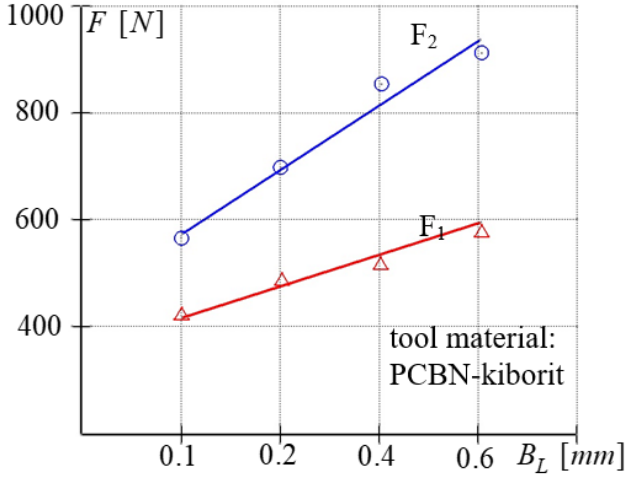
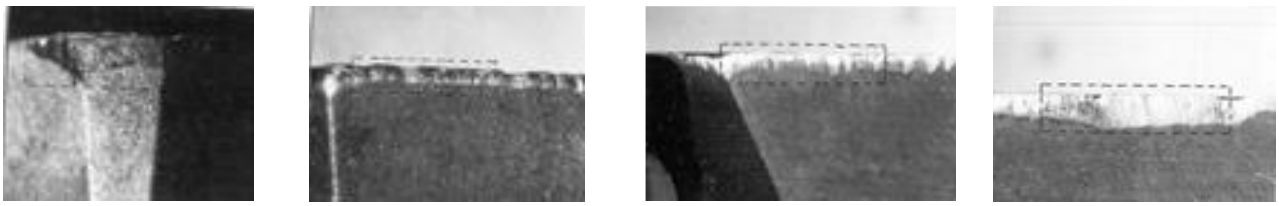


Figure 6. The effects of flank wear height B_L on cutting force components during the turning of coating $Fe_{80}B_{20}$ ($v = 1.7 m/s$, $s = 0.05 mm/rev$, $a = 0.15 mm$)

Source: original copyright

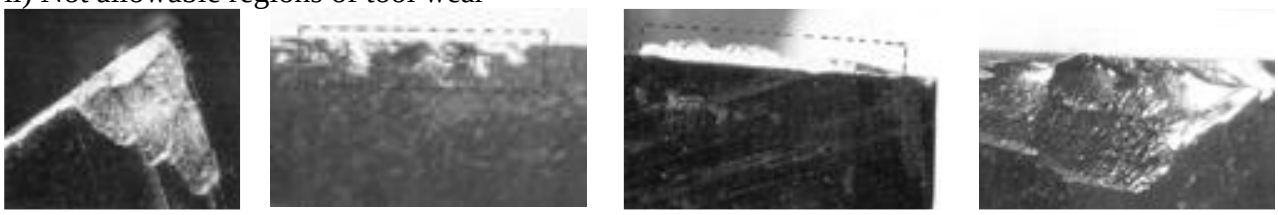
Tool wear is associated with content of amorphous component in the machined coating. During the turning of coatings with 70% of amorphous component, inflicted by $Fe_{80}B_{20}$ electrode, wear occurs on the rake and clearance face, creating strip chip caused by grater contact length with rake face of the tool. During the turning operation of the coating hard crystal fragments, in its structure, are abrasive particles causing tool wear. In this conditions abrasive tool wear occurs. Presence of large number of hard crystalline impurities in the structure of the coating with lower content of amorphous component causes more intense tool wear than coatings with high content of amorphous component particularly during the turning operation using less cutting speed $v < 1 m/s$. Increasing the cutting speed $v > 1.5 m/s$ comes to changes of the contact interaction between tool and workpiece-coating and increasing of the temperature in the cutting zone. On the rake and clearance face deposits can be observed whose structure includes elements of mating surfaces (Fe, Cr, Si, B, Ni) which indicates changes of the chemical composition of the surface layer of the tool. Deposits formed on the tool represents loose layer with significant thickness. It is well known that tool flank wear has great effect on machining accuracy and surface finish. Based on analysis of tool wear with hard metal insert all forms of wear on clearance face are given in Figure 7.

i) Allowable regions of tool wear



a) Nose wear b) average flank wear c) central flank wear d) lateral wear

ii) Not allowable regions of tool wear



e) Nose wear f) fraying of the cutting edge g) deposits h) breakage of the cutting edge

Figure 7. Morphology of flank wear: i) allowable regions of tool wear; ii) not allowable regions of tool wear.

Source: original copyright

During the turning of coatings with 50% of amorphous-crystalline structure, PCBN-kiborit primarily has flank wear, Figure 8. This is because, the structure of this coatings is formed form separated fragments as opposed to highly amorphous coatings are insufficiently deformed in the process of coating and poorly united primarily due to diffusion process.

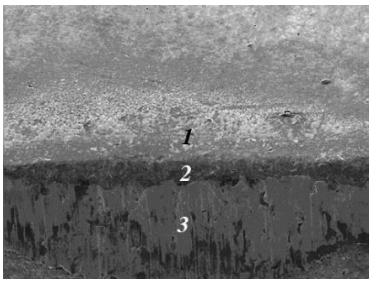


Figure 8. PCBN-Kiborit wear:1- clearance surface, 2-cutting edge, 3-flak wear ($v = 1.7\,m/s, s = 0.05\,mm/rev, a = 0.2\,mm, \gamma = -10°$)

Source: original copyright

5. ORTHOGONAL CUTTING ANALYSIS

Tool's cutting wedge penetrates in the workpiece under the influence of the resultant force F acting on the back of the chip and opposite to the resultant force F' acting on the shear plane (cutting resistance) [6]. In Figure 9 is shown orthogonal cutting-Merchants model. A single straight cutting edge with a plain face and flank is used to cut a workpiece of constant width at a constant cut thickness. Orthogonal cutting-Merchant's model assume the following: perfectly sharp tool with no concentrated edge force on the cutting edge, a continuous chip, plane strain, uniform shear stress distribution on the shear plane, and equilibrium of the under the action of equal and opposite resultant force acting at the shear zone and tool-chip interface. This has resulted in the well-known Merchant model [6]:

$$F_1 = \frac{\tau b a \cos(\rho - \gamma)}{\sin\phi \cos(\phi + \rho - \gamma)} \tag{1}$$

$$F_2 = \frac{\tau b a \sin(\rho - \gamma)}{\sin\phi \cos(\phi + \rho - \gamma)} \tag{2}$$

$$\rho = \arctan\mu = \gamma + \arctan\left(\frac{F_2}{F_1}\right) \tag{3}$$

$$\tau = \frac{(F_1\cos\phi - F_2\sin\phi)\sin\phi}{ba} \tag{4}$$

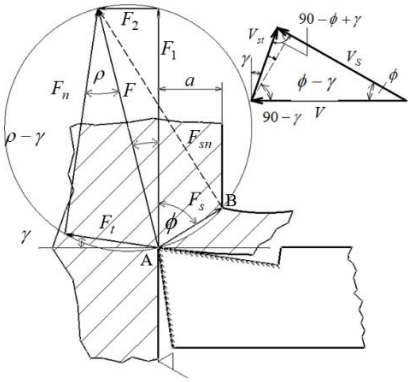


Figure 9. Forces during orthogonal cutting-Merchant's model
Source: Mechanics of the metal cutting process [6]

Experiments showed that that an increase of depth of cut a leads to increase of cutting forces F_1 and F_2, Figure 2. Increase of the rake angle γ leads to decrease of force components F_1 and F_2. Friction angle ρ, shear angle ϕ and shear stress τ are independent of cutting depth a[12]. During the cutting process flank wear height B_L occurs as one of predominant forms of tool wear. Introducing the flank wear height into Merchant's model means that in addition to force for chip formation R_S is the introduction of wearland force /resistance R_h, caused by existence of flank wear height B_L, Figure 10.

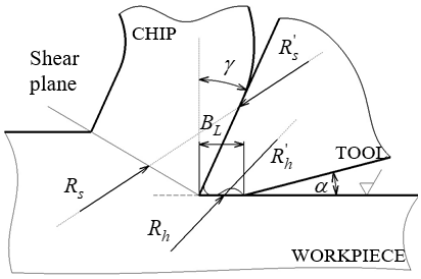


Figure 10. Introducing the flank wear force/resistance caused by the existence of the flank wear height into Merchant's model of orthogonal cutting
Source: Mechanics of the metal cutting process [6]

It has been suggested by many researchers that since the cutting edge is not perfectly sharp, a rubbing or ploughing process could occur in the vicinity of the cutting edge increasing total cutting force, in addition to the force for chip formation. The overall cutting force R, using tool with flank wear height, consists of the sum of the force for chip formation R_S and wearland force R_h:

$$R = R_s + R_h \tag{5}$$

where:
R_h – wearland force/resistance generated by the existence of the flank wear height B_L, R_s – force/resistance for chip formation during the orthogonal cutting for perfectly sharp tool $(B_L = 0)$. Wearland force R_h can be calculated by subtracting force for chip formation R_s (when the measured force is extrapolated for zero flank wear height) from the overall measured force R, equation (5). Wang's experimental results show that there is no effect of the flank wear height B_L and depth of cut a on the shear angle ϕ, friction angle ρ and shear stress τ which means that the force generated by increase of the flank wear can be treated in the same way as the force for chip formation. This means that Merchants model can be completed introducing wearland force, Figure 11. According to

the completed Merchant's model wearland force /resistance R_h, caused by existence of flank wear height B_L, can be decomposed into two components in primary cutting force and radial direction. Component F_{1h},of the wearland force R_h, generated between the clearance face of the cutting tool and the newly formed surface of the workpiece in the primary cutting force direction and component and F_{2h}, of the wearland force R_h, generated between the clearance face of the cutting tool and the newly formed surface of the workpiece in the radial force direction.

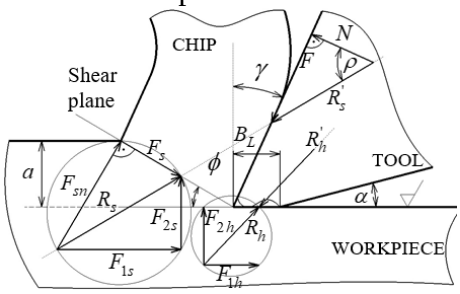


Figure 11. Completed Merchant's model of orthogonal cutting.
Source: original copyright

Based on the completed Merchant's model, the overall cutting force components F_1 and F_2 can be established based on equation (5):

$$F_1 = F_{1s} + F_{1h} = \frac{\tau b a \cos(\rho - \gamma)}{\sin\phi \cos(\phi + \rho - \gamma)} + F_{1h} \tag{6}$$

$$F_2 = F_{2s} + F_{2h} = \frac{\tau b a \sin(\rho - \gamma)}{\sin\phi \cos(\phi + \rho - \gamma)} + F_{2h} \tag{7}$$

Completed Merchant's model includes force analysis occurring in orthogonal cutting with special reference to wearland forces generated between the clearance face of the cutting tool and the newly formed surface of the workpiece which is typical for adhesion-abrasive wear model. According to the fundamental law of adhesion wear, adhesion flank wear volume, dV_A, per unit length is proportional to the rubbing force between the clearance face of the cutting tool and the newly formed surface of the workpiece in the radial force direction F_{2h}, which leads to the following equations:

$$\frac{dV_A}{dl} \propto F_{2h} \tag{8}$$

By changing cutting parameters (feed, cutting speed, depth of cut) leads to increase or decrease of wearland force components and wearland height:

$$F_{2h} = K v^{a'} s^{b'} B_L^{c'} \tag{9}$$

$$F_{1h} = K_1 v^a s^b B_L^c \tag{10}$$

$$B_L = C v^p s^q T^x \tag{11}$$

where: a', b', c', a, b, c, p, q, x, K, K_1 are constants to be evaluated by the experiment; v- cutting velocity; s- feed, B_L- flank wear height, T - tool life. Based on equation (5) wearland force R_h can be calculated by subtracting force for chip formation R_s (when the measured force is extrapolated for zero flank wear height) from the overall (measured) force R:

$$R_h = R - R_{s(B_L=0)} \tag{12}$$

$$F_{1h} = F_1 - F_{1s(B_L=0)} \tag{13}$$

$$F_{2h} = F_2 - F_{2h(B_L=0)} \tag{14}$$

Based on these facts tool life can be defined as:

$$T = \left(\frac{B_L}{C v^p s^q} \right)^{\frac{1}{x}} \tag{15}$$

According to ISO3685 tool is worn when flank wear height reaches threshold criterion $B_L=0.9mm$. Based on equation (14) tool life can be determined in production environment, [1, 3].

6. CONCLUSION

The paper shows the influence of the flank wear height at the clearance face on tool life and the forces that appear in two ways. The first one represents the completed Merchant's model of orthogonal cutting which, in addition to force for chip formation, comprises wearland force generated by increase of the flank wear or rubbing between clearance face of the cutting tool and the newly formed surface of the workpiece. The second way represents mathematical model that defines the correlation between tool life, cutting velocity, feed and flank wear height. Mathematical model is based on the fundamental law of adhesion wear. This leads to efficient prediction of tool life in production environment which is very important because it provides good machined part in manned factories so that a new tool may be introduced at the instant at which the existing tool has been worn out, thus preventing any hazards occurring to the machine or deterioration of the surface finish. Based on the above, mechanism of tool wear during the turning of workpiece with amorphous-crystalline coatings has complex character caused by abrasive, adhesion and chemical interaction in cutting zone. Tool wear characteristics are depending of the workpiece material, cutting conditions and tool geometry. Intensive adhesion wear of the hard metal insert P10 is consequence of the increasing plasticity of amorphous component in machined coating structure. In turning of the coating, surface layer of the tool is in contact with hard material, and temperature in cutting zone and cutting forces create good conditions for interaction between tool and workpiece material. During the turning of more heterogeneous coatings contact conditions with tool are unstable and changing rapidly which affects the reduction of deposits. In turning of crystalline coatings on contact surfaces of the PCBN tool adhesion wear is not present. Increasing the cutting speed influence of heterogeneity of the machined workpiece with coatings on tool wear intensity is significantly lower.

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ENVIRONMENT AND SUSTAINABLE DEVELOPMENT. MECHATRONICS. OCCUPATIONAL SAFETY AND HEALTH AND FIRE SAFETY. SMART MANAGEMENT SYSTEMS. GRAPHIC ENGINEERING. DESIGN. TRAFFIC ENGINEERING. BIOTECHNOLOGY AND HEALTHCARE. MECHANICAL ENGINEERING. ECOTOURISM AND RURAL DEVELOPMENT.

DYNAMIC CALCULATION OF FRICTION STIR WELDING TOOLS USING THE FINITE ELEMENT METHOD

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Abstract: *The aim of this paper is the dynamic calculation of the tool used in friction stir welding of aluminum alloy plates. The friction stir welding process ensures the joining of materials without melting them and using additional material. This procedure was created as a result of research carried out in order to find new solutions when welding aluminum alloys in order to avoid the problems that occur with conventional welding procedures. Using this procedure, welded joints with good mechanical properties are obtained. The paper presents the design and dynamic calculation of welding tools using the finite element method in Abaqus software.*
Keywords: Friction Stir Welding Tool, Dynamic Calculation, Equivalent Stress, Finite Element, Deformation

1. INTRODUCTION

Friction Stir Welding, i.e. FSW was created at the end of 1991 by Wayne M. Thomas from the Welding Institute TWI (Cambridge, UK), who successfully welded aluminum alloy sheets. The procedure was very quickly, already in 1994, received its commercial application and caused great attention of researchers in practice. The first application of the FSW procedure was related to the production of railway vehicles and the welding of aluminum and its alloys, but over time the scope of application has expanded. To join two or more working plates using the FSW process, you need: a machine, a cylindrical tool, two or more working plates that are made of the same or different materials, a backing plate and clamping tool [1,2,3]. The equipment for FSW is shown in Figure 1.

Figure 1. Equipment for friction stir welding
Source: original copyright

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2. MATERIAL OF WORKING PLATES

The following materials can be successfully welded by friction stir welding: aluminum, titanium, lead, aluminum alloys, copper alloys, magnesium alloys, lead alloys, titanium alloys, nickel alloys, structural steel, low-alloy steel, mild still, stainless still, austenitic steel, duplex steel and polymers [4]. The working plates to be welded were 5xxx series of aluminum. The designation 5xxx refers to alloys of aluminum with magnesium (hydronaliums). These alloys are well polished and polished. Of all heat-resistant aluminum alloys, they are characterized by the highest strength. Working plates are made of aluminum alloy 5052-H32. The chemical composition of this alloy according to the EN 573-3:2009 standard is given in Table 1 [4].

Table 1. Chemical composition of aluminium alloy 5052-H32
Source: https://www.alcoa.com/mill_products/europe/en/nautical_products.asp

Content of alloying element in %							
Cu	Mn	Mg	Si	Fe	Zn	Ti	Cr
0-0.1	0-0.1	2.2-2.8	0-0.25	0-0.4	0-0.1	0.01	0.15-0.35

3. WELDING TOOL

The special tool used for welding is cylindrical in shape and consists of the tool body and the working part of the tool, which consists of two concentric parts: the shoulder and the mandrel of tool pin. The shapes of the face and the tool pin can be different. The tool shoulder can have a concentric depression on its surface, while the pin is most often conical, profiled with a coil or grooves. The body of the tool serves to fix it in the chuck of the machine. The pin height is usually greater than half the thickness of the material of working plates, but it is always less than the total thickness of the material that is welded (the height of the pin is less than the thickness of the material by a few tenths of a millimeter). Figure 2 shows the geometry and part of the workshop drawing of the tool with the names of the basic dimensions [5].

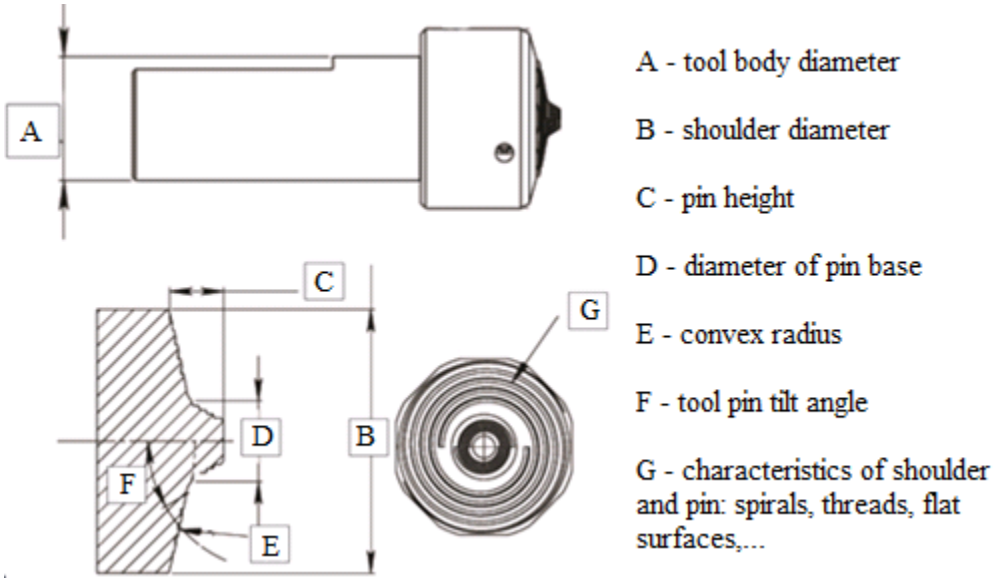

Figure 2. Geometry of welding tools
Source: http://megastir.com/

Table 2 shows the designations of tool steel H13 in certain countries according to certain standards. The chemical composition is given in Table 3, while the mechanical properties are given in Table 4. [6]

Table 2. Common H13 tool steel related specification
Source: https://www.astmsteel.com/

Country	USA	German
Standard	ASTM A681	DIN EN ISO 4957
Grades	H13	1.2344/X40CrMoV5-1

Table 3. H13 tool steel chemical composition (%)
Source: https://www.astmsteel.com/

	C	Mn	P	S	Si	Cr	V	Mo
ASTM A681	0.32-0.45	0.2-0.6	0.03	0.03	0.8-1.25	4.75-5.5	0.8-1.2	1.1-1.75
DIN EN ISO 4957	0.35-0.42	0.25-0.5	0.02	0.03	0.8-1.2	4.8-5.5	0.85-1.15	1.1-1.5

Table 4. Mechanical properties of H13 tool steel, at 20°C
Source: https://www.astmsteel.com/

Property	Tensile strenght, ultimate	Tensile strenght, yield	Reduction of area	Modulus of elasticity	Poisson's ratio
Value	1200-1590 MPa	1000-1380 MPa	50%	215 GPa	0.27-0.30

During welding, the tool undergoes dynamic loads. A dynamic load is a load that changes in intensity and direction over time. Tool loads during the welding process, directions of forces and directions of bending moment and torque are given in Figure 3.

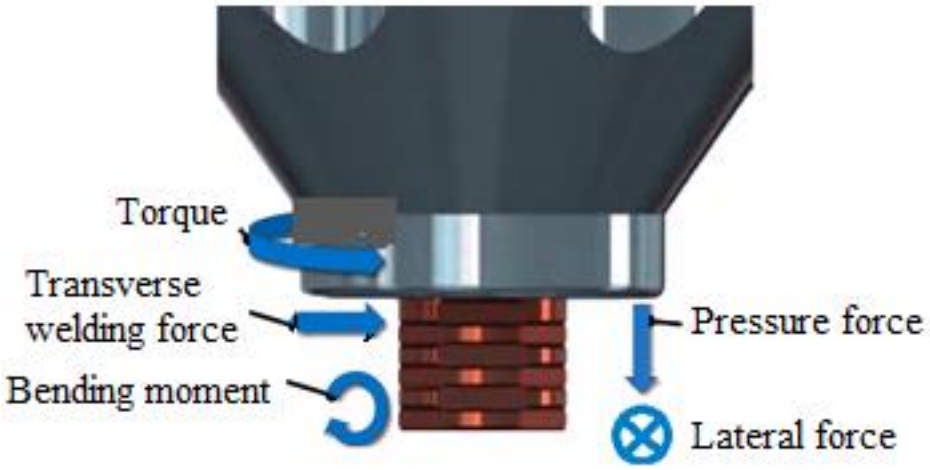

Figure 3. Tool loads during the welding process
Source: [7]

Tool torque depends on several parameters and influencing variables, such as vertical force, tool geometry, tool tilt angle, local shear stress on the tool due to contact with working plates, and coefficient of friction. By measuring the value of the torque, values can be assumed about the stress around the tool and the amount of slip between the tool and the working plates, but only when the other variables are constant.

4. NUMERICAL MODEL AND CALCULATION METHOD

The calculation was done according to the specified standards and using the finite element method in the ABAQUS software [8,9,10,11,12]. The tool model for friction stir welding is shown in Figure 4 a, while the computational model of the tool is shown in Figure 4 b. The finite element mesh is shown in Figure 4 c. Tetrahedron type finite elements were used.

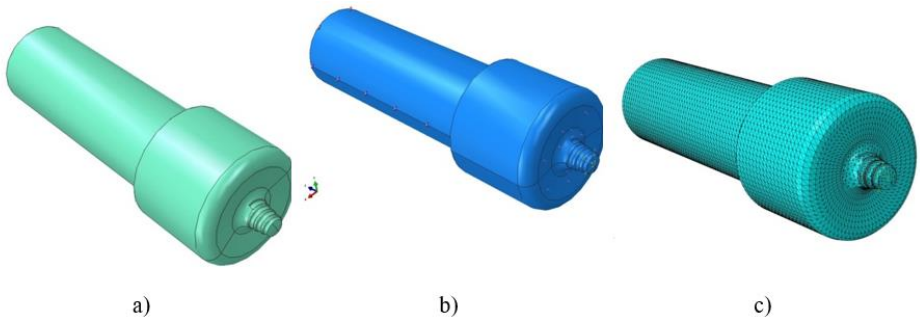

Figure 4. a) Welding tool model, b) Numerical tool model - boundary conditions and c) Numerical tool model - finite element mesh
Source: original copyright

The initial conditions, which were the input data for the numerical calculation, will be specified in this paragraph. The dimensions of the tool model are as follows: the total length is 750mm (of which the tool shank length is 50mm and the pin height is 5.5mm), the tool shank diameter is 18mm, the shoulder diameter is 25mm, and the pin tip diameter is 4mm, and the pin cone angle is 10°. From the mechanical characteristics, the Modulus of elasticity E=210GPa and Poisson's ratio ν =0.3 were used as input for the calculation. The mesh of finite elements consists of 140135 elements in the shape of a tetrahedron. Load value, i.e. torque is 60Nm.

5. DYNAMIC CALCULATION

The results of the calculation obtained using the ABAQUS software are given in the following figures. Equivalent stress distribution is given in Figure 5, and in Figure 6 is given the distribution of total displacement.

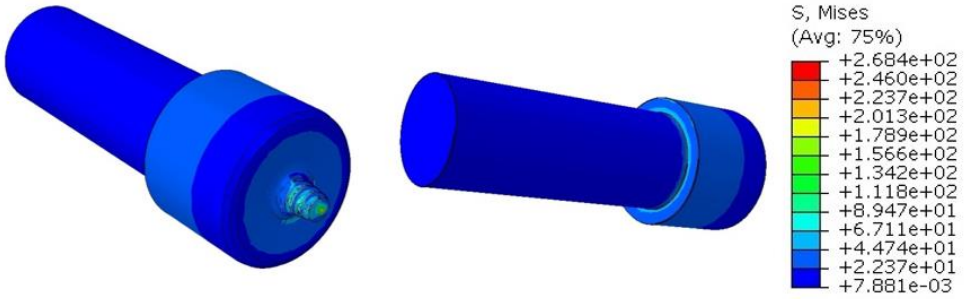

Figure 5. Equivalent stress distribution according to the Hencky-Mises hypothesis with the corresponding scale in MPa
Source: original copyright

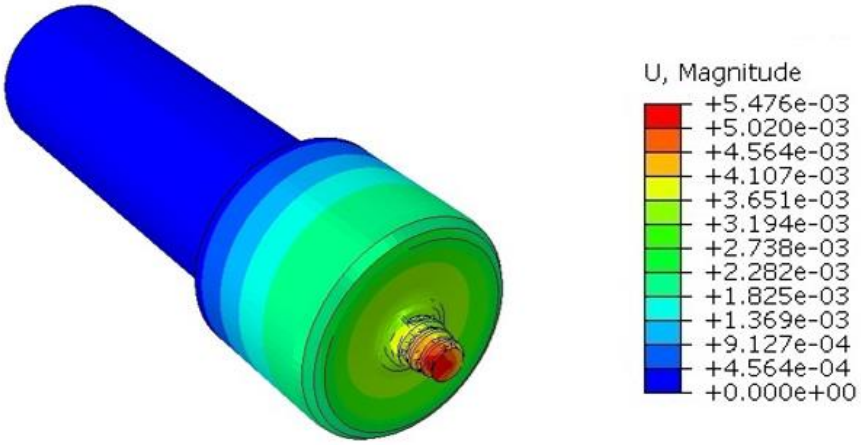

Figure 6. Total displacement with corresponding scale in mm
Source: original copyright

The results given in the figures show that the values of the obtained stress and displacements are within the recommended limits. On the scale, Figure 5, the maximum stress value of 268.4 MPa is observed. That value is much lower than the permissible stress, i.e. Tensile strength - yield stress (1000-1380 MPa, according to Table 4). Also, on the scale given in Figure 6, a maximum displacement value of 0.005mm is observed. This value is small, so that for the given initial conditions, there will be no impermissible deformations of the tool.

6. CONCLUSION

The work is the result of years of research into the deformation and stress state of structural elements. Initial considerations are given, which include an overview of previous research related to friction stir welding, as well as an overview of the available literature. As part of the work, calculation models of tools for FSW were made and dynamic calculation was carried out using the finite element method. The method of calculating the stress and deformation state of tools for FSW, which is presented in this paper, can be recommended for use in practice. The conclusions obtained from the calculation of this type of structures can be included in the process of designing new similar tools. The knowledge gained during the implementation of this work can be directly applied to identify the behavior of real structures in their working conditions.

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CRITICAL REVIEW ON THE SAFETY BARRIERS FROM THE STRUCTURAL AND DEFORMATION PARAMETERS ASPECTS

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Abstract: *The paper gives an overview of the safety barriers from the aspect of the standards that establish the absorption of the part of the kinetic energy with which the vehicle collides with it. The role of the safety barriers is threefold: to prevent the vehicle from leaving the roadway but to enable the vehicle to continue moving, then to prevent the vehicle from leaving the roadway, while also foreseeing the possibility of the vehicle being unable to continue moving, as well as absorbing part of the kinetic energy at which foresees the possibility of the vehicle leaving the roadway. The work considers the standards related to the geometric and construction characteristics of barrieres that are present in Serbia, as well as updated contemporary bariers with rollers. Also, the influence of the environment on the choice of barrier is considered.*
Keywords: Safety Barriers, HIC, Safety Barriers with Rollers, Deformation Work, THIV

1. INTRODUCTION

The road as well as the road equipment, which includes, among others, the safety barriers, have a primary role in enabling road safety. This implies the prevention of a fatality and the minimization of material damage in extreme conditions of road exploitation. These conditions refer to situations where it is impossible to keep the vehicle on the road, which is especially evident in curves with a smaller radius when the vehicle moves at an inappropriate speed and when the angle of collision with the barrier exceeds 20^0. Vehicle speed overruns as well as the height of the vehicle's center of gravity are of particular importance. The paper deals with the principles of choosing a suitable barrier, both from the structural and geometrical aspects. In doing so, the standard applied in Serbia, SRPS EN 1317, is analyzed, where the choice of the type of barriers is established, both from the aspect of movement speed, and from the aspect of vehicle mass and height of the center of gravity.
Also, the dependence of the inertial force and the acceleration of the head and neck region at the moment of impact, on the acceleration severity index when the vehicle crashes into the safety barriers is analyzed, which is an indicator of risk from the aspect of the fatality of the accident. The size of this index is directly influenced by the level of absorption of part of the kinetic energy with which the vehicle hits the barrier and part of the kinetic energy that the vehicle retains after the collision. In accordance with that, safety barrierss with rollers are being considered, which allow a higher percentage of vehicles, that hit the barrier, to stay on the roadway and continue moving with a minimum of material damage. These barriers are widely present on the worldwide roads from 2017.

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2. SAFETY BARRIERS, CONCEPT AND DEFORMATION WORK IN THE EVENT OF A VEHICLE COLLISION

Parameters of steel safety barrier, Fig. 1, as well as layered, New Jersey type, Fig. 2, are defined by the EN 1317 standard. The steel safety barrier is installed with or without curbs. Height of curbs is 200mm while on the highways such height must not exceed 70 mm, [1]. Barrier is located 500 mm from the edge of the road, [1] and is made of steel sheet which is elastically attached to steel vertical supports with screws. Stabilization of light vehicles after hitting a barrier is foreseen by bending and pushing up the side of the barrier that was struck while the posts bend in the direction of the force. In the case of heavier vehicles, it is assumed that the impacted elements will deform to a large extent and the posts will break, along with the removal of the cap and the elastic distance elements between the post and the sheet.

Figure 1. Steel safety barriers
Source: morava info, online portal, [12]

Figure 2. Concrete safety barrier New Jersey type
Source: MAPECURE SRA, MAPEI, [13]

In 90% cases when light vehicle weighing up to 1250 kg collids the barrier at a speed of 80 to 100 km/h and at gusting angle not greater then 30^0, concrete safety barriers New Jersey type ensures, even the continuaty of driving. In the case of heavy vehicle weighing up to 12.000 kg gusting at a speed of 70 km/h and at gusting angle not greater then 20^0, it allows to stay by the barrier without rejecting. The safety barriers belong to the road equipment, the main purpose of which is to prevent vehicles from running off the road. The road equipment consists of an indicator of the top of the separation surface, a linear reflector, a marker, a mounting curb, anti-dazzle equipment for the driver, a traffic mirror, a roadside traffic post and a shock absorber, [2]. The technical characteristics that the safety barriers should satisfy are prescribed by the SRPS EN 1317, standard [4], which is recognized and accepted by the legislation of the Republic of Serbia, [3], Table 1, and Table 2, [4]. Vehicle restraint system is shown in Figure 3, where W represents width of deflection, Table 1.

Depending on the size of the ability of absorption for the same size of deflection at impact, W, Table1, Figure 4, barriers are classified into type "N", corresponding to the low and normal level of retention, and "H", H1, H2, H3 and H4b for the level of strong and very strong retention, Table 2 [7]. The stress of the barrier is in the zone of plastic deformation. According to [8], and in accordance with the EN 1317 standard, it is established correlation between parameters: speed of movement, vehicle mass, as well as the height of the vehicle's center of gravity and the type of barrier, Figure 4. On the same figure it is presented the size of kinetic energy that could be absorbed by the corresponding barrier, as well as deformation work from barrier type and vehicle restraint levels for various types of vehicles and movement speed.

Table 1. Relation between barrier class and size of deflection

Class	Deflection size, Fig. 4
W1	W<0.6m
W2	W<0.8m
W3	W<1.0m
W4	W<1.3m
W5	W<1.7m
W6	W<2.1m
W7	W<2.5m
W8	W<3.5m

Table 2. Vehicle restraint levels for various safety barriers

Source: Designing safety barriers in technical documentation [1]

Vehicle restraint levels		Test	Total vehicle mass (kg)	Gusting speed (km/h)	Gusting angle (^{0})
Low level	T1	TB21	1300	80	8
	T2	TB22	1300	80	15
	T3	TB21	1300	80	8
		TB41	10000	70	8
Normal level	N1	TB31	1500	80	20
	N2	TB32	1500	110	20
		TB11	900	100	20
High level	H1	TB42	10000	70	15
		TB11	900	100	20
	H2	TB 51	13000	70	20
		TB11	900	100	20
	H3	TB61	16000	80	20
		TB11	900	100	20
Very high level	H4a	TB71	30000	65	20
		TB11	900	100	20
	H4b	TB81	3800	65	20
		TB11	900	100	20

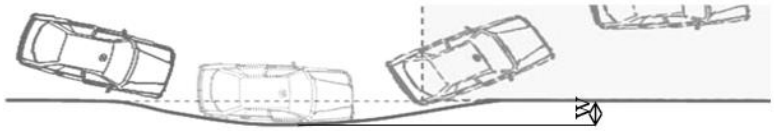

Figure 3. Safety barrier deflection

Source: Ren Z. and Vesenjak M.,2005, [15]

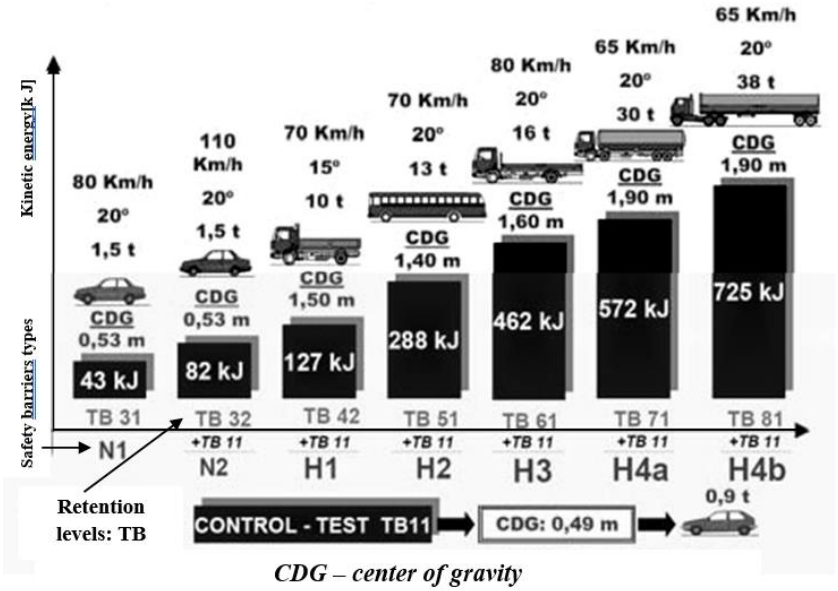

Figure 4. Dependence of kinetic energy and deformation work from barrier

Source: HIASA Group [8]

Presented amounts of kinetic energy are related to the retention level defined by the tests: TB 11 for light cars, TB 31 and TB 32 for heavier cars, while test TB 32 is to be integrated with TB 11 test. Corresponding safety barriers are N1 and N2. Tests applied for heavy vehicles movements in traffic are according to total weight, speed and gusting line angle. These are: TB 42, TB 61, TB 71 and TB81 together with TB 11.

Four types of barriers suitable for stronger and very strong retention are assumed. These barriers are: JDO/1.33, Super rail, Super rail reinforced and Super rail double side, Figure 5. Barriers classes W4 to W7 correspond to the deflection size, Table1.

Table 3. Safety barriers, types and characteristics
Source: SRPS EN 1317-2:2013, *Sistemi za zadržavanje na putevima — Deo 2*, [2]

Kind	Sign	Type	Class	Gusting intensity	Length on which testing is realizing
JDO/1.33	S 1.2-120	H1	W5	Low	80m
		H2	W7	Low	80m
Super rail	S 1.2-310	H2	W4	High	36m
Super rail double side	S 1.2-320	H2	W4	High	36m
Super rail	S 1.2-520	H2	W4	High	32m
Super rail double side	S 1.2-320	H4b	W7	High	40m
Super rail reinforced	S 1.2-340	H4b	W6	High	80m

Table 3 gives the relationship between the barrier types: H1 to H4, Table 2, class, Table1, gust strength: A and B and the length on which the test is performed during testing. Appropriate barrier types are: H1 to H4. Correlation between types of H safety barriers, impact intensity and length on which the test is performed on is, according to standard EN1317, given in Table 3.

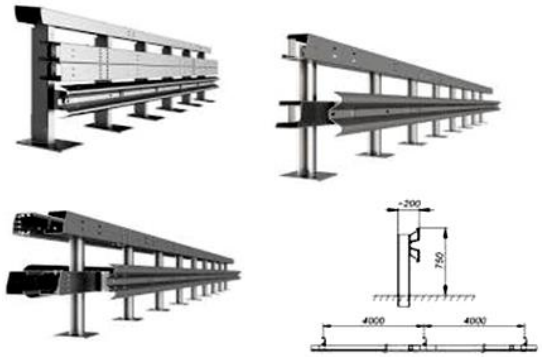

Figure 5. Safety barriers
Source: Unipromet.co.rs/super-rail Eco Bw and Latifović cinkara Kruševac, JUS U.S4.108-JO

3. GUSTING INTENSITY LEVEL AND WAYS FOR SAFETY BARRIER CHOICE

The seriousness of the accident in terms of the risk of a fatality when a vehicle gusts into a safety barrier is defined by the dependence of the inertial force of the head and neck region: HIC (Head Injury Criteria), Figure 6, as well as the speed that the head and neck region reach at the end of the impact: THIV (Theoretical Head Injury Impact Velocity), from accident severity expressed by Acceleration Severity Index: ASI, Table 4. ASI represents the dimensionless dependence of the intensity of the vehicle acceleration ratio in orthogonal directions on time, [9], as follows:

$$ASI = ASI(t) = \sqrt{\left(\frac{a_x}{x_l}\right)^2 + \left(\frac{a_y}{y_l}\right)^2 + \left(\frac{a_z}{z_l}\right)^2}$$, where: a_x, a_y and a_z represent acceleration of vehicle in x, y and z direction, while x_l, y_l, z_l are in the sum of $12 \cdot g$, where g corresponds to acceleration of gravity. Dependency diagram represents regression curve formed by applying the least squares method to pairs of values obtained by performing tests, [10]. On the same way it is obtained dependence of HIC from THIV, Figure 7.

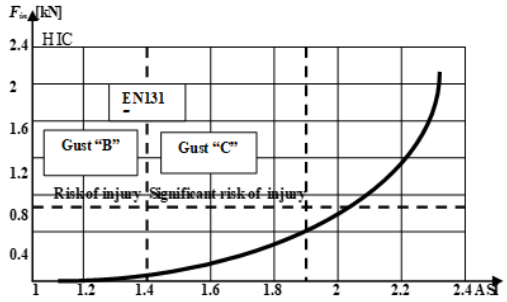

Figure 6. Head injury coefficient versus Acceleration severity index
Source: Authors and Shojaati M., ETH Zurich, https://ethz.ch/en/utils/contact.html [14]

It is characteristic that the critical speed reached by the head and neck region at the end of the collision, defined by the EN1317 standard, is 33 km/h, and from the point of view of the occurrence of fatality. That speed corresponds to inertial force of approximately 0.7kN, [9], as well as to acceleration of approximately 65.5 m/s2, which corresponds to 6.7·g. It is assumed that the mass of the head and neck region, in total, amounts to 15% of the mass of the entire body, that is, 10 to 12 kg. The head and neck injury criterion, HIC, Fig 7, represents the inertial force of the driver's or passenger's head at the moment of impact: F_{in} [N]. Gust time duration is expected to be between 140 and 160ms. The specified acceleration value corresponds to gust duration of 140 ms, which is less favorable. Necessity for safety barriers of specific type or no one depending of the risk for road surrounding and passengers in the car from traffic flow, mean allowable speed and heavy trucks.

Table 4. Dependence of injury severity level from ASI index and Head Injury Criteria
Source: Sturt R, Fell C., [10]

Injury severity level	ASI	HIC[N]
Risk exists	≤ 1	50
Significant risk	≤ 1.4	115
Significant risk with the possibility of fatality	≤ 1.9	1000

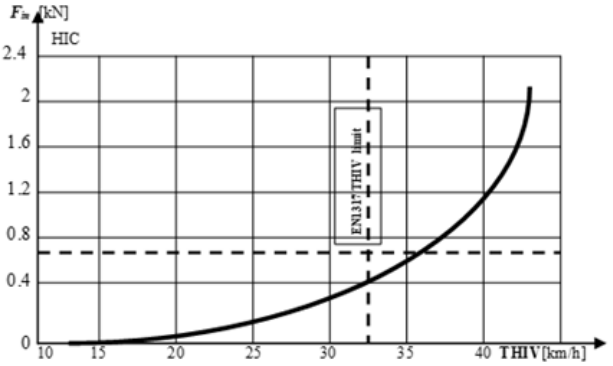

Figure 7. Head injury criteria versus theoretical head impact velocity
Source: Sturt R, Fell C. [10]

4. SAFETY ROLLER BARRIERS

For the difference safety barriers mentioned before, safety barriers with rollers, (Roller barrier system), Figure 8, are proposed, to prevent vehicle rolling out the road, assuming, at the same time, continuity of movement, Figure 9 and 10.

Figure 8. Safety roller barriers
Source: IndiaMART>Road Barriers & Safety>Road Barriers, Muskaan Safety Solutions Jangpura N Delhi [17]

Figure 9. Safety roller barriers enabling driving continuity
Source: Safe Direction, Crash Barrier Solutions, Australia, [18]

Safety Roller Barrier System provides greater kinetic energy with which vehicle is leaving the barrier, being able to continue movement. Collide energy is consisted of part transformed to deformation work and the part transformed to inertia moment of the rollers too. Namely, the difference in kinetic energies with which the vehicle hits and leaves the barrier is not only the deformation work, but also the roller's rotational energy, which is the product of the moment of the tangential force created by the vehicle's collision and the angle of rotation of the roller.

Figure 10. Safety barriers on low radius curves and for obstacles protection
Source: HE Shock Resistance Barriers for Highway Tunnel Corner [19]

This type of safety barriers was originally developed in South Korea, after which it was improved by Gregory Industries, based in Ohio, USA, under the designation: MASH TL-4. The installation permit was issued by the American Traffic Safety Services Association, and the presentation was at the 2017 Traffic Expo in Phoenix, Arizona. An improved model of this type was launched for impact loads of vehicles weighing over 36 tons, under the designation: MASH TL-5. The first installations of these barriers were realized not only in the USA, but also in South Korea, and in China, Malaysia and Australia. They are widely distributed for smaller radius curves, as well as for protection of obstacles on the road. Rotary roller, Fig. 14, is notable for its yellow-orange color and fluorescent strips.

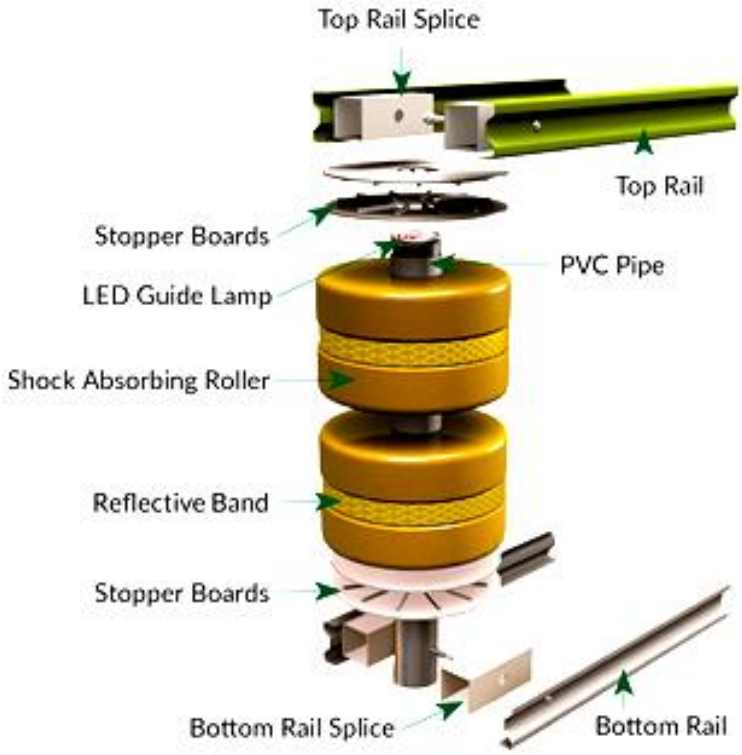

Figure 11. Safety roller barriers roller
Source: Gregory Industries Roller, World Highways Routes Du Monde, [20]

It is made of polyurethane or ethylene-vinyl acetate, which are polymer composite hydrocarbon materials of high strength and toughness. There is also the possibility of filling them with broken glass, plastic granulate or other fillings. Steel parts are made of galvanized sheet. One of the main advantages of such barriers is easier installation, lower weight, as well as simpler and partial replacement of damaged parts. The geometry of the roller with the support is given in *Gregory Industries Roller, World Highways Routes Du Monde,* [20].

5. CALCULATION OF THE ENERGY BALANCE IN THE CASE OF SAFETY ROLLER BARRIERS

The calculation of the energy balance is based on the laws of maintaining the amount of movement as well as the transformation of part of the kinetic energy into mechanical work and momentum of inertia in the form: $M = I_r \cdot \varepsilon = m \cdot r^2 \cdot \frac{d\omega}{dt} = F_{\tan} \cdot d\varphi,$ where *m* represents the mass of the roller, *r* - the radius of the roller's center of gravity from the point of contact with the vehicle, the angular acceleration of the roller, F_{tan} the tangential force, $d\varphi$ the angle of rotation of the roller and *dt* the duration of contact between the roller and the vehicle. The physical quantity that, in those terms, has the greatest influence on the fatality of the collision is the duration of the gust, which must be extended as much as possible. In the case of a plastic collision, deformation work occurs due to the deformation of the vehicle and the barrier. That work: A_{def} is the scalar product of the inertial force: F_i and the deflection *W,* in the form: $A_{def}[J] = \vec{F}_i[N] \cdot \vec{W}[m]$. Expression for the energy balance will be in view: in contrast to classic barriers, which is the main advantage of Safety roller barriers. Therefore, the expression for the energy balance will be in view: $E_{k_1} = E_{k_2} + A_{def} + M,$ in contrast to classic barriers: $E_{k_1} = E_{k_2} + A_{def}$. This statement represents the main advantage of Safety roller barriers.

6. CONCLUSION

The goal of the work is a critical review of the EN1317 standard, which is also applied to safety barriers in the Republic of Serbia. There is also a broader overview of the types of barriers in accordance with the Standard and from the aspect of the amount of deformation work that, depending on the type, is absorbed by the barrier, Fig. 5. There is also a review of the choice of safety barrier depending on the frequency and nature of the traffic, Fig. 6. Reviewing the criteria on the basis of which the Standard was formed, which refers to the dependence of HIC and THIV on ASI, was also the subject of this paper. A more comprehensive scope of consideration of these dependencies, on which the Standard is based, is, also, one of the contributions of the Work. The basic approach in Paper is to take into account the real traffic flow, which is permissible from the aspect of road parameters. The work is based on the premise of non-observance of the prescribed traffic conditions and, accordingly, the safety barrier is expected to prevent a fatal outcome and minimize material damage. The size of the deformation work needs to be as large as possible in order to reduce the ASI, Fig. 8 and Fig. 9. Also, it is necessary to take into account the road environment as much as possible, and in accordance with that, select a barrier, Fig. 10, from the aspect of the total volume of traffic, the maximum speed of the traffic flow that can be realized, as well as the participation of oversized vehicles. The key contribution of the work is a broader overview of Safety roller barriers, which are increasingly common in the world, and the main advantage is the energy of the rotation of the roller, which, along with the deformation work, absorbs most of the kinetic energy of the vehicle when it hits the barrier. These barriers are not foreseen by the EN1317 standard, and the author's intention is to expand the Standard by including this category of safety barriers.

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WIRE-ARC ADDITIVE MANUFACTURING: RECENT DEVELOPMENTS AND POTENTIAL

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Abstract: *Wire-arc additive manufacturing (WAAM) is a promising technology for producing medium and large components without traditional subtracting technologies. It is a hybrid of two manufacturing techniques: additive manufacturing and welding. The use of this technology has grown significantly due to advantages such as material and energy savings while achieving high deposition rates and low cost. However, there are some issues with microstructure homogeneity, and properties are affected due to the complexity of the arc-induced thermal cycles and metallurgical mechanisms, resulting in high residual stresses, distortion, porosity, cracks, and delamination. This article summarises the progress made in the field of wire additive manufacturing, with a focus on welding systems, tool path design software, material analysis, and control systems. It also highlights some critical aspects that must be addressed to ensure high-quality production, such as control and diagnosis mechanisms for defect monitoring, the effects of parameters and their optimisation possibilities for improving quality, ensuring process stability, and possible post-deposition heat treatments. The conclusions suggest further improvements to the wire-additive manufacturing process in terms of accuracy, reliability, and efficacy, as well as future applications of the technology and research activities.*
Keywords: Additive manufacturing, WAAM, Welding, Mechanical properties, Monitoring system

1. INTRODUCTION

Additive manufacturing (AM) uses the joining of materials to create three-dimensional structures, typically layer by layer [1]. In fact, it is one of the primary technologies in engineering that enables near-net-shape fabrication, which is thought to increase design freedom while achieving lower lead times and great potential for smart production [2]. It has mastered the production of high-end products while meeting sustainability standards by employing environmentally friendly manufacturing techniques, resulting in minimal waste and CO_2 emissions and a strong circular economy [2]. While there has been continuous progress in AM research over the years, there have also been some difficulties and problems encountered along the way, such as raw material incompatibilities, the lack of testing facilities, and the numerous defects in the AM parts [2]. Poor surface quality, flaws, and decreased corrosion resistance are some of the important problems that prevent the real-time application of AM products in some industries, but there are significant efforts to resolve these problems through research and there are also some post-processing techniques that can be used to overcome these difficulties [2]. AM technology has found great interest in applications in aerospace,

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automotive, biomedicine, energy and chemical industry, micro-nano manufacturing, marine, and aeronautics.

A fundamental AM system is made up of a motion system, a heat source, and feedstock [3]. The process parameters and material used determine the quality of parts created using AM procedures. AM can use metals and alloys, polymers, ceramics, composites, and natural materials [2]. Metal additive manufacturing is one of the most difficult modern technologies. Powder bed fusion (PBF), direct energy deposition (DED), binder jetting (BJ), and sheet lamination (SL) are the four major categories of AM technologies for metal materials [4]. The primary distinctions between these technologies are the nature of the heat source and the form of metal used. Depending on the AM technology used, the metal can take the form of powder, wire, foil, or laminate. Powder-based fusion technologies involve spreading layers of powder on a metal building plate and melting this powder with a laser or electron beam heating source. PBF techniques include direct laser metal sintering (DLMS), electron beam melting (EBM), selective laser melting (SLM), and sintering (SLS) [4]. When using a laser beam, the part must be built in an inert atmosphere, whereas when using an electron beam, the part must be built in a vacuum [5]. These processes can produce products with high geometrical accuracy, but the equipment and overall process are very expensive, and the metal powder can be hazardous to people, necessitating additional precautions and control of the working environment [4]. When metal wire is used as feedstock instead of metal powder, not only is the powder protection and recycling system eliminated, but the raw material cost is reduced significantly [4]. These are referred to as wire-based (WB) technologies. The wire-shaped material is fed into the deposition zone and melted by a heat source (laser beam, electron beam, or electric arc). A controlled atmosphere is required when using a laser or electron beam as a heat source, whereas an electric arc is shielded by the gas that covers the melted pool of metal [5]. The technology that uses an electrical arc as a heating source and a wire to feedstock is known as wire-arc additive manufacturing (WAAM). WAAM has many advantages over other AM technologies, such as the ability to produce very large parts, higher deposition rates, less expensive welding equipment, less expensive hardware systems, a wide range of standard wires, efficient material utilization, and energy savings [5,6,7]. However, when compared to other metal additive technologies, WAAM has several disadvantages, including high heat input, which can result in residual stresses, distortion, poor accuracy, and roughness, which necessitates the use of additional finishing manufacturing operations. It also cannot produce very complex parts; the low accuracy makes geometry optimization algorithms ineffective [6].

WAMM is ideal for producing parts made of various metals and alloys, particularly highly reflective metal alloys such as aluminum, copper, magnesium, titanium and nickel alloys, and steel [4, 7, 8]. The WAAM hardware system is very simple; it employs a cartesian or robotic device for positioning the welding torch, welding equipment with a shielding gas source, a wire feeding unit, and power and control units, as illustrated in Figure 1.

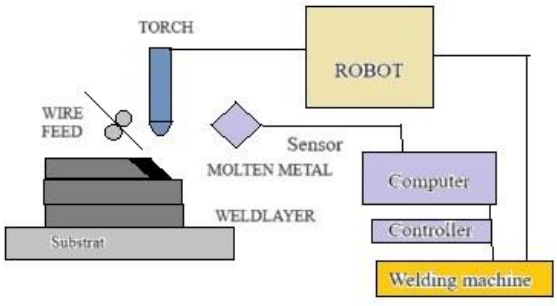

Figure 1. A schematic representation of WAAM system

When using reactive titanium alloys, an additional controlled chamber must be installed to control the production environment [5]. WAAM can be integrated into a hybrid machine that can also operate with other machine operations, making it suitable for in-between tasks [5]. The thermal cycles during the welding process have a significant impact on the microstructure and mechanical properties of

WAAM parts. Each layer is heated and cooled, resulting in multiple fusion, solidification, phase transformation, and highly non-linear dissipation. Another important factor influencing microstructure, defects, geometrical accuracy, and mechanical properties is heat accumulation [7].
The WAAM technology is very popular in research, and some of the findings in many articles suggest that the process can be used in production, owing to the favorable mechanical properties obtained. This review focuses on some aspects of welding processes and equipment, as well as material analysis and control systems. Additionally, potential optimization approaches for increasing product quality are discussed, and some ideas and recommendations for additional process enhancements are outlined.

2. WIRE-ARC ADDITIVE MANUFACTURING

Wire-arc additive manufacturing technology has been studied since the 1990s [3]. It employs standard welding equipment such as a power source, torch, and wire feeding system. Robotic or computer numerically controlled (CNC) systems can be used to control movement patterns [3]. It is critical to provide tools and guidelines for the process planning phase, particularly for the tool path, which must correspond to the shape and dimensions of the part [5]. The high deposition rate with minimal geometry constraints is ideal for the rapid production of large components as well as gradual manufacturing [5, 8]. The WAAM filler material is like the one for welding, therefore there is an available palette of materials that can be used for fabricating parts with this technology. The CNC machine or robot directs the torch along the deposition path, allowing metal layers to accumulate and form the desired shape. Using different arc welding machines and operating units, various hardware systems, each with its own set of characteristics and utility, have been developed [4]. Figure 2 depicts an example of a robotized WAAM setup [2].

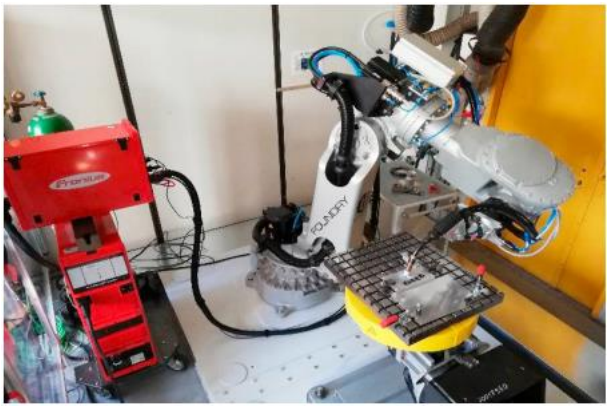

Figure 2. WAAM system with Fronius welding source
Source: Robot-Based Wire Arc Additive Manufacturing System with Context-Sensitive Multivariate Monitoring Framework. Procedia Manufacturing 2020

2.1 Welding processes

There are six types of arc welding-based AM: gas metal arc welding (GMAW), gas tungsten arc welding (GTAW), cold metal transfer (CMT), plasma arc welding (PAW), laser additive manufacturing (LAM) and electron beam welding (EBW) technology [4, 2]. The metal solidified during WAAM has a large column grain microstructure, which is useful for high-creep resistance applications [2].
In GMAW additive manufacturing (GMAW-AM) an electric arc forms between the continuous electrode and workpiece on the substrate surface. A robotic path that the torch follows is created from a CAD model at the beginning of the process [9]. A stable path generation and simple programming procedure are established due to the torch and wire being in a coaxial position with one another [4]. The electrode is a continuous wire that is supplied to the arc via a feeding mechanism. It melts and deposits in a defined pattern with relative movement of the torch and the worktable [10]. Inert gas is

used to shield the weld pool from the atmosphere, preventing any reactions or environmental contamination. The product is taking shape because of the overlapping weld layers creating bonds when they solidify. Shape, size, density, mechanical characteristics, and quality define each layer of welds that are deposited on the substrate. This process's high heat input causes the layers' geometry to become uneven, which negatively impacts the layers' shape and quality of the product [11]. Compared to the other three WAAM technologies, GMAW-AM has higher deposition rates, ranging from 3 to 4 kg/h [4]. However, the rates can be further increased by combining two GMAW processes or by using a pulse GMAW technique. In these situations, more external cooling atmosphere is required due to the higher heat. To increase the material utilization rate, GMAW and GTAW torches can also be combined [4]. There are process modifications with more potential because of the arc's poor stability in GMAW-AM. This applies to the modified GMAW process known as cold metal transfer additive manufacturing (CMT-AM), which depends on a regulated dip transfer mechanism [3]. Its superior arc stability, low heat input that results in less distortion, nearly zero spatters, and high process tolerance make it extremely promising [3]. CMT-AM is a high-resolution system for creating three-dimensional near-net-shaped objects that work with a robot system and simulation software [8]. Modeling software, material feeding via cord, data connection lines, soldering power, and activator operation make up this economical prototyping method [8]. The high-frequency alternation of forward wire and retraction sets apart the various CMT-based WAAM systems, some of which use CNC machines for the 3D path of the tool [8]. The advanced current dynamic creates the liquid droplet at the top of the wire, which is then unbundled at low pressure to produce a solid solder, stable arc, low heat input, and no spatter [8].

High-quality welds are produced by GTAW welding, also known as tungsten inert gas (TIG) welding, which forms an electric arc between the non-consumable tungsten electrode, the workpiece, and the filler metal. Because it is a splatter-free process that produces very little slag, it can be used for welding in all positions without the need for additional cleaning procedures. In GTAW-AM technology, GTAW is utilized as a heat source. The substrate surface is covered in melted metal as the filler wire is inserted into the arc from the torch's side. It is easier to control GTAW-AM because it has a lower heat input than GMAW-AM and because changes in heat input do not alter the arc length or the rate of deposition [11]. Numerous scholars have examined how control factors affect output metrics like deposition breadth and height [2, 11]. Their results indicate that the width and height of the deposition decrease with increasing tilt angle [2]. Anisotropy in terms of elongation at break is evident in tensile tests conducted on additively manufactured parts but yield and ultimate strength show uniformity in both directions [2]. Studies on the use of nanoparticle-enhanced aluminium wire in GTAW-AM have also been conducted; the findings indicate that the printed layers have larger metal grains [2].

While the GTAW and PAW processes are similar, the PAW process concentrates the arc more, improving stability, increasing heat transfer efficiency, and producing fast welding [6]. The majority of industrial metals, such as titanium and its alloys, nickel and its alloys, and stainless steel, can be welded using PAW. It requires less heat and is easier to control the feeding rate than the GTAW and GMAW-AM [2]. Although PAW-AM is more expensive than GMAW and GTAW-AM processes, it produces a final product with fewer defects and more consistent results. The wire fed in GTAW-AM and PAW-AM is not coaxial, which can cause variations when there is a direction change and cause the arc length to vary [6]. To make the process application possible, the robot system's rotary axis must be used to orient wire feeding and maintain it in the same direction as the welding [6]. Additionally, electron beam welding (EBW) and laser additive manufacturing (LAM) can be used to fabricate large individual components with reduced internal stress. These are additive manufacturing techniques based on high-energy-density (HED) welding [2]. Custom-built devices that use the EBW and LW processes with a separate wired procedure make up the majority of research employing these technologies [2]. Additional wire feeds and working chambers are included in the apparatus. A key component of Industry 4.0 is additive manufacturing based on laser beam welding, which makes extensive use of sensors for process control [2]. The most common issue that researchers are attempting to solve is geometry inaccuracy. Numerous factors have been taken into account, such as

trace height and width, breadth, depth, geometrical responses, and dilution. The findings of these studies indicate that there is an influence on the width but no relationship between the laser power and the trace height [2]. There are benefits and drawbacks to employing these methods. These methods have the advantage of having a narrow heat-affected zone, low heat input, high solidification rates, reduced distortion, deep penetration, excellent energy transfer efficiency, and lower consumable costs. The primary drawbacks are increased initial investment costs and the challenge of enhancing the fusion zone properties using filler metal. The use of additive manufacturing technologies based on fusion welding is restricted due to the production of extremely columnar grains with anisotropic characteristics [2]. Friction stir additive manufacturing (FSAM), ultrasonic additive manufacturing (UAM), and additive friction stir deposition (AFSD) are examples of solid-state welding-based additive manufacturing techniques that offer a metal a deformation processing path. Material addition and bonding are achieved through extreme temperatures and severe plastic deformation. One of the most innovative solid-state additive manufacturing (AM) technologies, FSAM is based on the FSW principle and has the potential to overcome limitations, especially in the case of light alloy additive manufacturing [2].

2.2 WAAM monitoring systems

WAAM technology has numerous potential applications in a variety of industries due to the many benefits it offers. This has led to a significant increase in interest in topics for the future development of WAAM in academic research and industry over the last decade. There are some challenges to fully implementing the technology, which can be attributed to a lack of process monitoring and closed-loop control over the entire process [10]. As a result, implementing process monitoring and feedback control is one of the most significant advancements that can be made [10]. Because the main challenges remain manufacturing precision, quality assurance, and automation level, various solutions for improving quality with the improvement of monitoring systems are proposed. Vision, spectral, acoustic, and thermal sensing are all used, and they all have different roles in the monitoring process. Visual sensors are used for surface monitoring, while spectral and acoustic sensors are used for internal changes in the metal [10].
A great deal of research has been done on feedback control systems in the last few years. Newly developed devices use feedback signal systems to measure the distance between the nozzle and the top of the surface to control the height of the layers. Additionally, neural self-learning PSD controllers for bead width measurement and adaptive controllers that maintain this distance constant through wire-speed adjustments are available [10]. If the wire feed is constant, the robotic movements in WAAM processes should decelerate at sharp corners, which leads to over-fill. The adaptive control system, which adjusts the wire feed based on the dynamic constraints of various sections, can be used to accomplish this. The bead can be observed using a thermal camera and laser scanner, and a closed-loop control can be put in place [4,10]. Most of the research on WAAM controlling systems indicates that this process is still in the early stages of development and that control systems and additional study are necessary to bring it closer to commercialization.

3. CONCLUSION

The manufacturing sector has changed as a result of additive manufacturing's (AM) use of layer-by-layer deposition to produce structures with nearly net shape and little material waste. However, by combining additive manufacturing (AM) with different welding techniques, it is possible to overcome the dimensional constraints of the parts produced through AM. This article aims to give a summary of the current state of welding-based additive manufacturing (AM) and the underlying principles of the WAAM technology. There is a great deal of research on arc-welding-based AM techniques in comparison to other techniques, like the beam welding AM technique, and a broad range of concepts used in AM with arc-welding filler metals. With fusion welding-based AM, only simple structures can be produced. The production of high-quality metal parts can be facilitated by the hybridization

of beam welding-based AM with arc to enhance process capabilities. This concept has many promising prospects, so it is expected that more research will be done in the future for the application of different welding techniques and materials in the additive manufacturing process. Research opportunities for the advancement of the WAAM process include the development of new materials, fabrication in different patterns, management of grain structure, and phase transformations for a wide range of alloys. Numerous benefits stems from the FSAM process, including efficient structural design, favorable microstructures and mechanical qualities, and environmentally friendly procedures. Further research on FSW-based AM is required to create innovative techniques that get around the drawbacks of fusion welding. Additional findings from this review include the following: GMAW-AM has a higher rate of deposition than the other basic welding technologies; CMT welding is a GMAW modification suitable for large stainless steel products; GTAW and PAW techniques are suitable for small to medium parts with medium to high mechanical properties; LBW-AM requires less energy and provides effective control over the weld pool and surface quality; FSW-AM has the potential to consume a small amount of material with low emissions, waste, and energy. This article's informational goal also includes providing details on the state of development and monitoring and control systems at this moment. The monitoring systems are designed to record process signals on the possible occurrence of a defect, while the control system controls the bead geometry and heat input. The monitoring and control system's goal is to improve process stability, accuracy, quality, and application of online defect diagnosis.

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PRODUCTION OF A LAP JOINT USING FRICTION STIR WELDING AND MICROHARDNESS MEASUREMENT USING THE LEEB METHOD

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Abstract: *In recent years, friction stir welding (FSW) methods have been used to obtain joints with good mechanical properties. The development of FSW lap joint assembly will expand its use in ahigh number of industrial applications that can benefit from this technology. In this paper a study based on experimental methods were performed on FSW lap joints. The investigation includes experimental welding and measurement of microhardness using the Leeb method. The lap joint is welded by friction stir welding process. The welding process is implemented on a 3-axis milling machine. With Leeb's method, it was possible to measure only the microhardness on the face of the weld metal, and the microhardness was measured in three zones. This paper also represents an attempt to verify whether the Innova Test Time 5350 device can measure the microhardness of aluminum alloy series 5xxx.*
Keywords: Lap Joint, Friction Stir Welding, Microhardness, Leeb method

1. INTRODUCTION

Currently, riveting is the most used joining technology for manufacturing reinforced panels of aircraft structures. However, there are important disadvantages in the use of this technology that have to be solved. Among them, the low productivity and the significant contribution to weight increase are the most significant ones. By contrast with riveting, welded structures show remarkable benefits such as reductions in the number of parts to produce the structures, weight saving as well as significant reductions in manufacturing time and cost. Nowadays the most promising alternative joining technologies for the manufacturing of aircraft structures are laser beam welding (LBW) and friction stir welding (FSW) [1,2].
Friction stir welding is solid-state welding technology which provides joining of materials without melting and without the use of additional materials. Joining of material is performed by combined action of heat and mechanical work. Tool and base material stay in solid-state, while in the welding zone base material is in a slightly softened, i.e. plastic-state. Geometrical parameters and technological parameters are the main factors that affect the efficiency of the joint. Geometrical parameters include: dimension of the shoulder, dimensions of the pin, and the pin profile. Technological parameters include: tool rotating speed, tool feed rate, and the tool depth sinking into the sheets to be welded. These process parameters have to be properly chosen on the basis of the working material in order to maximize the joint strength, and to obtain a joint without defects. A schematic representation of the friction stir welding process during the joining of two working plates in order to produce a lapjoint is shown in Figure 1 [3,4].

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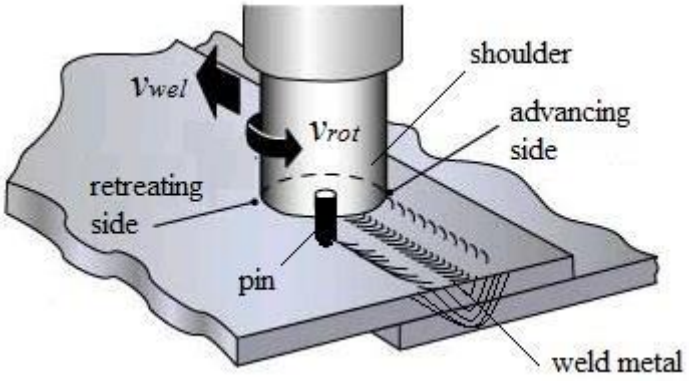

Figure 1. Friction stir welding of lap joint
Source: [5]

The shape of the weld metal is asymmetrical and the advancing side and retreating side are clearly visible. The advancing side is also called the direct side (the directions of the tool rotation speed vector and the welding speed vector coincide) [6]. The retreating side of the weld metal is the side where these two velocity vector directions are opposite.

The shape of the working part of the tool (Figure 1) is a combination of two concentric cylinders known as the tool shoulder (a cylinder with a larger diameter) and a tool pin (a cylinder with a smaller diameter). The transition between the shoulder and the pin is called the face of the tool, and it can be flat or embossed, with or without recesses.

2. EXPERIMENTAL PROCEDURE

Friction stir welding experiment were implemented on a 3-axis milling machine. Figure 2. a) shows the welding process. The tool is in direct contact with the working plates. Working plates are firmly clamped on the milling machine table using a clamping equipment. The tool is made of tool steel, the clamping equipment is made of stainless steel, and the working plates are made of aluminum alloy. The thickness of the working plates is 3mm.

a) b)

Figure 2. Experimental welding of lap joint: a) Welding process and b) Lap joint at the end of the welding process
Source: original copyright

The welding process begins with the immersion of the rotating pin into the material of the two working plates (working material). During this process, the temperature in direct contact between the surfaces of the rotating tool and the working materials is constantly increasing. The process continues

until the temperature in direct contact between the rotating tool and the working materials increases up to a temperature of softening of the working materials. The softened material is forced to move around the tool pin due to its rotation and due to penetration into the material. There is also direct contact between the shoulder of the rotating tool and the surface of the working plates. Heat is also generated due to the friction of the tool face and the upper surfaces of the working plates, causing the material of the plates in direct contact to lose all its strength, i.e. to soften. This is followed by the welding phase. The working temperature is reached and is about 0.8 of the melting temperature, the material is soft enough to be mixed and transported. The tool moves along the welding line with constant rotation. The softened material is forcibly transported around the pin of the tool, and along the axis of the tool, i.e. between the face of the tool and the solid walls of the material. A nugget is formed from the softened material that is located at the end edges of the tool pin in layers. With each translational movement of the rotating tool, the transport of the softened work material will be on the rear edge of the tool, and the front edge will capture and introduce new work material of a lower temperature. At the end, the rotating tool stops moving along the material joining line, pulls away from the work materials, leaving behind a cylindrical hole (Figure 2. b). A lap joint was obtained where the length of the weld metal is 170mm.

3. MEASUREMENT OF MICROHARDNESS

Microhardness was measured using Leeb's method. This method is usually used for measuring the hardness of field samples, which are massive. Leeb hardness measurement is regulated by the SRPS EN ISO 16859-1:2016 standard. The measurement was made on the face of the weld metal. The sample is first prepared, the surface is finely ground and leveled before hardness measurement. Measurements were made with the device Innova Test Time 5350. It is a portable device for measuring hardness. The device works on the principle of measuring the rebound speed of the ball, which is located in the probe. Measured values are in Leeb units HL, and conversion can be done in Vickers HV or Brinell HB units. Figure 3. shows its representation. The accuracy of measurement is quite satisfactory, but the accuracy of hitting a certain spot that can be seen under the eyepiece is not.

Figure 3. Innova Test Time 5350 - device for measuring microhardness
Source: original copyright

The sample was cut from the welded joint. The surface was prepared for measurement and three zones were marked. Zone 2 includes the weld metal surface. Figure 4. shows the marked zones and places of microhardness measurement (ball impressions).

Figure 4. Places of microhardness measurement on the sample
Source: original copyright

4. RESULTS AND DISCUSSION

The measurement points per zone were chosen randomly. Due to the construction of the measuring device, i.e. the probe, it is impossible to precisely choose the measuring point. Table 1. shows the measurement results.

Table 1. Measured microhardness values (HL)
Source: *original copyright*

Zone 1	186	193	213	176	189	260	202		
Zone 2	171	198	184						
Zone 3	189	229	222	282	214	268	304	285	249,1

In Zone 1, 12 measurements were made, and 6 were successful. In zone 2, 22 measurements were made, and only 2 were successful. In zone 3, 15 measurements were made, and 8 measurements were successful. Problems that can arise when measuring with the Leeb method are that field samples, which are large in size, are usually measured. This method also has limitations regarding the hardness of the material being measured. Due to the low hardness value of the aluminum alloy, the device could not display the values of individual measurements at all.

The lowest value of microhardness was observed in Zone 2. This is area of weld metal, and the material of the working plates was in direct contact with the tool. In case of thermally non-workable aluminum alloys that have been strain-strengthened, series 5xxx-H, a drop in microhardness is observed in the weld metal nugget. This happens as a result of the release of material, which occurs due to the heat generated by friction [7]. In Table 1, the mean values of microhardness in the respective zones are shaded.

After measuring the microhardness on the face of the weld metal, the measurement was also started on the surface normal to the face of the weld metal. It is actually the area that encompasses the entire cross-section of the joint. According to Leeb's method, it was not possible to measure the microhardness on that surface of the samples, because the joint is very thin (6mm) and a probe cannot be placed.

6. CONCLUSION

Two aluminum alloy plates were experimentally welded on a 3-axis milling machine and a lap joint was obtained using friction stir welding. The aim of this work, in addition to experimental welding, was to measure microhardness values according to Leeb's method. Until now, all measurements of the microhardness of welded joints weremade according to the Vickers method. This is actually an attempt to check if the device Innova TestTime 5350 can deliver results. In zone 2, only 2 measurements out of 22 attempts were successful. The reason for this is that the surface of the weld metal was slightly softer than the surface of the working plates, so more measurements failed. According to Leeb's method, microhardness measurements on the surface at an angle of 90° from the surface ofthe weld metal face failed, because the plates are very thin and the probe cannot be placed.
In this experimental measurement, the hardness was not measured by the typical zones of the welded joint (base metal, heat-affected zone, thermo-mechanically affected zone and the nugget), but as shownin Figure 4. In fact, the average microhardness values were obtained, which are given in Table 1. The disadvantage of the device is that the accuracy of hitting the specific place under the probe is low. And that's the reason why a typical microhardness measurement per weld zone could not be done. The microhardness measurement locations per zone were randomly selected and the measured values are given in Table 1. For this reason, average values were calculated which are shaded and are also given in Table 1.

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MECHANICAL ENGINEERING. ECOTOURISM AND RURAL DEVELOPMENT.

COMPARATIVE ANALYSIS OF THE MANUFACTURING TIME OF A PART ON A CNC LATHE OBTAINED BY CALCULATION AND SIMULATION OF MACHINING USING THE CAD/CAM SOFTWARE SYSTEM

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Abstract: *The manufacturing time is a factor that greatly affects the total cost of manufacturing a machine part. The manufacturing time and, therefore, the price of the manufactured part depend on the part's geometry, prescribed tolerances of measurements, shape and position etc. Depending on the machining method, according to generally accepted mathematical equations, the main machining time is calculated based on the machining regime obtained through machinability functions or recommended values. During the manufacturing of machine parts, CNC machines are often used. During the machining process, CNC machines execute movements based on a pre-prepared G-code program. Today's available CAD/CAM software systems, which generate G-code programs for CNC machines, also provide the main processing time for each of the defined sequences within the machining process. In this paper, a technological manufacturing process is defined for the selected machine part. The technological process includes defined operations, sequences, tools and machining regimes. Based on the manufacturing technology, the main machining times were first calculated for each sequences using mathematical equations. Subsequently, the main machining times were determined using a CAD/CAM software system. Determining the main machining times using two different methods aims to ascertain the reliability of the results provided by the CAD/CAM software system. For this purpose, a comparative analysis of the obtained results is presented, which leads to the corresponding conclusions.*
Keywords: CAD/CAM, CNC lathe, G-code, manufacturing, main time

1. INTRODUCTION

Market demands for the manufacturing of high-precision machine parts, within the shortest possible timeframe, have led to the development and implementation of software solutions, such as CAD/CAM systems. The use of CNC (Computer Numerical Control) machines has found broad application in the production of various machine parts. The accuracy of manufactured parts and reduced processing time are significant advantages of using CNC machines compared to traditional CNC machines. The machining process on a CNC machine is executed based on a pre-defined G-code instructions. Thanks to the application of CAD/CAM software, the generation of G-code programs for CNC machines has been significantly simplified. This greatly reduces both the preparation time and the main processing time for each of the defined operations within the overall machining process. The processing time represents a significant parameter from an economic perspective, and by calculating it in advance, the cost of the entire technological process can be determined. Through the analysis of the required processing time, it is possible to identify unnecessary time losses and, by rationalizing auxiliary processes, optimize the time.
The main processing time is influenced by the geometry of the machine part with specified tolerances for dimensions, shape, and position as defined on the workshop drawing.

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The main processing time for a machine part can be obtained in two ways:

- through classical calculation, which involves using traditional mathematical equations based on the machining conditions while taking into account workability functions or recommended values or
- by using appropriate CAD/CAM software.

In this paper, a comparative analysis of calculating the main processing time required for machining a machine part on a lathe using two different methods is presented. Determining the main processing times through two methods aims to assess the accuracy and reliability of the results obtained by the CAD/CAM software system being used.

2. CALCULATION OF THE MAIN PROCESSING TIME

2.1 Calculation of main processing time using traditional methods

In this paper, for the selected mechanical part provided with a workshop drawing (Figure 1.), a manufacturing process has been defined. The manufacturing process includes the following steps:

- definition of all operations,
- definition of sequnces (tools and manufacturing regimes for each sequences individually).

According to the manufacturing technology, the main processing times for each of the operations were first calculated using mathematical equations [1, 2].

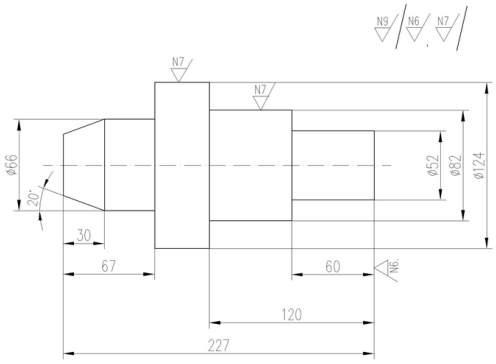

Figure 1. Sketch of mechanical part
Source: original copyright

The calculation of additive machining allowances for turning is a crucial step in the manufacturing process. These allowances are necessary to account for material removal during the machining operation and ensure that the final workpiece meets the desired dimensions and tolerances. Based on the selected additive machining allowances and the nominal dimensions of the finished part, calculated dimensions of the workpiece setup are obtained (Figure 2.):

$$D_P = 140\ mm\ ,\quad L_P = 240\ mm \tag{1}$$

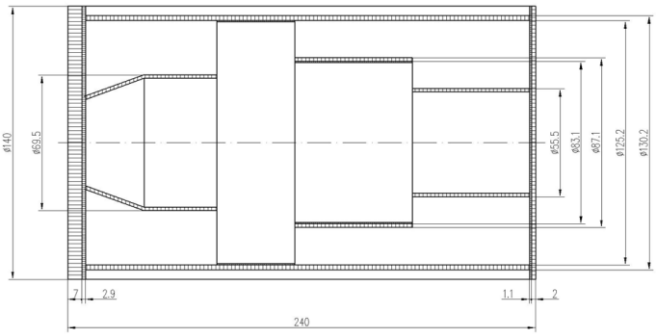

Figure 2. Workpiece definition with additive turning allowances
Source: original copyright

In manufacturing and machining, a technological process outlines the steps and procedures required to produce a specific product or component. It includes a sequence of operations, with a focus on ensuring that each operation is performed accurately and in the correct order to achieve the desired end result. Proper sequencing of operations, including tightening or fastening, is essential to ensure the quality and functionality of the final product.
The technological procedure defines appropriate operations with required sequences, as follows:

- Operation 10:
  - Sequence 01: rough radial facing of diameter Ø140 mm;
  - Sequence 02: fine radial facing (finishing) of diameter Ø140 mm;
- Operation 20:
  - Sequence 03: rough turning to diameter Ø52 mm;
  - Sequence 04: rough turning to diameter Ø83.1 mm (82 mm+1.1 mm);
  - Sequence 05: rough turning to diameter Ø125.2 mm (124 mm+1.2 mm);
  - Sequence 06: finish turning to diameter Ø82 mm;
  - Sequence 07: finish turning to diameter Ø124 mm;
- Operation 30:
  - Sequence 08: parting-off to Ø140 mm;
- Operation 40:
  - Sequence 09: rough radial facing of Ø140 mm;
  - Sequence 10: rough turning of cylinder with diameter Ø66 mm and cone from diameter Ø66 mm to diameter Ø44.162 mm.

Within each operation, processing parameters, tools, and toolpaths are defined.
Subsequently, the main processing time was calculated using traditional methods.

2.2 Calculation of main processing time through CNC machining simulation using CAD/CAM software

In the further work, a computer simulation of the machining of the required machine part on a CNC lathe is presented. The procedure for simulating the machining of the machine part on a CNC lathe is defined by an algorithm, which is provided in Figure 3.
The procedure for simulating the machining of a machine part using an appropriate CAD/CAM software system is based on the following steps [3, 4, 5]:

1. defining a 3D model within the 3D design module, based on a pre-defined workshop drawing;
2. defining a workpiece;
3. defining the coordinate system (workpiece zero point);
4. defining the machine center:
   a. definition of type of CNC machine (lathe)
   b. number of degrees of freedom
   c. fixtures
5. defining an operation:
   a. selection of type of CNC machine (lathe)
   b. define a retract surface
   c. define a coordinate system
6. defining each individual NC sequence (within the same operation):
   a. select or create a tool
   b. define NC parameters
   c. customize the tool path
7. machining process simulation, including visual monitoring of tool movement and material removal for each individual NC sequence;
8. calculating the main processing time;
9. generating CL-data;
10. postprocessing: generation of G-code for an operation.

Then, the main processing times for each sequence were determined using the CAD/CAM software system.

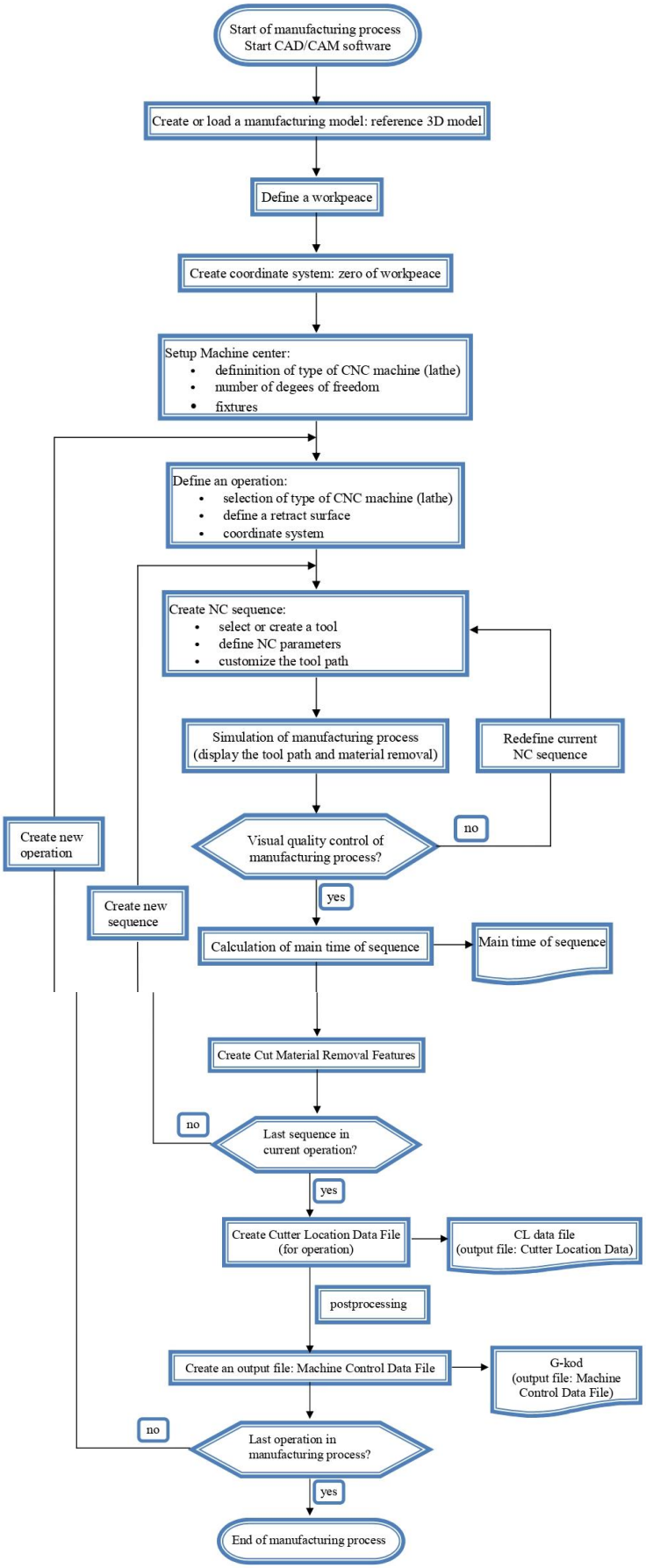

Figure 3. Algorithm
Source: original copyright

2.3 Comparative analysis of main processing times

In Table 1, a comparative overview of the main processing times is provided for traditional (conventional) machining calculations and the main processing time obtained through software simulation of machining a workpiece on a lathe.

Table 1. Operations and sequences with their respective main processing times
Source: *original copyright*

Operation	Sequence	Description	$Tm_{calculated}$ [min]	$Tm_{software}$ [min]
Operation 10	Sequence 01	rough radial facing of Ø140 mm	0.83	0.83
	Sequence 02	fine radial facing (finishing) of Ø140 mm	2.11	2.11
Operation 20	Sequence 03	rough turning to diameter Ø52 mm	*12.40	32.42
	Sequence 04	rough turning to diameter Ø83.1 mm	*9.30	24.05
	Sequence 05	rough turning to diameter Ø125.2 mm	*1.34	4.08
	Sequence 06	finish turning to diameter Ø82 mm	**0.89	0.92
	Sequence 07	finish turning to diameter Ø124 mm	**0.95	1.08
Operation 30	Sequence 08	parting-off to Ø 140 mm	32.00	32.00
Operation 40	Sequence 09	rough radial facing of Ø140 mm	0.83	0.83
	Sequence 10	rough turning of cylinder and cone	12.08	*33.26

3. CONCLUSION

Based on the data provided in Table 1, the following conclusions can be drawn:

- The main processing times for facing are identical.
- The main processing times for rough turning sequences significantly differ (marked with *). This difference is a result of taking into account the time required for the tool's back stroke, resulting in an almost double toolpath length in the software calculation compared to the classical calculation, which does not consider the time needed for the back stroke. The difference is more prominent in cases of turning sequences involving a greater number of passes (rough turning). The main processing times are approximately the same for finish turning, as they are completed in a single pass (marked with **).
- Through a detailed analysis, it has been observed that in these two types of calculations, the same measure of tool entry/exit is not included, resulting in slight deviations in the calculated main processing time.

This study has established a high level of accuracy and reliability in the results provided by the utilized CAD/CAM software system, in contrast to the classical (conventional) calculation approach.

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OPTIMIZATION OF FGD PROCESS IN TPP KOSTOLAC 'B'

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Abstract: *This paper presents the first flue gas desulphurization system in the Republic of Serbia, which was built at the Kostolac "B" thermal power plant. The applied desulfurization technology using wet limestone with forced oxidation is described. Possible increases in energy efficiency, optimization of the desulfurization process and optimization of the absorber circulation pumps were presented. When the main operating parameters of the process were changed, the results of increasing energy efficiency were shown. By increasing the absorber slurry pH value above the regulation range, it is possible to save electricity from 718 kWh to 1115 kWh per FGD unit. The pH value was increased by adding more limestone slurry to the absorbers. A larger amount of limestone slurry in the absorbers did not compromise the obtained gypsum quality and absorbers' operating performances.*
Keywords: flue gas desulfurization, energy efficiency, optimization, circulation pump

1. INTRODUCTION

Thermal power plant (TPP) Kostolac "B" has two generating units, B1 and B2, of 348.5 MW capacity each. TPP Kostolac "B" uses coal (lignite) as the main fuel with a sulfur content of 1.3 %. The emission of sulfur dioxide (SO_2) ranges from 5000 mg/Nm^3 to 7000 mg/Nm^3 per generating unit. In order to comply with the legislation of the Republic of Serbia (RS), regulation on limit values of air pollutant emissions from combustion plants ("Official Gazette of RS", no. 6/2016) [1] and the legislation of the Energy Community, that is, the EU (Directive 2010/75 /EU) on industrial emissions [2], the first flue gas desulfurization (FGD) system in the Republic of Serbia was built in the TPP Kostolac "B" for units B1 and B2. The purpose of the FGD system is to reduce SO_2 emissions by 97.5 % (desulfurization efficiency), thereby achieving emissions lower than 200 mg/Nm^3 [3], which is the limit value of SO_2 emissions according to current RS and EU legislation. The goal of the analysis shown in this paper was to save electricity, optimize the process, and optimize the absorber's circulation pumps. The research was carried out over a period of one month.

2. WET LIMESTONE FGD WITH FORSED OXIDATION TECHNOLOGY

The desulfurization of flue gas is designed to use an alkaline reagent (sorbent) to remove acidic SO_2 in flue gas according to the gas absorption, gas adsorption, or catalytic conversion desulfurization mechanism. In general, FGD systems are classified as 'wet' or 'dry', with wet systems the most common. The desulfurization technology applied in the FGD system is the desulfurization of wet limestone flue gas with forced oxidation. In this process, a limestone slurry is used as a reagent, which reacts with SO_2 to perform its absorption and neutralization [3]. The desulphurization scheme in the TPP Kostolac "B" is shown in Figure 1.

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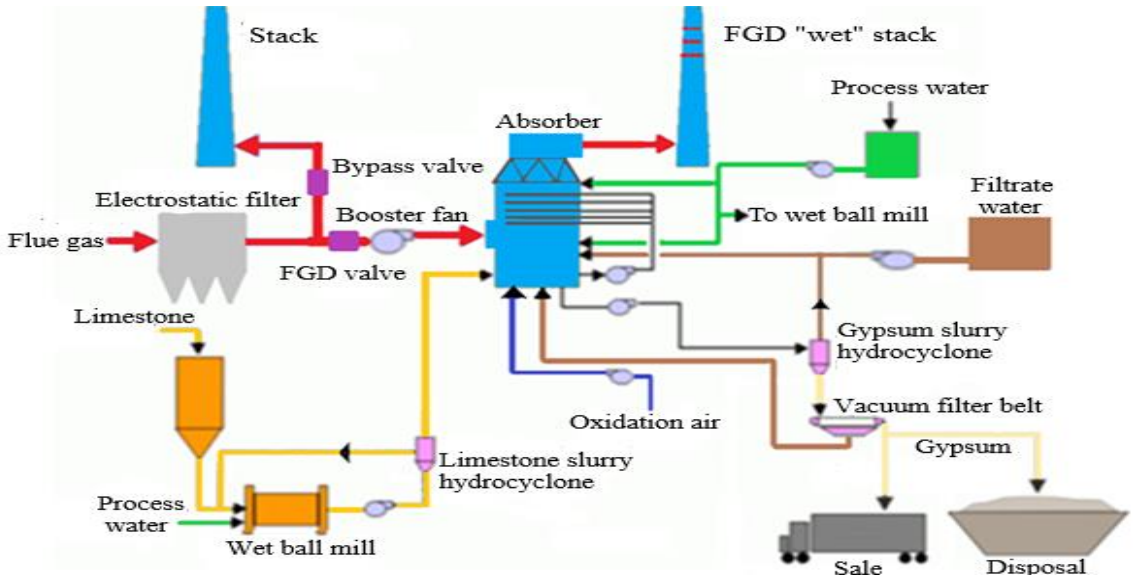

Figure 1. The desulphurization scheme in the TPP Kostolac "B"
Source: Original copyright

The flue gas, which is a product of the combustion of coal in a steam boiler, passes through an electrostatic filter. The bypass and FGD valve are used to direct the flue gas toward the FGD system or towards the stack in the case of a FGD system malfunction. The dedusted flue gas is directed towards the booster fan, in order to achieve the required flue gas velocity through the absorber. The absorber is the main component of the FGD system, a counterflow tower in which the desulfurization process takes place. The flue gas is introduced into the absorber just above the slurry level in the absorber tank and flows upward, coming into contact with the sprayed limestone slurry, which falls downward from the five spray levels. Each spraying level has its own circulation pump and distribution pipe for supplying nozzles (sprinklers) with slurry. The nozzles are arranged to ensure uniform spraying over the entire absorber cross section, ensuring uniform contact of liquid droplets and flue gas, and optimal absorption of sulfur dioxide. The ratio of slurry flow to flue gas flow is defined as the L/G ratio. The limestone slurry is prepared using a wet ball mill and a hydrocyclone to ensure the required grinding and density (solids content 30 %). The supply of the absorber with new limestone slurry is achieved through a pipeline in which the limestone slurry continuously circulates, replacing the previous one that was used for the absorption of SO_2. Dosing of the required amount of limestone slurry is done by regulating the main process parameter, the pH value of the circulating limestone slurry in the absorber slurry tank [3]. As the flue gas cools suddenly upon entering the absorber in contact with water, a certain amount of water evaporates, so the flue gas is saturated with moisture. The desulfurized flue gas is first directed through a mist eliminator to eliminate any water droplets. Following this, the gas enters the FGD "wet" stack, designed to handle wet flue gas from the absorber exit. The stack is optimized to disperse the flue gas effectively after it exits [4]. Following the reaction between the flue gas and the limestone slurry, calcium sulfite ($CaSO_3$) is generated. Then, this compound is directed by gravity into the absorber slurry tank, situated in the lower section of the absorber. Agitators in the absorber are used to prevent sedimentation of the slurry and to uniformly distribute oxidizing air in the absorber slurry tank. In the wet limestone process, an air oxidation system is used, which supplies an additional amount of oxygen in the absorber slurry tank, in order to oxidize calcium sulfite (12 hours residence time) into a more stable compound, calcium sulfate $CaSO_4$, i.e. gypsum, as a by-product of the desulphurization process with commercial use. Gypsum slurry settles at the bottom of the absorber slurry tank and when it reaches a certain density and quantity, it is transported by a gypsum bleed pump to the gypsum dehydration system. The removal of excess water from the gypsum slurry, with a solid content of approximately 25 %, was achieved using a hydrocyclone and a vacuum belt filter [3]. The outcome of the dewatering process yields gypsum as the end product, containing a moisture content of less than 10 %. The overflow (filtrate)

water from the hydrocyclone and the vacuum belt filter flows back to the absorber. Only a small amount of filtrate water is drained from the FGD system to the wastewater treatment plant. Gypsum is disposed of at the Drmno mine landfill, in case of irregular gypsum sale [3]. The construction industry is interested in this material, so almost the entire amount of gypsum is sold to wallboard and cement manufacturers. The FGD gypsum must comply with the quality criteria defined by Eurogypsum, presented in Table 1.

Table 1. Quality Criteria for FGD Gypsum
Source: https://fenix.tecnico.ulisboa.pt/downloadFile/1689244997256407/resumo.pdf

Quality Parameter	Unit	Quality Criteria
Moisture (H_2O)	mass %	<10
Calcium sulfate bihydrate ($CaSO_4.2H_2O$)	mass %	>95
Magnesium salts, water soluble	mass %	<0.10
Sodium salts, water soluble	mass %	<0.06
Chlorides (Cl^-)	mass %	<0.01
Calcium sulfite hemihydrate ($CaSO_3.^1/_2H_2O$)	mass %	<0.5
pH		5 - 9
Color		White
Odor		Neutral
Toxicity		Non-toxic

Eurogypsum, the European federation representing the gypsum product manufacturing industry, created a standard for FGD gypsum. Depending on the commercial use of gypsum, there may be different quality specifications [5]. Manufacturers of wallboard and cement sourcing gypsum from TPP Kostolac "B" demand adherence to the Eurogypsum standard. The most important criteria are gypsum purity (calcium sulfate bihydrate content), moisture, and chloride content.

3. OPTIMIZATION OF FGD PROCESS

The initial hypothesis of this research derives from the correlation of the FGD process parameters: limestone slurry density, limestone slurry flow rate added to the absorber, absorber slurry pH value, the gypsum quality criteria obtained, the operating order and number of absorber circulation pumps, the SO_2 inlet and outlet values SO_2. Through many years of research and experience with FGD systems, it is concluded that the pH value range of the absorber slurry should be regulated and used between 5 and 6. When the pH value of the absorber's slurry falls below the specified range, it leads to a decrease in the desulfurization efficiency. In contrast, if the pH exceeds the desired range, there is a higher removal of SO_2, but this results in a reduced gypsum purity [5]. The pH value of the absorber slurry is a crucial parameter of the FGD process that is constantly regulated and controlled during operation and has a direct impact on the efficiency of desulfurization, the amount of limestone used, and the quality of the gypsum [6]. In this research, the pH value was increased above 6 in both absorbers, to turn off one circulation pump of each absorber and thus save electricity. In addition, the goal was to maintain sulfur dioxide within the emission limit value and to maintain the obtained gypsum quality. According to the instructions of the Chinese company BOQI/NEPDI-Beijing, which built the FGD system in the TPP Kostolac "B", four absorber circulation pumps are continuously running, with an additional one serving as a backup. The circulation pumps are named A, B, C, D and E, from bottom to top, according to the spray levels of 20.4 m to 28.4 m [3]. Before the research, the pH value was maintained within the range of 5.2 to 5.8, following the same instructions provided. During operation, the A, C, D and E circulation pumps were in use. In order to make research results

as valid as possible, the density of the limestone slurry was kept constant at 1250 kg/m^3 (mean value of the regulation range). The gypsum obtained from both absorbers is stored in one depot. In order to make the obtained gypsum sample as valid as possible, research was done for both FGD units. To increase the pH value to 6.2, limestone slurry flow added to the absorbers has increased from the previous 30 m^3/h average to 35 m^3/h average per one absorber and the SO_2 output was 60 mg/Nm^3. At that moment, as the fourth operating pump, the circulation pump A of both absorbers was turned off. During the operation of circulation pumps C, D and E, the input SO_2 value ranged from 5100 mg/Nm^3 to 6100 mg/Nm^3, the outlet SO_2 value ranged from 160 mg/Nm^3 to 200 mg/Nm^3. Adding more limestone than required for the desulfurization process can consequently lead to residual (excess) limestone in the absorber slurry tank and thus in the gypsum [6]. Residual limestone in gypsum can compromise its purity. This was determined by daily FGD chemical analyzes, providing FGD system operators with insight into the FGD process and guidance on how to manage it further. The average values of limestone slurry, gypsum, and absorber slurry during the research period are shown in Table 2.

Table 2. Monthly FGD report
Source: TPP Kostolac „B"-Chemistry department

TPP Kostolac "B" Chemistry department	**MONTHLY FGD REPORT**	04.15.2023. 8:00 h	
LIMESTONE SLURRY ANALYSIS			
Parameter	**The limit values**	**Limestone slurry**	
Density (kg/m^3)	1250±50	1246.29	
$CaCO_3$ (%)	≥94.00	94.39	
Grinding (<44μm)	>85%	96.97	
GYPSUM ANALYSIS			
Parameter	**The limit values**	**Gypsum**	
Moisture (%)	<10.00	7.17	
$CaCO_3$ (%)	<1.50	1.17	
$CaSO_4 \cdot 2H_2O$	≥93.00	98.02	
ABSORBER SLURRY ANALYSIS			
Parameter	**The limit values**	**Absorber 1**	**Absorber 1**
pH	5.0-5.6	6.15	6.25
Density (kg/m^3)	1160±80	1176.12	1183.17
$CaCO_3$ (%)	<3.00	1.25	1.14
$CaSO_4 \cdot 2H_2O$	≥93.00	97.48	97.44

Gypsum analyses showed the limestone content in gypsum was 1.17 %, which did not exceed the limit value of 1.50 %, that is, obtained gypsum purity was not compromised. Before the research, with four operating circulation pumps, the value of $CaCO_3$ (%) in gypsum was 0.3 % in daily chemical analyses. The excess of limestone in the absorber is deposited and leads to the formation of deposits that can negatively affect the absorber performance. After three months of operation with three circulation pumps, the absorber inspection hatch was opened; larger limestone deposits than usual were not observed.

3.1 Saving electricity

The average electricity consumption before the investigation was 8.5 MW/h per FGD unit. The consumption per FGD unit is higher if the gypsum dewatering process is in progress. Devices that consume the most electricity are booster fans, wet ball mills, oxidation fans, vacuum pumps, and absorber circulation pumps. The electricity consumption of the absorber circulation pumps varies depending on the minimum and maximum density of the absorber slurry during FGD operation, as shown in Table 3.

Table 3. Circulation pumps electricity consumption depending on absorber slurry density for units 1 and 2.
Source: Original copyright

Slurry circulating pumps for units 1 and 2	Minimum slurry density 1080 kg/m^3	Maximum slurry density 1240 kg/m^3
Slurry circulating pump A	466 kWh	561 kWh
Slurry circulating pump B	523 kWh	617 kWh
Slurry circulating pump C	605 kWh	674 kWh
Slurry circulating pump D	636 kWh	750 kWh
Slurry circulating pump E	649 kWh	800 kWh

The shutdown of the circulation pump resulted in a decrease in the resistance to flue gases, thus reducing the spray level. Consequently, this led to a reduction in the load on the booster fan and, consequently, a decrease in its electricity consumption. The booster fan load fluctuates due to the regulation of flue gas under pressure. As a result of the circulation pump shutdown, the electricity consumption of the booster fan was reduced by approximately 252 kWh to 315 kWh. The smallest amount of electricity is saved when the 'A' pump is turned off at the lowest absorber slurry density and the booster fan's electricity consumption of 252 kWh. For one FGD unit, that is:

$$466\,kWh + 252\,kWh = 718\,kWh \tag{1}$$

The greatest amount of electricity is saved when the E pump is turned off at the highest slurry density and the booster fan electricity consumption of 315 kWh. For one FGD unit, that is:

$$800\,kWh + 315\,kWh = 1115\,kWh \tag{2}$$

Limestone slurry density in absorber reaches its minimum and maximum value during one day due to the formation of gypsum and its drainage from the absorber, so that the average saving during the day is 916.5 kWh. The working schedule of the circulation pumps is constantly changed in order to equalize their working time. The FGD system is in operation about 300 days a year. With three circulation pumps in operation, it is possible to save electricity of 6,598.8 MWh on an annual basis on average. Shutting down any circulation pump results in electricity savings, reduced pump run time, resulting in lower pump maintenance costs, and longer pump life [6]. The sequence in which the pumps operate influences the desulfurization efficiency by determining the duration of contact between the flue gas and the limestone slurry. A higher spray level provides more contact time between the flue gas and the limestone slurry and a higher desulfurization efficiency.

4. FURTHER FGD PROCESS OPTIMIZATION DIRECTIONS

Further optimization directions are software implementation, such as the CENTUM VP integrated process control system, i.e., the process optimization system of the Japanese company Yokogawa Electric Corporation. CENTUM VP regulates outlet SO_2 value. Based on the input SO_2 value and limestone density slurry value, it performs an optimized pH value calculation and limestone slurry flow, turns off one circulation pump and changes pumps operating order. After the pH value is adjusted to 6.3, gypsum is produced with a purity of over 95%. The advantages of CENTUM VP are: saving electricity, optimal limestone usage, monitoring operating times of each circulation pump and equalizing operating times of the pumps, shortened operating times of the pumps (lower pumps

maintenance costs) and extended pumps life. The FGD system of a 700 MW thermal power plant in Japan implemented the CENTUM VP. The FGD was in operation about 300 days a year. An optimization system was employed to reduce active circulation pumps from five to three, resulting in annual cost savings of 900,000 dollars, in accordance with market conditions in Japan. Furthermore, this modification successfully maintained the outlet SO_2 value below the specified regulatory threshold [7, 8, 9].

5. CONCLUSION

The FGD process often creates an unnecessarily large gap between the required and actual SO_2 output value. The optimization system solves this problem by turning off one circulation pump while keeping the SO_2 output below the emission limit value, so this operating mode is the most economical. When SO_2 inlet concentration reaches a critical value (>6500 mg/Nm^3) the operation of three pumps will exceed the SO_2 emission limit value. The additional circulation pump must be turned on at that time. The research findings suggest that it is achievable to optimize the FGD process while simultaneously staying within SO_2 emissions limits, upholding gypsum quality standards, and cutting down maintenance costs for the FGD system. Investment in optimizing the FGD process is profitable in several ways, as shown in this paper.

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MATHEMATICAL MODEL OF CAR ROTATING DURING OVERTAKING IN A LEFT ROADWAY CURVE

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Abstract: *The aim of the work is to establish the basic kinematic and dynamic parameters important for ensuring vehicle stability during the overtaking procedure in a critical situation. The movement of the vehicle during overtaking, which is considered by this paper, is realized in a curve to the left, which implies, first, a straight line movement, then entering the curve with the center of rotation on the opposite side from the center of the roadway curve, and then returning the vehicle to the roadway curve. This paper investigarte potential loss of stability occurs due to drifting and skidding of the vehicle during rotation, as well as due to the loss of contact of the rear wheels with the ground.*
Keywords: *Vehicle stability, Roadway curve, Kinetic energy*

1. INTRODUCTION

The work defines the procedure for overtaking a vehicle in a curve to the left, whereby the return of an overtaking vehicle to the lane in front of the vehicle being overtaken is realized by moving along a graded curve with damping to the right. After that, the overtaking vehicle enters the curve with the center of rotation on the opposite side of the previous one. The overtaking procedure is realized through three phases: straight-line movement, rotations in front of the vehicle being overtaken, as well as through the return to the the roadway curve line.
Previously, these are to be adopted:

- input parameters, the initial speed of the overtaking vehicle, the speed of the vehicle being overtaken and the amount of acceleration / deceleration on the straight section, as well as the angle of the corresponding curve of the vehicle returning to the lane in front of the vehicle being overtaken,
- roadway parameters: roadway curve angle of lateral and longitudinal slope and coefficient of rolling and sliding friction,
- boundary conditions that refer to the condition that the speed of the overtaking vehicle must not be less or equel to zero nor greater than the permissible speeds defined by the vehicle's stability conditions.

The paper describes the mathematical model on the basis of which the author of the paper created the program package: ACADPRET. The application of the software package to some variants of overtaking is given in the paper. The main contribution of the work is the definition of roadway parameters:

- the corresponding minimum required radius of the roadway curve,
- coefficient of sliding friction from the aspect of the roadway surface,
- the size of the appropriate longitudinal and lateral slope of the roadway,

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in order to maintain the stability of the vehicle in case of imposed initial overtaking conditions. The variants refer to the driver's response in cases if he would accelerate on a straight section in order to avoid a conflict with an oncoming vehicle, or he would slow down in order not to enter the lane in front of an vehicle being overtaken too fast in order to avoid loss of stability. The program itself "corrects" the entered initial values, as the output being consisted of the maximum possible admissible initial values.

2. ANALYSIS OF THE VEHICLE ROTATING IN THE CURVE TO THE LEFT

As it is mentioned vehicle movement during overtaking is considered through three phases:

1. Overtaking along the rectilinear path; it is foreseen with variable initial speed, [5, 6], and with possibility for acceleration maximum absolute 4.5[m/s^2], as well as to be varied by program in order to control speed on the end of rectilinear path. Also, the value of the speed is not to be insufficient due to overtaking time being too long because it could cause conflict of the vehicles.
2. Vehicle rotates to right, in front of the vehicle being overtaken, [1] along the arc defined by the curve in the form: $f(x) = const \cdot \left(1 - e^{bx}\right)$,
3. Vehicle turns to right, rotating along the circle with the center on the opposite roadway side comparing the previous one. Speed which the vehicle exiting the previous curve line is equal to velocity vehicle entering this one.

3. MATHEMATICAL MODEL OF VEHICLE MOVEMENT

This analysis is important by the reason of critical situations have to be considered as to prevent skidding, [2] and [3], Figure 1 [4].

3.1. Rectilinear movement

Function which is taking in consideration the roadway parameters is in the form, [5]:

$$f_1 = -a_p \cdot m_v + G_v \cdot \left(\cos\alpha_p \cdot \mu_k + \sin\alpha_p\right).$$

Parameter which is taking into consideration the air resistance is in the form: $K = \frac{A_č \cdot c_x \cdot \rho_v}{2}$,

Where are:

- $A_č$ – Equivalent front vehicle area [m^2],
- c_x - Aerodynamic coefficient,
- ρ_v – Air density, [kg/m^3],
- m_v – Vehicle mass [kg],
- G_v – Vehicle gravity [N],
- μ_k – Sliding friction coefficient,
- a_p - Acceleration on rectilinear section, [m/s^2],
- α_p – Lateral slope angle.

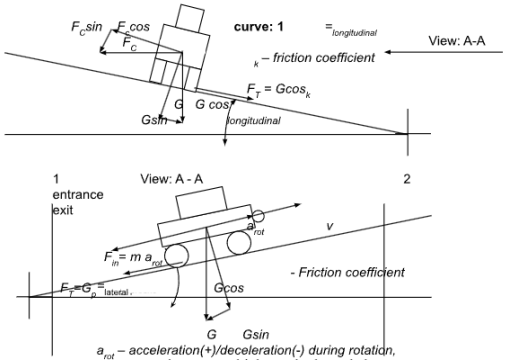

Figure 1. Vehicle on the lateral slope
Source: Authors

By the point of view of the initial speed, the velocity with which vehicle enters into the curve 1, (rotation in front of the vehicle being overtaken) is in the form:

$$v_{ul_1} = \sqrt{v_0^2 \cdot \left(1 - K \cdot \frac{l_p}{m_v}\right) - \frac{2 \cdot l_p \cdot f_1}{m_m} \cdot \frac{1}{1 + \frac{K \cdot l_p}{m_v}}}. \tag{3.1}$$

Acceleration on the rectilinear section could be found from the condition that expression (3.1) is to be ≥0:

$$\text{if } v_0^2 \cdot \left(1 - K \cdot \frac{l_p}{m_v}\right) - \frac{2 \cdot l_p \cdot f_1}{m_v} \cdot \frac{1}{1 + \frac{K \cdot l_p}{m_v}} < 0 \Rightarrow \text{if } a_p < 0 \Rightarrow a_p = a_p - \Delta a_p \rightarrow f_1,$$

$$\text{if } v_0^2 \cdot \left(1 - K \cdot \frac{l_p}{m_v}\right) - \frac{2 \cdot l_p \cdot f_1}{m_v} \cdot \frac{1}{1 + \frac{K \cdot l_p}{m_v}} < 0 \Rightarrow \text{if } a_p > 0 \Rightarrow a_p = a_p + \Delta a_p \rightarrow f_1.$$

On the other side, maximum permissible speed must not be exceeded. By that reason it follows:

$$\text{if } v_{ul_1} > v_{\max} \Rightarrow \text{if } a_p < 0 \Rightarrow a_p = a_p + \Delta a_p \rightarrow f_1,$$

$$\text{if } v_{ul_1} > v_{\max} \Rightarrow \text{if } a_p > 0 \Rightarrow a_p = a_p - \Delta a_p \rightarrow f_1.$$

In any case, the desired value of acceleration/deceleration: a_p on the straight section is the input data, so the speed with which the vehicle enters curve 1 is obtained as high as possible.

3.2. Curvilinear movement

Speed of the vehicle which is overtaking, on the lines along the curves 1 and 2, Figure 2, [5] and [6], could be found on the basis of boundary velocities established by the condition of skidding absence on the curve 1, (3.2) and on the curve 2, (3.3). The less value is critical and represents maximum speed which must not be exceeded.

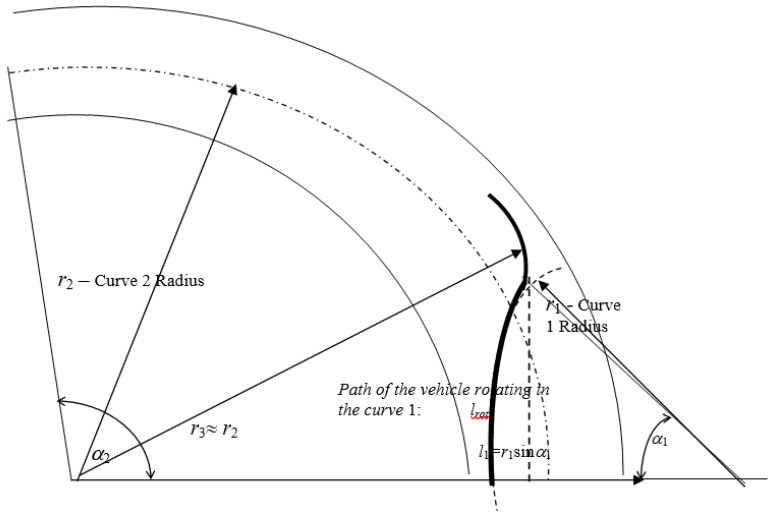

Figure 2. Curvilinear section of the roadway
Source: Authors

Boundary speed in curve 1 is in function of radius 1 and lateral slope of the roadway for the difference of the other one which is function of the radius 2 and longitudinal slope of the roadway, Figure 2 and Figure 3:

$$v_{iz_1 boundary} = \sqrt{\frac{r_1 \cdot G_v \cdot \left(\cos\alpha_p \cdot \mu_p - \sin\alpha_u\right)}{\left(\cos\alpha_p + \sin\alpha_p \cdot \mu_p\right) \cdot m_v}}, \tag{3.2}$$

$$v_{iz_2 boundary} = \sqrt{\frac{r_2 \cdot G_v \cdot \left(\cos\alpha_u \cdot \mu_p + \sin\alpha_u\right)}{\left(\cos\alpha_u - \sin\alpha_u \cdot \mu_p\right) \cdot m_v}} \tag{3.3}$$

Vehicle movement path in curve 1 is defined by:

$$f(x) = l_1 \cdot \left(1 - e^{-bx}\right), x \in (0, k), k = r_1 - r_1 \cdot \cos\alpha_1 \text{ , } b = 1 \text{ – attenuation rate,} \tag{3.2}$$

While: $l_1 = r_1 \sin\alpha_1$ and $r_1 = f(\alpha_1)$.

Path length is defined, [5,6,7], according to (3.2), by:

$$l_{rot} = \int_0^{r_1 - r_1\cos\alpha_1} \sqrt{1 + f'(x)^2}\, dx \text{ , } f'(x) = l_1 \cdot e^{-x} \Rightarrow l_{rot} = \int_0^{r_1 - r_1\cos\alpha_1} \sqrt{1 + \left(l_1 \cdot e^{-x}\right)^2}\, dx \text{ .} \tag{3.3}$$

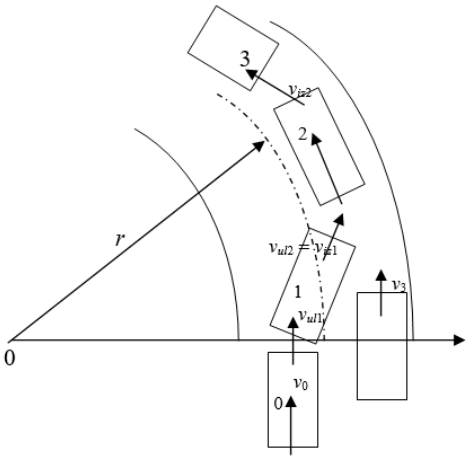

Figure 3. Vehicle positions during overtaking procedure
Source: Authors

Correlation between r_1 and α_1, Figure 2 is defined by regression curve has got by using least squares method, in the form: $r_1 = k_2 \cdot e^{\frac{1}{\alpha_1}}, k_2 \in (15,\ldots,30)$. In calculation, value for k_2 is adopted in the sum of 20. Circumstances that must be met are as follows:

$$\text{if } v_{iz_1} > v_{gran} \Rightarrow a_{rot} = a_{rot} - \Delta a_{rot}, v_{gran} = v_{iz1gran} \wedge v_{iz2gran}.$$

Acceleration and deceleration during rotation are regulation sizes by which it is possible to modify the velocity to be inside the limits. In the case as follows:

$$\left(\cos\alpha_p \cdot \mu_p - \sin\alpha_p\right) < 0 \Rightarrow \alpha_p = \alpha_p - \Delta\alpha_p, \alpha_p > 0, \alpha_p = \alpha_p + \Delta\alpha_p, \alpha_p < 0\,,$$

it is necessary to correct the lateral slope.

Value for the vehicle speed leaving the curve 1 that is vehicle speed entering the curve 2 is to be found by:

$$l_{rot} = \frac{m_v \cdot \left(v_{ul_1}^2 - v_{iz_1}^2\right)}{2 \cdot \left(a_{rot} \cdot m_v + G_v \cdot \left(\cos\alpha_u \cdot \mu_p + \sin\alpha_u\right) + const_4 \cdot \frac{\left(v_{ul_1}^2 + v_{iz_1}^{2\ldots}\right)}{2}\right)}, a_{rot} < 0, \tag{3.4}$$

$$l_{rot} = \frac{m_v \cdot \left(v_{ul_1}^2 - v_{iz_1}^2\right)}{2 \cdot \left(a_{rot} \cdot m_v + G_v \cdot \left(\cos\alpha_u \cdot \mu_k + \sin\alpha_u\right) + const_4 \cdot \frac{\left(v_{ul_1}^2 + v_{iz_1}^{2..}\right)}{2}\right)}, a_{rot} \geq 0, \quad (3.5)$$

where μ_p and μ_k represent sliding and rolling friction coefficients. Overtaking duration time could be found on the basis of expression (3.6) for the overtaking vehicle and according to (3.7):

$$t_{v_1} = \frac{2 \cdot l_p}{v_o + v_{ul_1}} + \frac{l_{rot}}{\left(v_{ul_1} + v_{iz_1}\right) \cdot \frac{1}{2}}, \quad (3.6)$$

$$t_{v_2} = \frac{l_p}{v_2} + \frac{r_2 \cdot \alpha_2[rad]}{v_2}. \quad (3.7)$$

Conflict of the vehicles will occur if $t_{v_{,1}} > t_{v_2}$. Loss of vehicle stability due to detaching rear wheels off the roadway line will appear in the cases when reactions on the rear wheels in curves 1 and 2:

$$F_{b_1} = \frac{F_{in_{rot}} \cdot h_c + G_v \cdot \left(\cos\alpha_p \cdot l_1 + \sin(\alpha_p) \cdot h_c\right)}{l_v}, \text{ and } F_{b_2} = \frac{F_{in_{rot}} \cdot h_c + G_v \cdot \left(\cos\alpha_u \cdot l_1 + \sin(\alpha_u) \cdot h_c\right)}{l_v},$$

where inertia force is in the form: $\vec{F}_{in\,rot} = m_v \cdot \vec{a}_{rot}$, respectively, become less then zero. In such cases program routines are to correct F_b by increasing roadway slope in the form:

$$\text{if } F_{b_1} < 0 \Rightarrow \alpha_u = \alpha_u + \Delta\alpha_u, \text{ and if } F_{b3} < 0 \Rightarrow \alpha_p = \alpha_p + \Delta\alpha_p.$$

4. SOFTWARE FOR OVERTAKING AND ANALYSIS OF RESULTS

Analysis of vehicle stability is realized using the program package: ACADPRET, implemented by the author of the paper at the Academy of Applied Technical Studies in Belgrade. The program package foresees the establishment of appropriate accelerations/decelerations on the straight section in order to enable overtaking and during the rotation so that there is no loss of stability and no conflict of the overtaking vehicle with the overtaken. Output files from calculation are as follows:

ANALYSES OF OVERTAKING IN THE CURVE TO THE LEFT
ROADWAY DATA

Roadway curve radius R_2: 250 [m], Longitudinal roadway slope: 4 [%], Lateral roadway slope:-.5 [%],
Rectilinear section lenth l= 300 [m], Sliding friction coefficient: .2, Rolling friction coefficient: .02,
Established radius of the curve corresponding to returning vehicle in front of the one being overtaken: 56.78 [m],
Angle of the arc corresponding vehicle to returning in front of the one being overtaken: 60 [step],
Length of the path corresponding vehicle to returning in front of the one being overtaken: lrot= 73.69 [m].

VEHICLE DATA

Overtaken vehicle speed: 25 [km/h], Duration of time spent by the vehicle being overtaken Tv2= 43.19 [sec.]
Front area of the overtaking vehicle: 2 [m^2] Mass of overtaking vehicle 1000 [kg]
Aerodinamic coefficient of the overtaking vehicle: .35 Center of gravity hight for overtaking vehicle: .5 [m]
Interaxial distance for overtaking vehicle : 3.2 [m] Horizontally distance from front axis to center of gravity for overtaking vehicle: 1.5 [m]

CALCULATION RESULTS

Vmax= 39.9 [km/h]

Variant: 1 V0= 0 [km/h]
OVERTAKING IS NOT POSSIBLE TO REALIZE
Variant: 2 V0= 13.33 [km/h]
OVERTAKING IS NOT POSSIBLE TO REALIZE

Variant: 3 V0= 26.66 [km/h], Acceleration along rectilinear section - established: au= .71 [m/sec^2]
alfau= 4 [%], alfap=-.5 [%]
Venter1= 39.95 [km/h] Vexit1= 37.53 [km/h] Brot=-.1 [m/sec.^2] Fb1= 4.57 [kN] Fb2= 4.64 [kN]
Tv1= 39.27 [sec.]

Vmax= 60 [km/h]

Variant: 1 V0= 0 [km/h], Acceleration along rectilinear section - established: au= 1.05 [m/sec^2]
alfau= 4 [%], alfap=-.5 [%], Vexit1limit= 37.5 [km/h] Venter2limit= 87.69 [km/h]
Venter1= 59.99 [km/h] Vexit1= 37.89 [km/h] Brot= .9 [m/sec.^2] Fb1= 4.73 [kN] Fb2= 4.79 [kN]
Tv1= 41.42 [sec.]

Variant: 2 V0= 20 [km/h], Acceleration along rectilinear section - established: au= 1 [m/sec^2]
alfau= 4 [%]. alfap=-.5 [%],Vexit1limit= 37.5 [km/h] Venter2limit= 87.69 [km/h]
Venter1= 59.97 [km/h] Vexit1= 37.86 [km/h] Brot= .9 [m/sec.^2] Fb1= 4.73 [kN] Fb2= 4.79 [kN] Tv1= 32.43 [sec.]

Variant: 3 V0= 40 [km/h], Acceleration along rectilinear section - established: au= .87 [m/sec^2]
alfau= 4 [%], alfap=-.5 [%], Vexit1limit= 37.5 [km/h] Venter2limit= 87.69 [km/h]
Venter1= 59.97 [km/h] Vexit1= 37.87 [km/h] Brot= .9 [m/sec.^2] Fb1= 4.73 [kN] Fb2= 4.79 [kN] Tv1= 27.02 [sec.]

Vmax= 80 [km/h]

Variant: 1 V0= 0 [km/h], Acceleration along rectilinear section - established: au= 1.41 [m/sec^2]
alfau= 4 [%], alfap=-.5 [%], Vexit1limit= 37.5 [km/h] Venter2limit= 87.69 [km/h]
Venter1= 79.99 [km/h] Vexit1= 35.84 [km/h] Brot= 2.4 [m/sec.^2] Fb1= 4.96 [kN] Fb2= 5.03 [kN] Tv1= 31.58 [sec.]

Variant: 2 V0= 26.66 [km/h], Acceleration along rectilinear section - established: au= 1.33 [m/sec^2]
alfau= 4 [%], alfap=-.5 [%],Vexit1limit= 37.5 [km/h] Venter2limit= 87.69 [km/h]
Venter1= 79.96 [km/h] Vexit1= 35.79 [km/h] Brot= 2.4 [m/sec.^2] Fb1= 4.96 [kN] Fb2= 5.03 [kN] Tv1= 24.84 [sec.]

Variant: 3 V0= 53.33 [km/h], Acceleration along rectilinear section - established: au= 1.09 [m/sec^2]
alfau= 4 [%], alfap=-.5 [%], Vexit1limit= 37.5 [km/h] Venter2limit= 87.69 [km/h]
Venter1= 79.97 [km/h] Vexit1= 35.82 [km/h] Brot= 2.4 [m/sec.^2] Fb1= 4.96 [kN] Fb2= 5.03 [kN] Tv1= 20.78 [sec.]

EXPLANATION OF THE SIGNS

au - acceleration / deceleration on rectilinear section
Venter1 – Speed with which vehicle enters in front of the vehicle being overtaken [km/h]
Vexit1 – Speed with which vehicle enters in the roadway curve [km/h]
Vexit1limit – Boundary speed with which vehicle could leave the curve in front of the vehicle being overtaken [km/h]
Venter2limit – Boundary speed with which vehicle could enter in the roadway curve [km/h]
Brot – Deceleration on the curvilinear section [m/s^2]
Fb1 – Reaction on the rear wheels in the curve: 1 [kN]
Fb3 - Reaction on the rear wheels in the curve: 2 [kN]
Tv1 – Duration of the overtaking time for overtaking vehicle [sec.]
Tv2 - Duration of the overtaking time for vehicle being overtaken [sec.]
Vmax – Maximum permissible speed [km/h]
alfau - Longitudinal roadway slope – established
alfap - Lateral roadway slope - established

Difference between that one and the speed with which vehicle enters the curve 1 is criteria for obtaining the value of deceleration. Figure 4 shows the diagrammatically dependence of acceleration along the rectilinear section and the acceptable total overtaking time from the speed at the beginning of overtaking for specific permissible maximum speed.

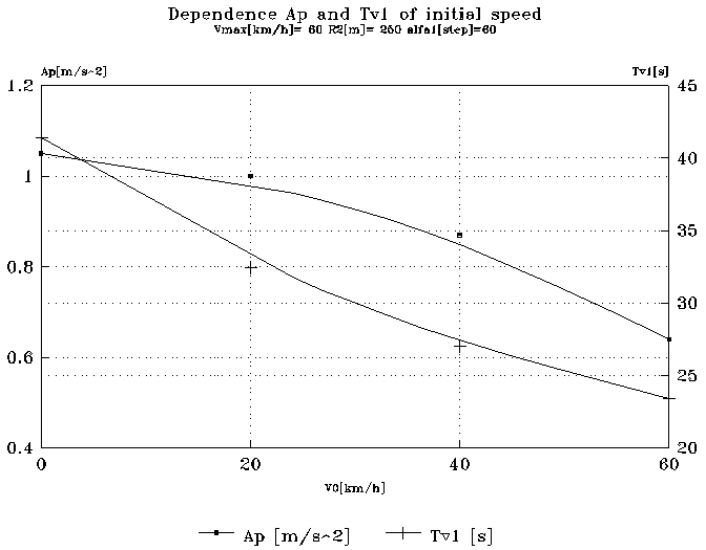

Figure 4. Dependence of acceleration along the rectilinear section and the acceptable total overtaking time from the speed at the beginning of overtaking
Source: ACADPRET, Harward Graphics and Authors

From calculation, it is clear that acceleration on the rectilinear section rises by growing the maximum of the permissible speed. On the other side that acceleration decreases by growing the speed on the beginning of overtaking. Deceleration along the curvilinear section rises with the growing the speed at the end of rectilinear section as well as with the lateral slope if it rises in minus direction. Also it is clear that speed with which vehicle exits the curve 1 is imposed with the lower of two boundary speeds.

5. CONCLUSION

The paper deals with the physics of vehicle behavior during overtaking in a left turn. In doing so, the critical case was chosen when the vehicle, during overtaking, enters a curve with the center on the opposite side from the center of the roadway curve, after which it enters the roadway curve. The work deals with cases of possible loss of stability due to vehicle skidding after returning in the roadway line, in front of an overtaken vehicle and when enter a roadway curve, afterwards. Drifting is caused by a discrepancy between vehicle speed at critical points, due to inappropriate acceleration / deceleration and roadway parameters. Loss of stability can also occur due to the redistribution of the load on the vehicle caused by sudden braking and in conjunction with specific boundary conditions from the roadway aspect. Based on that, the main contribution of the Paper is formation coupling of the roadway parameters with the imposed boundary conditions of vehicle movement.

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THE LATEST STANDARDS OF ROLLING BEARING TESTING

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Abstract: *The wide use of rolling bearings requires a high level of control. Bearing damage can lead to serious consequences such as equipment failure, loss of control, human injury, increased maintenance costs, and issues with quality control. To reduce these risks, it is crucial to have bearings thoroughly tested and confirmed for their properties and accuracy before they are introduced to the market and put into use. In Serbia, this is achieved through the engagement of two accredited laboratories specializing in rolling bearing testing. These laboratories adhere to standards and regulations mandated by the state. By performing measurements and assessing permitted deviations for specific properties, they ascertain whether a bearing can effectively fulfill its intended function. The standards and methods for rolling bearing testing used in the LIMES laboratory (Laboratory for testing machine elements and systems) are presented in this paper.*
Keywords: standards, rolling bearings, measuring, tolerances, hardness, vibrations

1. INTRODUCTION

Standards have significant importance because they bring social, economic and technological benefits. For example, the whole planet benefits from standards that help protect the environment, such as standards for air and water quality, soil, gas emissions, and radiation. Also, standards related to traffic safety, machinery, tools, and similar areas contribute to the overall quality of life. In the field of economy and technology, standards enable a presence in global markets and a broader product offering, facilitate trade between countries, accelerate the penetration and application of innovations (particularly standards in terms of terminology, compliance, and safety), ensure product and service compliance with standards ensures their quality, safety, reliability etc.

1.1 History of standardization

Today's standardization is considered to be based on industrial standardization related to the middle of the 19th century and the development of the railway industry. The primary goal was to produce individual parts independently at different places and enable assembly at a third location without the need for subsequent processing or modification. The production of weaponry, firefighting equipment, machine tools, and later automobiles played a significant role in the development of industrial standardization.
In the beginning, standardization was developed within individual factories, and then it extended to related factories within the same industrial sector. Following that, standards were introduced that were valid at the state or regional level. These days, every developed nation has its own bodies where

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members are representatives from manufacturers, consumers, and scientific institutions. Finally, in order to harmonize standards at the global level, ISO was founded.

2. ISO (INTERNATIONAL ORGANIZATION FOR STANDARDIZATION)

ISO (International Organization for Standardization) is an independent, non-governmental international organization with a membership of 169 national standards bodies. ISO was founded on February 23, 1947. Up to date, it has published 24987 international standards, covering almost all aspects of technology, management, and manufacturing [1]. It has 824 technical committees (TCs) and subcommittees (SCs) to oversee standards development. The organization develops and publishes standardization in all technical and nontechnical fields, except for electrical and electronic engineering, which is handled by the IEC.

3. ISS

The Institute for Standardization of Serbia (ISS) is the sole national body for standardization in the Republic of Serbia. The founder of the Institute is the Government of the Republic of Serbia. ISS issues Serbian standards, which are indicated by a designation that begins with the abbreviation “SRPS”, followed by a sequence of numbers and letters that precisely identify the standard.
For example, in the case of the "SRPS ISO 1132-2:2017" standard, the meaning of the parts of the designation is as follows: "SRPS" indicates that it's a Serbian standard; "ISO" indicates that it's based on an international standard by the International Organization for Standardization; "1132-2" is the specific identifier for this standard within the ISO series; and "2017" represents the year when the standard was adopted or published.

4. BEARING

In a bearing, the connection between moving and stationary parts of a structure is achieved, namely, between parts rotating at different angular speeds. Relatively moving surfaces can exhibit either roll or slide against each other, leading to the classification into rolling bearings and plain bearings.
In the case of plain bearings, the moving surface slides along the stationary surface of the bearing's housing. To reduce friction, lubricant is introduced between the surfaces, and the bearing housing is typically made from materials with a low coefficient of friction.
Rolling bearings enable rolling friction to predominate during the relative motion of the working surfaces by inserting rolling elements, such as rollers or balls, between the stationary and moving surfaces.

4.1 The importance of bearing control

Depending on the nature of the damage and the intended function, bearing damage in mechanical systems can lead to a variety of dangerous consequences. Numerous machines and equipment depend significantly on their bearings, which might fail and cause a number of operational and safety issues. Potential dangers resulting from bearing damage include:

- Equipment failure: Damage to the bearings may result in total failure of the machinery (unexpected standstill, lost output, and expenses).
- Loss of control: In certain situations, such as in vehicles or airplanes, bearing damage can lead to unwanted vibrations and loss of control that can cause accidents and injuries.
- Fire and explosion: High friction resulting from damaged bearings can produce heat, which can lead to an explosion or fire, particularly in areas where flammable materials are present.
- Human injury: When bearing failure occurs, equipment may move unexpectedly and violently, injuring people around it.

- Increased maintenance costs: Frequent bearing damage can increase maintenance and repair costs, reducing the profitability and reliability of the machinery.
- Issues with quality control: Damage to bearings during precise manufacturing can compromise the accuracy and quality of the items produced, resulting in potential recalls and product issues.
- Etc.

This is why stringent bearing control is essential. In this paper, the focus will be on testing rolling bearings. In order to protect the country's economy, it is essential to pay attention to the quality of the bearings that are introduced to the market and put into use. For that purpose, the Republic of Serbia has adopted „Rulebook on technical and other requirements for rolling bearings" [8] and some standards that prescribe the conditions that the bearing must fulfill. Compliance with the conditions specified in those documents is determined in certified laboratories.
In the Republic of Serbia, there are two certified laboratories for rolling bearing testing. One of them is located within the rolling bearing factory FKL in Temerin. The other one is laboratory LIMES (Laboratory for testing machine elements and systems), located at the Faculty of Mechanical Engineering in Belgrade (Fig. 1).

Figure 1. Laboratory LIMES (Laboratory for testing machine elements and systems)
Source: Laboratory LIMES

This paper will present standards and methods used in certified laboratory LIMES.
The standards adopted by ISS that are used for rolling bearing control in LIMES are:

- Tolerances and radial clearance: SRPS ISO 1132-2:2017
- Hardness: SRPS ISO 6508-1:2017
- Vibrations:
  - SRPS ISO 15242-1:2018
  - SRPS ISO 15242-2:2018
  - SRPS ISO 15242-3:2018

5. TOLERANCE - SRPS ISO 1132-1:2016, SRPS ISO 1132-2:2017

The "SRPS ISO 1132-1:2016" standard was adopted on December 23, 2016, replacing the "SRPS ISO 1132-1:2015" standard. This standard is identical to ISO 1132-1:2000, Rolling bearings – Tolerances –Part 1: Terms and definitions.

The "SRPS ISO 1132-2:2017" standard was published on June 26, 2017. and replaced the "SRPS M.C3.800:1965". This standard is identical to ISO 1132-2:2000, Rolling bearings – Tolerances – Part 2: Measuring and gauging principles and methods.

The preparation for tolerance testing involves several steps. First, it is necessary to bring the measuring equipment, the reference standard (etalon), and the part being tested to room temperature (the recommended value is 20°C). Then, it is necessary to remove the anti-corrosion agent from the bearing surfaces to eliminate the possibility that the lubricant and a sealing or protective ring adversely affect the accuracy of the measurement, which is conducted on open bearings.
After the measurement, the bearing should be protected from corrosion.

5.1 Measurement principle of bore and outside diameter

Measuring devices for bore and outside diameter testing are different, but the principle of measurement is the same. This method can be applied to all types of rolling bearings. The first step is to zero the measuring indicator using an etalon. After the rolling bearing is positioned, the smallest and largest bore and outside diameter are measured in several radial planes. Based on these values, the average diameter, diameter deviation, and diameter variation are determined. Allowable tolerances are standardized, and based on them, it is determined that the diameters (bore or outside diameter) of the given rolling bearing are within allowed limits.

5.2 Measurement principle of radial clearance

The bearing is mounted on a mandrel. Then, the indicator is positioned toward the outer surface of the outer ring, in the direction of the centre of the rolling path. The mandrel rotates the inner ring. Radial load is applied, and it is possible to read the value of radial clearance on the scale.

6. HARDNES - SRPS EN ISO 6508-1:2017

The "SRPS EN ISO 6508-1:2017" standard was adopted on April 30, 2018, replacing the "SRPS EN ISO 6508-1:2016" standard. This standard is identical with EN ISO 6508-1:2016, Metallic materials – Rockwell hardness test –Part 1: Test method.

The measurement principle of the Rockwell method involves applying an initial (preload) force to indent the indenter. Then, an additional force is applied, and upon its termination, the force value returns to the initial value. Afterward, the depth of the indentation is measured. Many digital devices measure the depth, but they only display the hardness value.
To calculate hardness using the Rockwell method, in addition to the difference between the initial and final indentation depth (h), it is necessary to determine two more constants that depend on the scale (N and S) and apply the following formula:

$$\mathrm{HR} = N - \frac{h}{S} \tag{1}$$

The indenter can be in the form of a diamond cone or ball made of a tungsten carbide alloy. In LIMES, the HRC (Rockwell C) scale is used. In that case, the indenter type is diamond cone, the initial force (F_0) is 98.07 N, the total force (F) is 1.471 kN, the scale constant (S) is 0.002 mm, the full-scale constant (N) is 100, and the hardness range is from 20 HRC to 70 HRC, although the values below 35 HRC are unreliable. The formula for calculating HRC hardness is:

$$\mathrm{HRC} = 100 - \frac{h}{0.002} \tag{2}$$

Although there are many approximate conversion tables, there is no reliable way to accurately convert hardness measured on one scale to another (HB or HV) or to tensile strength.

7. VIBRATION

7.1 SRPS ISO 15242-1:2018

The "SRPS ISO 15242-1:2018" standard was adopted on March 26, 2018. and replaced the "SRPS ISO 15242-1:2016 " standard. This standard is identical to ISO 15242-1:2015, Rolling bearings – Measuring methods for vibration – Part 1: Fundamentals.

According to this standard, to determine the vibrations of a rotating rolling bearing, a measuring transducer is placed at a specific location on one of the bearing rings or on a device connected to one of the rings. The standard prescribes that the quantity to be measured is the speed of vibrations. The bearing under the determined load rotates at a constant frequency of rotation, and the signal from the measuring transducer is monitored. In the vast majority of cases, the outer ring is stationary and the inner ring is movable (although rare cases may have the opposite configuration).
The conditions required for vibration measurement depend on whether the bearings are pre-lubricated or not. If the bearings are previously lubricated, they are measured in the delivered condition. Previously unlubricated bearings should be thoroughly cleaned and lubricated with fine-filtered oil. Afterward, it is necessary to run-in the bearing in order to achieve a homogeneous distribution of the lubricant.
There are three scales on the vibration measuring device for three frequency ranges. Permitted values for each range can be found in the Rulebook on technical and other requirements for rolling bearings [8].

7.2 SRPS ISO 15242-2:2018

The "SRPS ISO 15242-2:2018" standard was adopted on March 26, 2018, replacing the "SRPS ISO 15242-2:2016" standard. This standard is identical to ISO 15242-2:2015, Rolling bearings – Measuring methods for vibration – Part 2: Radial ball bearings with cylindrical bore and outside surface.

As the title suggests, this part of the standard provides a detailed discussion of radial ball bearings. During the testing of these bearings, the rotation frequency should be 1800 min^{-1} (30 s^{-1}), with a specified tolerance range. Additionally, an axial load is applied to the bearing; first on one side of the stationary ring, and then the measurement is repeated with the load on the other side. Except in the case of single-row angular contact ball bearings. For their testing, the axial force acts in the direction of receiving the axial load of the bearing. Before measuring, it is necessary to position the measuring transducer on the outer surface of the stationary ring in the plane that is in the middle of the rolling contact path of the stationary ring.

7.3 SRPS ISO 15242-3:2018

The "SRPS ISO 15242-3:2018" standard was adopted on March 26, 2018, replacing the "SRPS ISO 15242-3:2016" standard. This standard is identical to ISO 15242-3:2017, Rolling bearings – Measuring methods for vibration – Part 3: Radial spherical and tapered roller bearings with cylindrical bore and outside surface.

This document refers to double-row radial cylindrical roller bearings and to single-row and double-row radial tapered roller bearings. The rotation frequency for measurements should be 900 min^{-1} (15 s^{-1}), and the measurement time should be at least 1 second.
Vibrations of double-row cylindrical roller bearings and tapered roller bearings are measured using a similar approach as that for radial ball bearings. However, for single-row radial tapered-rolled bearings, a specific loading force is applied in the direction of receiving the axial load.

When conducting measurements, it is necessary to position the measuring transducer on the outer surface of the stationary ring in the plane that is in the middle of the rolling contact path of the stationary ring.

8. CONCLUSION

In the Republic of Serbia, there are two accredited laboratories for testing rolling bearings. They use standards and regulations mandated by the State. On the basis of measurements and the permitted deviations of certain values, they determine whether the bearing corresponds to the customer order or prescribed technical documentation. The main contribution of this paper is to clarify the methods and standards used in the control of rolling bearings and to raise awareness about the importance of strict control measures for these bearings. By emphasising the role of thorough testing in accredited laboratories before market introduction, the paper aims to underscore that such measures not only protect end-users from potential hazards like equipment failure and human injury but also serve as a safeguard for manufacturers. A strict control system not only ensures the introduction of higher quality bearings but also contributes to establishing a competitive market environment. By raising the standard, it encourages innovation and quality production, ultimately benefiting manufacturers, customers, and the overall economic health of the country.

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SOLAR-POWERED FARMING: EVALUATING THE VIABILITY OF PV WATER PUMPING IN TURKISH AGRICULTURE

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Abstract: *This study investigates the viability of solar photovoltaic (PV) water pumping systems in three Turkish cities, Antalya, Aydın, and Samsun, focusing on their efficacy in agricultural irrigation. The research uses PVsyst software to examine the interplay between solar irradiation, water demand, and pump efficiency. Results reveal varying effectiveness among the provinces due to disparities in solar irradiation. Antalya and Aydın meet 97.69% and 96.43% of their annual water needs, respectively, while Samsun achieves only 73.99%, emphasizing the critical role of irradiation intensity. Evaluation of unused energy demonstrates surplus of 263 kWh for Antalya, 39 kWh for Aydın, and optimal energy utilization for Samsun. The Performance Ratio (PR) analysis underscores higher efficiency for Samsun due to its lower irradiation levels. These findings contribute valuable insights for regional solar energy applications, emphasizing the significance of location-specific strategies in advancing renewable energy technologies.*
Keywords: Solar Photovoltaic Systems, Agricultural Irrigation, Solar Irradiation, Water Pumping Efficiency, Renewable Energy Applications

1. INTRODUCTION

Energy efficiency is crucial globally since energy sources tend to decrease with increasing population. Renewable energy resources are utilized as alternatives to traditional ones. For instance, solar energy is clean and environmentally friendly without requiring maintenance [1]. It is also related to the availability of solar energy and water demand [2]. However, the negative effects of local drought and global warming on water resources should be considered. Considering these issues, more efficient agricultural irrigation is an important factor that could reduce the risk of threatening water sources. It is well-known that a pump is one of the critical elements for agricultural irrigation. Electrical energy and fossil fuels are widely used for the operation of pumps.

Nonetheless, the electricity availability of rural areas is a matter of general debate [3]. The same situation could be valid for fossil fuels. Mainly, shortfalls in the water pumping system could be provided via rainwater [4]. However, it may not be possible for all climate conditions. For this reason, alternative energy resources are also considered for the power requirement of the pumps. Based on these deductions, solar photovoltaic (PV) water pumping systems are significant for protecting water resources and are effective for energy sources. Solar PV water pumping systems are observed for areas without grid connections [5].

Additionally, surplus energy generated by the solar pumping systems can be effectively utilized for various supplementary needs. The pumps operate exclusively on solar energy in regions with abundant solar radiation. However, in cases where solar radiation is insufficient, an alternative energy source is required to ensure the continuous operation of the pumps. Moreover, cleaner drinking water

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could be supplied via solar PV water pumping systems [6]. For livestock water supply, these systems are also used [7]. The previous studies examined overall efficiency, component efficiency, economical availability, and design optimization for these systems [2]. One of these deductions is that the pump flow rate depends on solar radiation and PV array size [8]. For this reason, these systems are very influential in regions where greenhouse cultivation is intense. Loxsom and Durongkaveroj [9] compared four locations in the USA by using a developed algorithm related to solar PV water pumping systems. The total volume of pumped water has been predicted monthly by considering solar insolation data. Similarly, Kou et al. [10] used weather data, including horizontal radiation and temperature, to estimate long-term system performance in the USA. Arab et al. [11] considered four different stations in Algeria to analyze the system performance based on meteorological year data. The system optimization has been presented as a result of various configurations. Pande et al. [12] considered a pump for drip irrigation in arid zones. Several parameters have been taken into account for their system. Benghanem et al. [13] proposed an optimum array design supplying ideal energy for a pump used in Saudi Arabia. Setiawan et al. [14] recommended two significant parameters of solar water pumping system for India. Ammar et al. [15] estimated PV power to balance generated energy and pump requirements. Miran et al. [16] presented the optimization result for the design of a PV drip irrigation system.

2. MATERIAL AND METHODS

In this study, simulations for solar PV water pumping systems have been made for three provinces of Türkiye consisting of Antalya, Aydın, and Samsun, using PVsyst software. It is known that plants grown in summer need more water than plants grown in winter. Therefore, water need varies according to months, as in the simulation. The monthly water needs for the simulation have been given in Table 1.

Table 1. The variations in daily average water requirements for different months

Months	Daily Average Water Need	Months	Daily Average Water Need
January	70 m³/day	July	110 m³/day
February	80 m³/day	August	105 m³/day
March	90 m³/day	September	100 m³/day
April	100 m³/day	October	90 m³/day
May	105 m³/day	November	80 m³/day
June	110 m³/day	December	70 m³/day

Table 2. Drilling, well, and tank characteristics

Characteristics	Value	Characteristics	Value
Static level depth	-40 m	Number of elbows	2
Specific drawdown	-3 m/m³/h	Friction losses	0.5 m
Well Diameter	15 cm	Tank volume	150 m³
Pump level	-90 m	Diameter of tank	5 m
Lower dynamic level	-85 m	Pipe type	DN65
Pipe length	95 m	Tank altitude	5 m

The head is an important parameter for pump applications. In order to start the simulation, drilling and the well characteristics must be determined. Drilling, well, and tank properties used in the simulations have been given in Table 2.
Hydraulic power is calculated with the expression presented in Eq. (1) using the properties given in Table 2.

$$P_H = \frac{\rho\ g\ H\ \dot{Q}}{3.6 \times 10^6} \tag{1}$$

In this equation, ρ is water density, g is gravitational acceleration, H is static level depth, and $\dot{Q}$ is water flow rate. A pump driver converts electrical energy into shaft energy. In this case, certain losses occur while converting hydraulic power into shaft power. The shaft power of the pump is obtained as the ratio of the hydraulic power to the hydraulic efficiency of the pump (η_H), as in Eq. (2).

$$P_S = \frac{P_H}{\eta_H} \tag{2}$$

The energy required for the pump shaft is obtained from PV systems. Energy attained from PV systems is also subjected to certain losses while being transmitted to the shaft. The PV power (P_{PV}) is provided by using the shaft power of the pump. PV power is the ratio of the pump shaft power to the derate factor (DF), as seen in Eq. (3).

$$P_{PV} = \frac{P_S}{DF} \tag{3}$$

The parameters of the system have been given in Table 2, and the expressions of Eq. (1), (2), and (3) have been indicated in Table 3.

Table 3. Power of the pump and PV system used in agricultural areas

Parameter	Value
ρ	1000 kg/m^3
g	9.81 m/s^2
H	40 m
$\dot{Q}$	15 m^3/h
P_H	1.635 kW
P_S	4.672 kW ~ 4.8 kW
DF	0.825
P_{PV}	6 kW

Pump power has been determined as 4.8 kW for the pump, with a daily average flow rate of 92.5 m³/day. Four PS-1800 HR-14H models from the Lorentz brand with 1.2 kW power have been chosen as pumps connected in series. The PV system providing the pump power has been determined as 6 kW. Twenty units of LG 300 N1C-B3 models with 300 W from LG Electronics have been used as the PV module. PV modules consist of five strings and four series. In all systems, a tilt angle of 35° and an azimuth angle of 0° have been used.

3. RESULT AND DISCUSSION

Effective global irradiation is one of the most important parameters affecting the efficiency of PV systems [17-20]. Monthly average practical global irradiation values of Antalya, Aydın, and Samsun provinces considered within the scope of the study have been given in Figure 1.

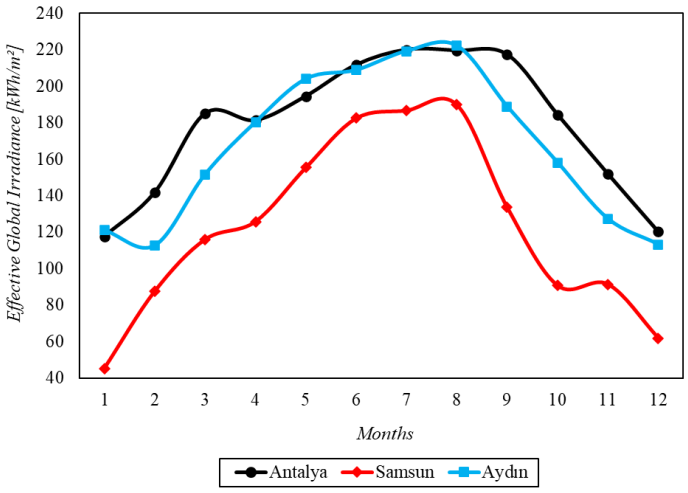

Figure 1. Monthly average effective global irradiation values of Antalya, Aydın, and Samsun

Table 4. Water needs of the system and water supply amounts of three cities

Months	Volume of water needs [m³]	Antalya		Aydın		Samsun	
		Volume of water used [m³]	Adequacy percentage [%]	Volume of water used [m³]	Adequacy percentage [%]	Volume of water used [m³]	Adequacy percentage [%]
January	2170	1921	88.53	2056	94.75	985	45.39
February	2240	2240	100.00	2005	89.51	1631	72.81
March	2790	2789	99.96	2661	95.38	2050	73.48
April	3000	2855	95.17	2959	98.63	2157	71.90
May	3255	3126	96.04	3215	98.77	2573	79.05
June	3300	3226	97.76	3271	99.12	2873	87.06
July	3410	3320	97.36	3309	97.04	3019	88.53
August	3255	3242	99.60	3255	100.00	3023	92.87
September	3000	3000	100.00	3000	100.00	2237	74.57
October	2790	2790	100.00	2636	94.48	1615	57.89
November	2400	2400	100.00	2174	90.58	1635	68.13
December	2170	2092	96.41	2034	93.73	1196	55.12
Overall	**33780**	**33001**	**97.69**	**32575**	**96.43**	**24994**	**73.99**

As expected, effective global irradiation increases towards the summer months and decreases towards the winter months in all cities. These irradiation values reaching the panel surface appear higher in Antalya and Aydın, located in the southern part of Türkiye, compared to Samsun, located in the north of Türkiye. Effective global irradiation values are 2145.7 kWh/m², 2007.5 kWh/m², and 1466.8 kWh/m² for Antalya, Aydın, and Samsun, respectively. Since the irradiation reaching the panel surface affects electricity production and system performance, the pump systems in Antalya and Aydın pump water. The water needs of the simulated system and the amounts of water pumped for the three cities have been shown in Table 4.

Water supply percentages are 97.69%, 96.43%, and 73.99% for Antalya, Aydın, and Samsun, respectively. For monthly examination, the entire water need is met in February, September, October, and November for Antalya, while it is only met in August and September for Aydın. On the other hand, the same situation is not valid for Samsun in any month. In addition to the amount of water pumped in these systems, many results could be obtained, such as unused energy in PV systems. The main results of these systems have been presented in Table 5.

Table 5. Main results the considered solar PV pumping systems

	Antalya	Aydın	Samsun
Water used	33001 m³	32575 m³	24994 m³
Specific volume	794 m³/kWp/bar	788 m³/kWp/bar	652 m³/kWp/bar
Water needs	33780 m³	33780 m³	33780 m³
Missing water	2.31 %	3.57 %	26.01 %
Energy at pump	10472 kWh	10126 kWh	7584 kWh
Specific energy	0.32 kWh/m³	0.31 kWh/m³	0.30 kWh/m³
Unused PV energy	263 kWh	39 kWh	0 kWh
Unused fraction	2.3 %	0.4 %	0 %
PV System efficiency	93.2 %	95.3 %	94.8 %
Pump efficiency	65.8 %	66.2 %	66.1 %

A critical significance metric is the surplus energy within PV systems. Specifically, the energy surplus in PV systems amounts to 263 kWh, 39 kWh, and 0 kWh for Antalya, Aydın, and Samsun, respectively. Within the PVsyst software framework, the Performance Ratio (PR) is an essential parameter utilized, a value computed according to Equation (4). This metric stands as a pivotal indicator, reflecting the efficiency and effectiveness of the PV systems under consideration.

$$PR = \frac{Energy\ at\ pump}{Incident\ global\ irradiation \times P_{PV}} \tag{4}$$

Annual incident global irradiation values are 2195.9 kWh/m², 2057.2 kWh/m², and 1502.1 kWh/² for Antalya, Aydın, and Samsun, respectively. Annual and monthly average PR values for Antalya, Aydın, and Samsun have been shown in Figure 2.

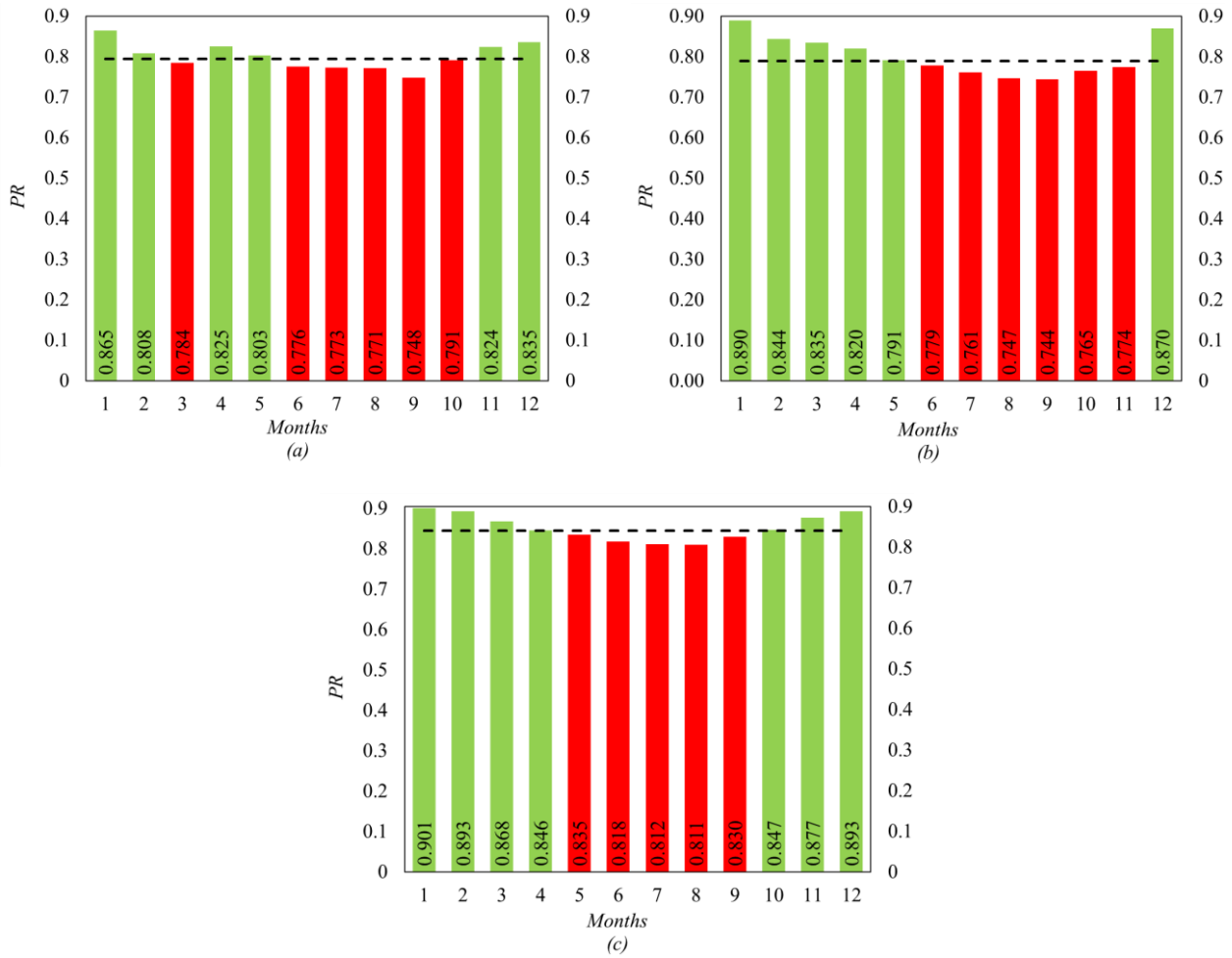

Figure 2. Annual and monthly average PR values of *(a)* Antalya, *(b)* Aydın, and *(c)* Samsun

The annual average PR values of Antalya, Aydın, and Samsun are 0.795, 0.820, and 0.841, respectively. Since PR is inversely proportional to the irradiation intensity reaching the panel surface, it is maximum in Samsun and minimum in Antalya.

4. CONCLUSIONS

The present study modeled the PV system-assisted pump system for three cities, including Antalya, Aydın, and Samsun, via PVsyst. The following statements have been listed as given below.

- Effective global irradiation values are 2145.7 kWh/m², 2007.5 kWh/m², and 1466.8 kWh/m² for Antalya, Aydın, and Samsun, respectively.
- Antalya and Aydın exhibited commendable performance, meeting 97.69% and 96.43% of their annual water needs, respectively. In contrast, Samsun achieved a modest 73.99%, underscoring the pivotal role of solar irradiation levels.
- Notably, Antalya demonstrated an unused energy surplus of 263 kWh, Aydın 39 kWh, and Samsun efficiently utilized all generated energy.
- Additionally, the PR analysis reinforced these findings, with Antalya, Aydın, and Samsun exhibiting annual average PR values of 0.795, 0.820, and 0.841, respectively.

While the system seems quite suitable for Antalya and Aydın, the 6 kWp PV system is insufficient for Samsun due to insufficient irradiation intensity. It is recommended to increase the installed capacity of the PV system for Samsun.

These findings underscore the critical importance of location-specific strategies in advancing renewable energy technologies. The study offers valuable insights into regional solar energy applications, emphasizing the need for tailored approaches in harnessing the potential of solar PV water pumping systems for sustainable agricultural practices.

Future studies could explore these systems' economic feasibility and scalability on a larger agricultural scale, considering varying crops and regional water demands, which would provide valuable insights for sustainable agricultural practices.

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THE PHENOMENA OF RIGID AND REVERSE WATERHAMMER AND THEIR INFLUENCE ON MAINTENANCE OF HYDROPOWER PLANTS WITH KAPLAN TURBINES

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Abstract: *Considerable amount of power produced worldwide is obtained from hydropower plants (HPPs). This remains one of the cleanest available renewable power sources. Initial investment in construction of HPPs is often high and their life cycles span decades in almost continuous operation. This is the reason why revitalization of exhisting hydropower facility may be viable choice compared to building a new one. Revitalization of HPP consists of many tasks and has to take into account various phenomena. Unsteady regimes both in water supply systems or HPPs, precisely in their pipelines, could be very harmful and dangerous and might provoke damage of the critical infrastructure when they ocurre. Paper reviews various aspects of Kaplan turbine maintenance and causes of downtime. More than hundred years since its inception, Kaplan turbine remains in use worldwide in many of the hydropower facilities. In more detail the phenomena of rigid and reverse waterhammer are explored and examined in this paper. Both rigid and reverse waterhammer, if occure during exploitation of HPP, can result in many negative consequences on its operation. On site measurements are combined with numerical simulations to suggest values of parameters of influence in order to prevent both these harmfull phenomena to appear.*
Keywords: Kaplan Turbine, Measurements, Numerical Simulations, Reverse and Rigid Water-hammer

1. INTRODUCTION

Kaplan turbine has been designed more than 100 ago. Still this type of turbine is in use in many hidro-power plants throughout the world and remains in focus of reserchers, designers and builders [1-5]. When a hydropower plant (HPP) is planned and designed initial cost of investment is high. This is the reason why it is viable choice to revitalize existing HPP instead of building a new one in some cases (and in some places). Revitalization of a HPP consists of many tasks. One obvious task can be to make transition from legacy technologies to contemporary technologies that often provide new options in plant‘s operation. If it is possible, together with revitalization of the plant, assesment should be made if its capacity can be expanded. Various phenomena should be examined and taken into account. Among these of great importance are transient regimes. Revitalization of the HPP often tries to reach two concurrent goals. One is the increase of the aggregate power and another is the trend to simultaneously reduce the machine dimensions. However, these two aspirations in design make the probability higher for transient regimes to appear in the plant after it is built.

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Transient regimes in technical systems can be the cause of failure or loss. Transient regimes in HPPs can be either normal or emergency. If they appear/ occur in HPPs, water supply systems, in oil pipelines or in pipelines in general, these are very dangerous and may turn harmful to critical infrastructure. Technical diagnostics following issues with transient regimes usually finds visible evidence on a HPP itself. Some consequences of occurrence of transient regimes in a HPP can be visible not just on a plant, but in one country or even throughout the world.

2. REQUIREMENTS OF MATHEMATICAL MODELLING AND MEASUREMENTS

Models should be made as close as possible to the real world systems they tend to be modelling. Kaplan turbine is being modelled in order to optimize its performance [1-5]. Timely and detailed analysis of transient regimes in order to avoid their occurrence contributes to the improvement of operational safety, higher reliability and functional safety of a whole hydropower plant. At the same time the reduction of waste and losses is enabled as well as the number of unwanted issues or events and damages are decreased on minimum. During the analysis of transient regimes in hydropower plants it is necessary to take in consideration inertia and pressure force, friction force and gravitational force, water compressibility and influence of elasticity on tunnel or pipeline walls.
One of the transient regimes in hydropowerplants and pipelines is denoted as reverse waterhammer. Rigid waterhammer is also example of a transient regime in HPP. The theory of rigid waterhammer is the first and the simplest theory among the theories of unsteady streaming. If either of these transient regimes occur this could have many negative consequences on the exploitation of hydropower plant. In order to prevent these unwanted transient regimes (either reverse or rigid waterhammer) to occure and to aleviate their consequences three turbine models were tested in the laboratory conditions [1-3]. All three turbines were of the same runner diameter, namely 9.5 m. Variables of importance and parameters of the models were computed by the numerical software. The first is the model of the existing turbine with specific rotational speed $n_Q = 137$, while the other two models were derived for the two revitalized turbines that have $n_Q = 133$ and $n_Q = 135$ respectively [2, 4].
All three installed Kaplan turbines have the same runner diameter, and results obtained in modelling the reverse waterhammer were similar. However, any of the three turbines did not pass critical values of axial hydraulic force, pressure on the turbine cover, etc. It was difficult at all times to obtain the discharge measurements in huge cross sections, which were within a wide range from 100 m^3/s to 840 m^3/s. For all three cases the high measurement accuracy and repetition of measured results were obtained in measuring the turbine power output (assesed from the generator output), and the variation of the turbine net head due to electricity consumption limitations. Hydraulic and energy turbine characteristics were tested and unit efficiency determined at the net head close to the rated one. Maximal rotational speed for each of the three turbines was obtained and calculated in the relative form/ units based on rotational speed that they achieve each in its own optimum.

3. INFLUENCE ON KAPLAN TURBINES IN HPPS CAUSED BY RIGID WATERHAMMER

The mathematical model of the unsteady discharge is based on the theory of the rigid waterhammer. The model of rigid waterhammer occurrence consists of a system of differential equations describing case of air introduction into the intake behind the inlet wheel gate. This model is simplified by neglecting the fluid compressibility and the elasticity of pipeline walls therefore it assumes that the water in supply pipes behaves like a rigid body.
The model of the turbo machine behaviour during the normal transient regime is determined usually based on the data obtained from the monitoring of the turbine model and expressed in so-called propeller curves. Several positions of runner blades with different values of guide vans opening can be obtained from those propeller curves. The basic equation for studying water masses behaviour is the dynamic balance equation, which is expressed as [2, 3]:

$$\frac{\mathrm{d}h}{\mathrm{d}x}+\frac{1}{g}\frac{\mathrm{d}c}{\mathrm{d}t}+\lambda\frac{c|c|}{2D}=0\,, \tag{1}$$

where the fluid density, ρ, is assumed to be constant. The list of all symbols is given in notations. Mathematical model of rigid waterhammer is applicable on relatively slow change of boundary conditions because fluid is assumed to behave like a rigid body – its compressibility doesn't exist. However if boundary conditions change rapidly, pressure change is high, or even huge and this is significant because it is usually followed by changes in the fluid density. Mathematical model which is derived and applicable under those conditions is well known as the hydraulic waterhammer. This is the case in Kaplan turbines, where the time for a pressure change and discharge change is shorter than the pipeline reflection time. The scheme of a low-net head HPP is given in Figure 1.a) [3], [2].

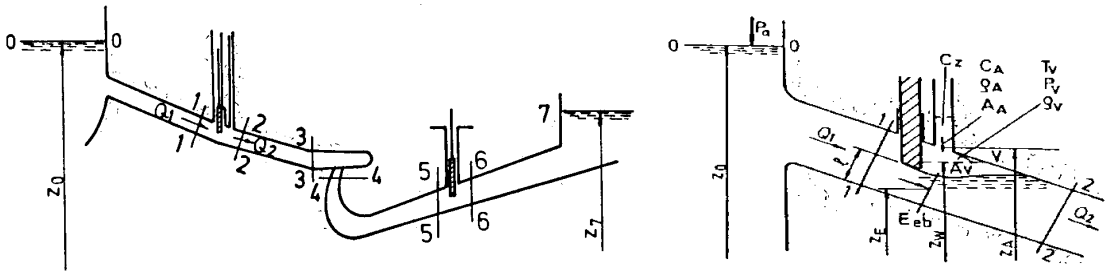

Figure 1. a) Scheme of mathematical model (on the left) [3], **b)** Intake structure (on the right) [3].

Unsteady discharge in the system is described by the following equations [2, 3]:

$$\frac{\mathrm{d}Q_1}{\mathrm{d}t}=\frac{\dfrac{p_a-p_v}{\rho}+g(z_0-z_v)-\sum_0^1\left(\dfrac{\lambda l}{4R_h}+\zeta\right)\dfrac{Q_1^2}{2A^2}}{\displaystyle\int_{l_0}^{l_1}\frac{dl}{A}} \tag{2}$$

$$\frac{\mathrm{d}Q_2}{\mathrm{d}t}=\frac{\dfrac{p_a-p_v}{\rho}+g(z_v-z_7-H)-\sum_2^7\left(\dfrac{\lambda l}{4R_h}+\zeta\right)\dfrac{Q_2^2}{2A^2}}{\displaystyle\int_{l_2}^{l_7}\frac{dl}{A}} \tag{3}$$

When discharges Q_1 and Q_2 are different ($Q_1 \neq Q_2$) and water elevation in the aeration pipe, z_v, is below z_a ($z_v < z_a$), then air discharge appears into the inlet structure (shown in Figure 1.b)). The corresponding equations describing this case are [3], [2]:

$$\frac{\mathrm{d}V_v}{\mathrm{d}t}=Q_1-Q_2\,,\qquad \frac{\mathrm{d}M_v}{\mathrm{d}t}=A_v\rho_v c_z\,,\qquad \frac{\mathrm{d}Z_v}{\mathrm{d}t}=\frac{Q_2-Q_1}{A_v} \tag{4}$$

where

$$\rho_v=\frac{M_v}{V_v}\,,\qquad p_v=\rho_v RT \tag{5}$$

$$c_z=\varphi\sqrt{\frac{2\kappa}{\kappa+1}\frac{p_a}{\rho_a}}\,,\qquad \rho_v=\rho_a\left(\frac{2}{\kappa+1}\right)^{\frac{1}{\kappa-1}},\quad \text{if}\quad p_v\le p_a\left(\frac{2}{\kappa+1}\right)^{\frac{1}{\kappa-1}} \tag{6}$$

$$c_z = \varphi \sqrt{\frac{2\kappa}{\kappa-1}\frac{p_a}{\rho_a}\left[1-\left(\frac{p_V}{p_a}\right)^{\frac{\kappa}{\kappa-1}}\right]}, \quad \rho_V = \rho_a\left(\frac{p_V}{p_a}\right)^{\frac{1}{\kappa}}, \quad \text{if} \quad p_v > p_a\left(\frac{2}{\kappa+1}\right)^{\frac{1}{\kappa-1}} \tag{7}$$

$$\rho_V = \lim_{V_V \to 0} \frac{M_V}{V_V} = \frac{0}{0} = \frac{p_V}{RT_V} \tag{8}$$

$$c_z = \frac{Q_2 - Q_1}{A_V}, \quad p_V = p_a, \quad \rho_V = \rho_a, \quad p_V = p_a - \frac{\rho_a c_z |c_z|}{2\varphi^2} \quad \text{if} \quad c < 40 \text{ m/s} \tag{9}$$

4. INFLUENCE ON KAPLAN TURBINES IN HPPS CAUSED BY REVERSE WATERHAMMER

To prevent reverse waterhammer, ranges for many physical values have to be determined appropriately. Among these neccesarry limit values, maximal and minimal pressure in the system and maximal rotational speed have to be assessed. Analyses of normal transient regimes on HPPs are focused on determination of the maximal net head cover pressure in the system and maximal rotational speed. It doesn't mean that low-pressure field, if appears, cannot endanger system safety especially if cavitation is present. Several different methods exist that can be used to estimate the risk of occurrence of reverse waterhammer; the two of these are: 1. the integral method or average pressure above turbine runner, and 2. the pressure distribution method.

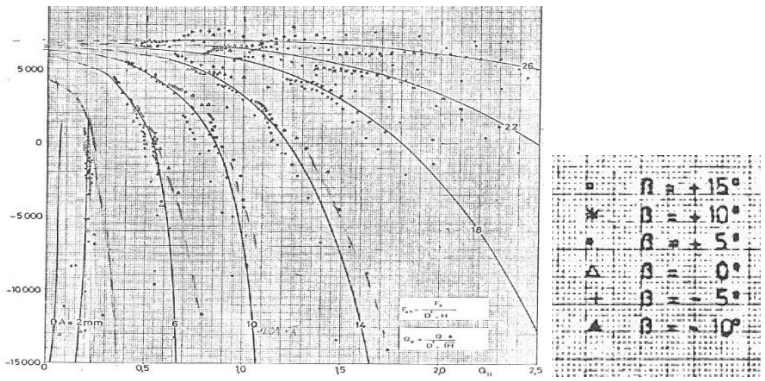

Figure 2. Axial hydraulic characteristics for range of angle β, where $-10^\circ \leq \beta \leq 15^\circ$ [2]

The first method is used in experiment which is described in [2] as well as in this paper. Values of average pressure above runner blade and below net head cover could be determined on the axial hydraulic force data. This force effects runner blades. For the first method it is necessary to obtain values of axial hydraulic force, F_a, by measurements in different stationary working points. It is more convenient to present this force as unit force F_{a11} in function of unit discharge Q_{11} for numerical presentation, see Figure 2. [2]. The curves in Figure 2. depend on values of relative angle of runner blade, β, as well as on the guide vane opening value, a_0. Characteristics shown in Figure 2. are applicable on the biggest Kaplan turbines in Republic of Serbia. Axial hydraulic force during any transient regime can be determined by using these data while neglecting the influence inertia makes on axial force. Unit axial force F_{a11} and unit discharge Q_{11} are given by equations as follows [2]:

$$F_{a11} = \frac{F_a}{D^2 H}, \quad Q_{11} = \frac{Q}{D^2 \cdot \sqrt{H}} \tag{10}$$

5. NUMERICAL SIMULATIONS AND HPP'S OPERATING REGIMES TESTED

Three turbine prototypes were tested with same shape of scroll case, guide vans and stator, except the shape of output edge stator's blades. Normal transient regimes were divided into two groups so that satisfactory and reliable results can be obtained [4], [2]:

- turbine quick closure and stoppage from 100% and 75% of maximal power output, and
- load rejection from 100% and 75% of maximal power output to the idle run.

Tests were based on using rigid waterhammer method and later on were calculated changes of axial hydraulic force (F_a), scroll case pressure (p_{sp}), net head cover pressure (p_{pok}), pressure below runner blades (p_{rk}) and guide vanes servomotor stroke (Y_a). Risk of appearing reverse waterhammer was also estimated during these tests. As a precondition to use numerical code it was necessary to obtain data about the parameters in optimal working point of each turbine (Q_0, H_0, M_0). These parameters are given in Table 1. [2, 4].

Table 1. Parameter values in optimal working point for each of tested turbines [4], [2]

Turbine	Q_0 [m^3/s]	H_0 [m]	P_0 [MW]	M_0 [Nm]	n_Q
A	539.5	27.8	194	19 000 000	137
B	550	28.7	205	19 500 000	135
C	568.62	30	210	20 000 000	133

Tests were performed for two net head values: H_n = 29.0 m and H_n = 26.5 m. Propeller curves refer only to turbine working area. Since the areas of low disharge are not included, all propeller curves have to be extrapolated not only to the areas of low discharge but also to areas with negative net head values. The same refers to $F_{a11} - Q_{11}$ characteristic that was mentioned in the previous chapter.

6. COMPARISON OF CHARACTERISTICS AND PARAMETERS OF INFLUENCE

Comparison of obtained relative values of axial hydraulic forces that refer to nominal working point of the turbine A or exciting turbine is presented in Figure 3. Equation that was used in order to obtain those relative values is described as [4], [2]:

$$F_{a11r} = \frac{F_{a11}}{F_{a11,0}}, \tag{11}$$

where F_{a11} refers to unit axial forces, $F_{a11,0}$ refers to unit axial force in optimal working point and F_{a11r} represents relative value of axial force. All measured axial hydraulic forces` values are achieved for different relative blade`s angles β at particular guide vanes opening values a_0 throughout model tests and test in laboratories.

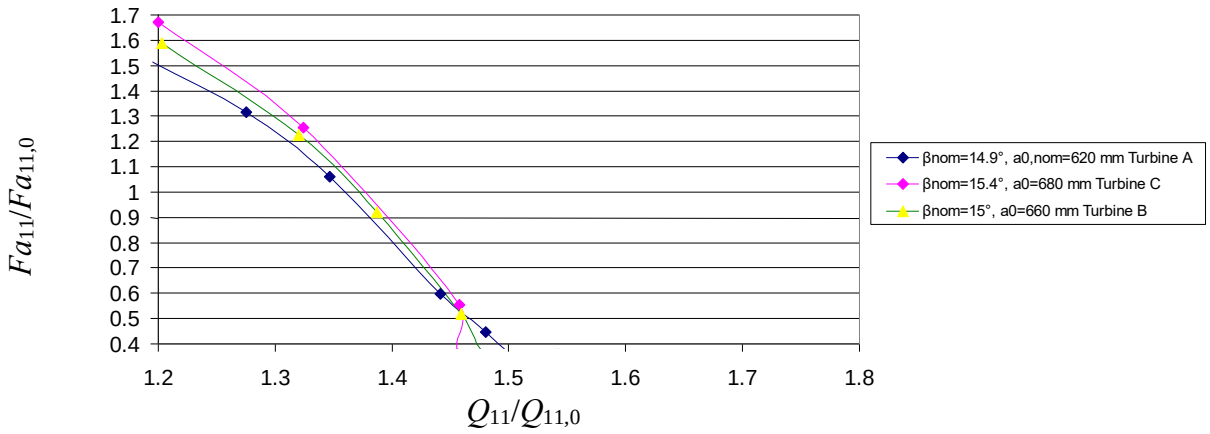

Figure 3. Comparative analysis $Fa_{11} - Q_{11}$ due to nominal point of turbine A [4]

7. CONCLUSION

Transient regimes and their analysis should give the answers about safety and functionality of a hydropower plant in order to obtain its efficient design, setup and exploitation. Here unsteady regimes were carried out and analysed on one hydropower plant. Analyses were fulfilled by using improved numerical programme which consist of extrapolated and interpolated methods that provide secure and reliable results in low discharge areas and especially in testing negative axial force and its influence on turbine rotor raising up. Guide vane opening curve have constant shape when the a_0 values are lower, but significantly differ when these values increase. Turbine quick closure and stoppage from 100% of maximal input as the most unpleasant regime is secure. Total axial force of approximately 1500 kN will perform its effect vertically down and turbine rotor will not be raised up. Vacuum on net head cover will not be present especially if air valves influences are taken in consideration. Reducing guide vane closing velocity is one of choices that can effect on range of $F_{a,\min}$ and $p_{pok,\min}$ critical values. Axial hydraulic force can be significantly reduced when guide vane closing velocity is nearly about 30% of nominal closing velocity. These are also recommendations gained from insights from good practice in order to avoid either rigid or reverse waterhammer to occurre.

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THE INFLUENCE OF INSULATION THICKNESS ON INVESTMENT AND OPERATIONAL COSTS IN HEATING SYSTEMS WITH A HEAT PUMP IN SERBIA

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Abstract: *Energy consumption is one of the most significant challenges in the modern world. Various types of buildings (commercial, residential, sports facilities, etc.) represent major consumers of energy. In households, energy is primarily used to achieve and maintain conditions of thermal comfort such as indoor temperature, relative humidity, and the required amount of fresh air. The aim of this paper is to explore various aspects related to insulation thickness and its impact on investment and operational costs. It will analyse how variations in insulation thickness can affect the energy efficiency of buildings, heating costs, and the maintenance of specified thermal parameters over time. In addition, economic factors such as investments in insulation and potential savings during the operation of the building will be analysed. Through a comprehensive analysis of relevant literature, energy consumption data, and economic analysis, this paper will contribute to a deeper understanding of the complex relationship between insulation thickness, construction costs, and operational costs throughout the lifespan of a building. The research results will enable investors, architects, and engineers to make optimized decisions during the design, construction, and maintenance of buildings, taking into account both short-term and long-term financial implications of energy performance and insulation thickness.*
Keywords: Optimal Insulation Thickness; Building Insulation; Energy Efficiency in Buildings.

1. INTRODUCTION

Many authors have already worked on a similar problems, analysing the optimal insulation thickness for residential buildings. In the paper [1], the authors conducted an analysis from the perspective of life cycle economic evaluation. Additionally, in [2], the authors performed a theoretical analysis, calculating the optimal insulation thickness for the climatic region in the territory of the People's Republic of China. The paper [3] involved numerical optimization of the thickness and layer arrangement of insulation for buildings in the climatic region of Riyadh, Saudi Arabia.

In this paper, a numerical analysis was conducted to determine the impact of insulation thickness on the walls of residential buildings, considering the climatic conditions prevailing at the territory of the city of Belgrade in Serbia. Furthermore, the analysis was conducted based on electricity prices and investment costs that are currently applicable in the territory of the Republic of Serbia.

Insulation materials have a crucial role in maintaining conditions of thermal comfort. The insulation layer increases resistance to heat conduction through the walls of the building, minimizing the loss of thermal energy through the building envelope in winter and gaining heat from the sun in summer.

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The most commonly used insulation materials for building envelopes are: Expanded Polystyrene (Styrofoam), Extruded Polystyrene (Styrodur), Glass Wool, Rock Wool, etc.
All of the above-mentioned insulation materials are characterized by similar values of thermal conductivity coefficients ranging from 0.035 to 0.045 W/mK. The difference in prices of insulation materials is mainly influenced by the production technology and the amount of energy consumed during their manufacturing process.

1.1 Parameters of the analysed house

For the purpose of this paper, a residential building with a total living area of 74 m^2 and approximately 135 m2 of external wall surface was considered. The building is located in the vicinity of Belgrade, in a windy area with an exposed position. For the purpose of analysis, heat losses of the building were calculated without external insulation, and subsequently, heat losses were calculated by adding 1 cm of Styrofoam on the external side, up to a total thickness of 15 cm. A recapitulation of heat losses for Styrofoam thicknesses of 0 cm, 5 cm, 10 cm, and 15 cm is shown in [4]. Where the values of heat losses are provided for individual rooms of the building and the total heat losses of the building are shown for the range of external temperatures from -15°C to 12°C. Based on the obtained data, it is possible to derive an equation representing the relationship between the building's heat losses and external temperature - a "sliding diagram". This relationship has a linear characteristic and can be represented by a general equation of the form:

$$P_b = a + b \cdot t_e \text{ [kW]} \quad (1)$$

Where:
- P_b [kW], is the heat loss for the residential building,
- t_e [℃], is the external (atmospheric) temperature.

Coefficients *a* and *b* can be determined based on regression analysis, and their values for different insulation thicknesses are shown in Table 1.

Table 1. Values of coefficients *a* and *b* for equation (1)
Source: BSc thesis [4]

Insulation thicknesses, cm	Coefficient *a*	Coefficient *b*	Insulation thicknesses, cm	Coefficient *a*	Coefficient *b*
0	5.74	-0.25	8	4.20	-0.18
1	5.34	-0.24	9	4.13	-0.18
2	5.04	-0.22	10	4.07	-0.18
3	4.82	-0.21	11	4.01	-0.17
4	4.65	-0.20	12	3.96	-0.17
5	4.51	-0.20	13	3.91	-0.17
6	4.39	-0.19	14	3.86	-0.17
7	4.29	-0.19	15	3.82	-0.17

1.2 External Conditions

In order to perform a precise analysis, temperature data for every hour, during the representative winter season, were used in this study. The data were collected for every hour in the period from October 15, 2016, to April 15, 2017 at the meteorological station located in the Power Plant "Konjarnik" [4].

1.3 Heat source

In this study, an air-to-water heat pump was utilized as a simulated heat source for heating the building. Technical data from the manufacturer "DAIKIN," model "Altherma ERQL011CW1", were employed. Table (2) presents data (heat power) that the given heat pump can provide for the

selected discharge water temperature, depending on the external temperature, as well as, information about the COP (Coefficient of Performance) value that the selected heat pump can achieve for the chosen water temperature, depending on the external temperature.

Table 2. Heating capacity, and COP of Altherma ERQL011CW1 Heat pump
Source: [5]

Heatin capacity, kW						
t_o, °C	The discharge water temperature, °C					
	30	**35**	**40**	**45**	**50**	**55**
-20	7.31	7.29	7.29	6.76	6.09	5.51
-15	8.78	8.67	8.49	7.78	6.88	6.12
-7	9.14	8.81	8.5	8.16	8	7.1
-2	9.56	9.16	8.77	8.56	8.59	7.84
2	9.53	9.06	8.6	8.87	8.36	7.58
7	11.92	11.32	11.18	10.98	10.65	9.99
12	12.93	12.31	12.2	12.02	11.69	11.01
15	13.99	13.34	13.24	13.07	12.74	12.02
20	15.9	15.2	15.13	14.98	14.22	13.46

COP						
t_o, °C	The discharge water temperature, °C					
	30	**35**	**40**	**45**	**50**	**55**
-20	1.98	1.80	1.63	1.44	1.30	-
-15	2.25	2.03	1.82	1.67	1.47	1.30
-7	2.91	2.57	2.26	2.01	1.74	1.52
-2	3.29	2.88	2.51	2.25	2.00	1.70
2	3.71	3.20	2.75	2.58	2.21	1.81
7	5.21	4.46	3.95	3.49	3.03	2.54
12	5.82	4.98	4.42	3.89	3.38	2.84
15	6.36	5.44	4.83	4.24	3.69	3.11
20	7.43	6.33	5.60	4.93	4.16	3.51

2. METHODOLOGY

The analysis was conducted according to the following algorithm:

- Based on the external temperature at a specific hour, using equation (1), the heat energy losses for that hour were calculated. Depending on the hour in which the heat losses were calculated, the thermal energy needed to compensate for the heat losses is consumed either at the lower tariff (LT - from 00:00 to 08:00) or at the higher tariff (HT - from 08:00 to 00:00). The energy consumed in the lower and higher tariffs in the green, blue, and red zones was taken into account. Additionally, all other costs and discounts that the Electric Power Industry of Serbia (EPS) as the electricity distributor calculates (social discount, excise, discount, RTS fee, etc.) were considered.
- For the selected water temperature at the discharge, which in this analysis is 45°C, the available thermal power and COP of the heat pump were calculated. Since these values in the manufacturer's catalog are given for external temperatures with an approximate 5°C interval, the thermal power and COP were calculated using linear interpolation between two external temperature values.
- The engaged electrical energy (in kWh) is obtained from the ratio of heat losses in a given hour and the COP of the heat pump in the same hour. Depending on the hour in which the heat losses were calculated, the engaged electrical energy is consumed in either the lower or higher tariff.
- By summing up the consumed electrical energy in each hour for the entire month, the total consumption of electrical energy in the lower and higher tariffs for the entire month is obtained.

3. RESULTS

This described procedure is repeated for each month, first for the uninsulated building, and then for the building insulated with insulation thicknesses ranging from 1 cm to 15 cm of Styrofoam. To make the analysis more accurate, in addition to the electrical energy needed for heating the building, the electrical energy required for the operation of other appliances (hot water boiler, stove, washing machine, etc.) was added. This combined electrical energy was obtained based on electricity bills for the months when there was no need for heating or cooling (May and October).
Investment costs for all necessary materials and labour were adopted (for buildings without insulation, the costs of plastering were taken into account, and for insulated buildings, the costs of Styrofoam, mesh, adhesive, battens, and other necessary materials were included). When calculating seasonal electricity consumption, a seasonal electricity price increase of 3% was adopted, representing the average increase in electricity prices over the past 5 years.
Investment costs for the heat source (heat pump) and other heating system equipment were not taken into account. In Table 3, the second column displays the investment costs required for

plastering or insulating the building, while the other columns show the total heating costs for the building per season, for different insulation thicknesses.

Table 3. - Cost of Consumed Electricity per Season
Source: BSc thesis [4]

Insulation thickness		Exploitation + investment, RSD/season							
d, mm	Invest., RSD	1	2	3	4	5	6	9	12
0	191372	323327	459241	599232	743423	891940	1044912	1531918	2064083
1	296654	420336	547729	678944	814095	953300	1096682	1553155	2051956
2	302736	420136	541059	665609	793895	926030	1062129	1495418	1968884
3	310845	423508	539550	659074	782183	908986	1039593	1455396	1909755
4	320981	429950	542187	657791	776864	899509	1025833	1428002	1867462
5	321657	427622	536766	649184	764975	884240	1007083	1398168	1825517
6	329766	433242	539822	649599	762669	879132	999089	1380986	1798295
7	335848	437091	541371	648780	759411	873361	990729	1364386	1772692
8	339902	439590	542268	648027	756958	869157	984723	1352639	1754672
9	348011	446396	547733	652109	759617	870350	984405	1347514	1744293
10	353417	450665	550831	654002	760267	869721	982458	1341372	1733566
11	361526	457761	556884	658979	764138	872452	984015	1339189	1727298
12	376393	471637	569739	670785	774861	882060	992474	1343994	1728108
13	384502	478850	576028	676122	779219	885408	994783	1342993	1723492
14	390584	484096	580414	679621	781804	887053	995460	1340585	1717713
15	398693	491489	587069	685517	786918	891361	998938	1341421	1715662

The results of Table 3 are also presented in the form of a diagram (Figure 1). The x-axis represents the heating season, and the y-axis represents the costs for exploitation (electricity) coupled with investment for all insulation thicknesses in RSD. For better visibility of the data, Figure 1 shows the results only for the uninsulated building, as well as for the building insulated with 5 cm, 10 cm, and 15 cm of insulation.

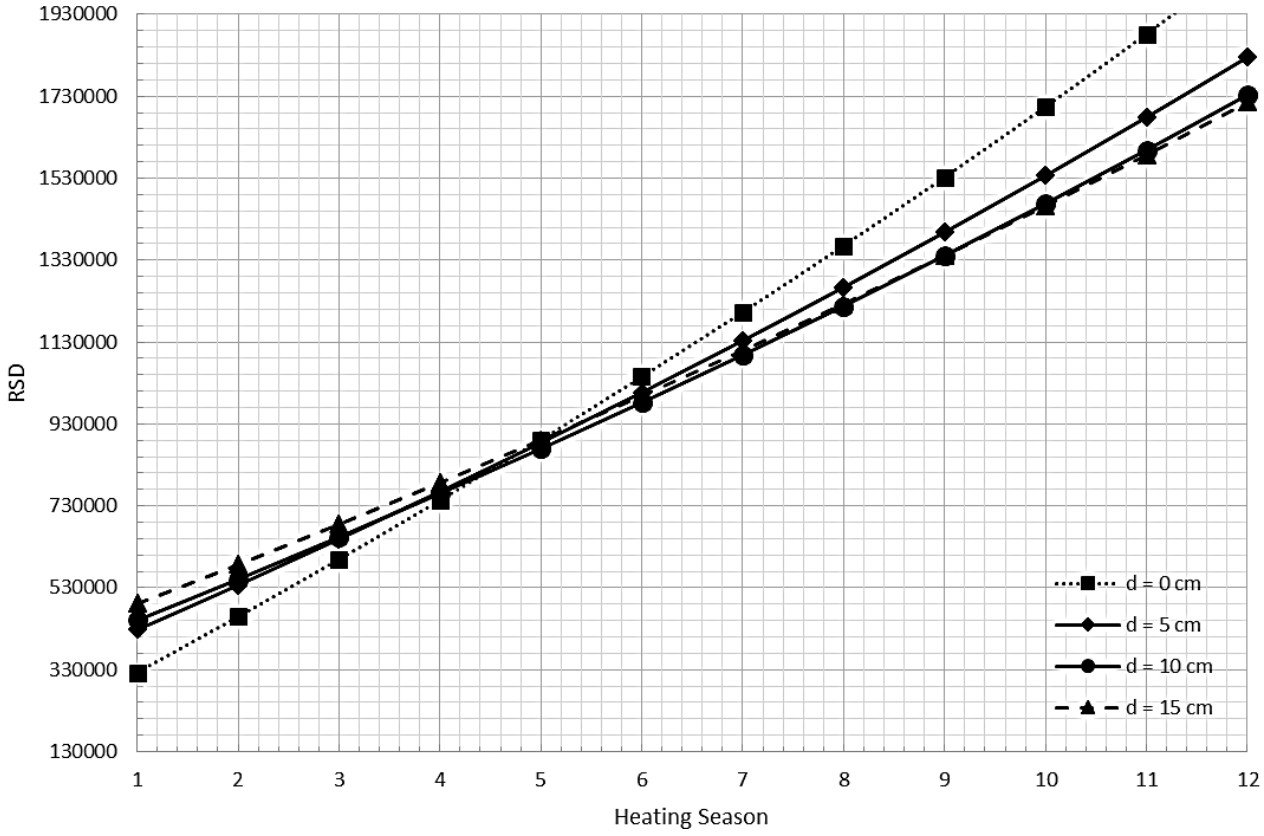

Figure 1. Total Costs by Heating Season
Source: BSc thesis [4]

4. CONCLUSION

During the construction of buildings in Serbia, the highest value of the heat transfer coefficient for external walls should not exceed 0.35 W/m^{2}K [6]. The most commonly used thickness of Styrofoam that meets these conditions is 10 cm. Based on the results of the conducted analysis, it can be concluded that by insulating the building with 10 cm thick Styrofoam, the investment will pay off within 4 heating seasons compared to an uninsulated building. By insulating the building with 15 cm thick Styrofoam, the investment would pay off within 5 heating seasons. By monitoring the trend of the curve shown in Figure 1, it is noticeable that the heating costs for a building insulated with 15 cm thick Styrofoam increase exponentially, but with a much lower slope compared to thinner Styrofoam, especially compared to an uninsulated building. Therefore, the recommendation, considering the relatively short period of investment payback, is to insulate the building with 15 cm thick Styrofoam.

The same model of heat pump was used as a heat source to compensate for heat losses for both the uninsulated building and the building insulated with Styrofoam of various thicknesses. This fact leaves room for additional investment savings, as the losses for the building insulated with thicker Styrofoam are proportionally smaller, allowing for the use of a smaller capacity heat pump and heating elements with a significantly lower investment cost.

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HEADWATER LEVEL GOVERNING AT SMALL HYDROPOWER PLANTS WITH OPEN CHANNEL CONVEYING SYSTEM

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Abstract: *From the ecological stand-point, the primary objective is to enable undisturbed release of ecologic flow downstream of the weir under any hydro-meteorological circumstances, whereas from the energetic stand-point, the tendency is to utilize available water flow through SHPP power-generating line as much as possible. In most circumstances, these objectives are confonted, because fulfillment of one binds restrictions onto the other one. Therefore, proper defining of hydro-technical functions of all the technological parts of SHPPs, especially weirs and water intakes, is of the utmost importance during the stages of SHPP design and exploitation. The entire variety of hydro-technical functions and ecological requirements is to be tailor-made defined for each particular SHPP, whereas their implementation is to be provided by state-of-the-art solutions of hydraulic waterways, hydro-mechanical equipment and automatic headwater level governing systems. Calibrated spillways, specifically embraced hydro-mechanical equipment and automatic control devices allow for proper consumption of water for the energy-generation purpose. The paper presents a case-study of SHPP, for which joint satisfaction of energy and ecological requirements is successfully achieved by implementation of appropriate headwater level governing system.*
Keywords: Small hydropower plants, headwater level governing

1. INTRODUCTION

In recent decades, small hydropower plants (SHPPs) are being constrained by ever more increase of rigorous exploitation conditions in regard of ecologic requirements (provision of adequately designed fish passes, release of ecologic/guaranteed flow downstream of the weir, adequate handling of floating debris, applying of oil-free bearings at turbine assemblies, fish-friendly types of turbine runners at run-of-river SHPPs, eco-friendly types of transformers, etc.).
Adequate and strict fulfillment of all of these requirements influences not only civil hydrotechnical engineering solutions, but electro-mechanical engineering solutions, as well.

2. HYDROTECHNICAL FUNCTIONS OF SHPPs AND TECHNICAL MEANS FOR THEIR FULFILLMENT

It is of utmost importance to clearly identify all necessary hydrotechnical functions which are to be fulfilled during exploitation of a SHPP, as well as appurtenant hydromechnical equipment. This task is to be done already within SHPP design stage.
Main hydrotechnical functions of SHPPs and their weirs comprise:

- undisturbed releasing of ecologic/guaranteed flow downstream of the weir,

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- intaking of flow for energy generation (turbines operation), and
- undisturbed releasing of flood flows.

Additional hydrotechnical functions of SHPPs and their weirs, depending on specifics of particular plants, may comprise:

- flushing of sediments accumulated at the weir upstream side,
- prevention of floating debris intrusion towards power conduit,
- sedimenting (and flushing) of water before its delivery towards power conduit,
- water intaking for other, non-energetic facilities (agricultural irrigation, touristic facilities, etc.).

Each of the above listed functions (being of permanent or occasional nature) require implementation of adequate hydrotechnical structures and/or hydromechanical equipment (with auxiliary devices) of either shut-off (occasional engagement) or regulating (permanent engagement) type. It is of utmost importance to adequately intertwine the first two main functions, i.e. releasing of ecologic/guaranteed flow and intaking of flow for energy generation. Releasing of ecologic/guaranteed flow is usually performed at fish pass. The uppermost section of fish pass (at weir) hydraulically acts as a spillway, so there is unique relation between spilling water level and spilling discharge through the fish pass. If operating value of the weir/reservoir water elevation is higher than actually necessary, more water than truly necessary will be discharged through it and therefore less water will be used for energy generation, and vice versa.

Therefore, it is of utmost importance to provide adequate and precise maintaining of the weir/reservoir water level during exploitation of SHPP. Such goal can be adequately fulfilled only by means of automatized system for SHPP headwater level governing (AHLG). In addition, concept of the headwater level governing system should be adequate to the overall layout of the weir.

3. HEADWATER LEVEL GOVERNING SYSTEMS

Conception of AHLG should be adopted in line with overall layout of SHPP and all of its specific hydraulic and hydro-technic issues.

There are several possible generic types of bloc-diagram schemes of AHLG for SHPPs, depending on SHPP overall layout. They comprise:

- SHPPs with weir and penstock (pressurized conduit),
- SHPPs with weir, derivation tunnel (including surge tank) and penstock (pressurized conduits),
- SHPPs with weir and derivation channel of selfregulating type (open-surface conduits), and
- SHPPs with weir and derivation channel of non-selfregulating type (open-surface conduits).

Generic types of bloc-diagram schemes of AHLG for SHPPs are thoroughly investigated in the sources [1, 2]. In this paper, however, only the last generic type is considered, i.e. bloc-diagram schemes of AHLG for SHPPs with weir and derivation channel of non-selfregulating type (Fig. 1).

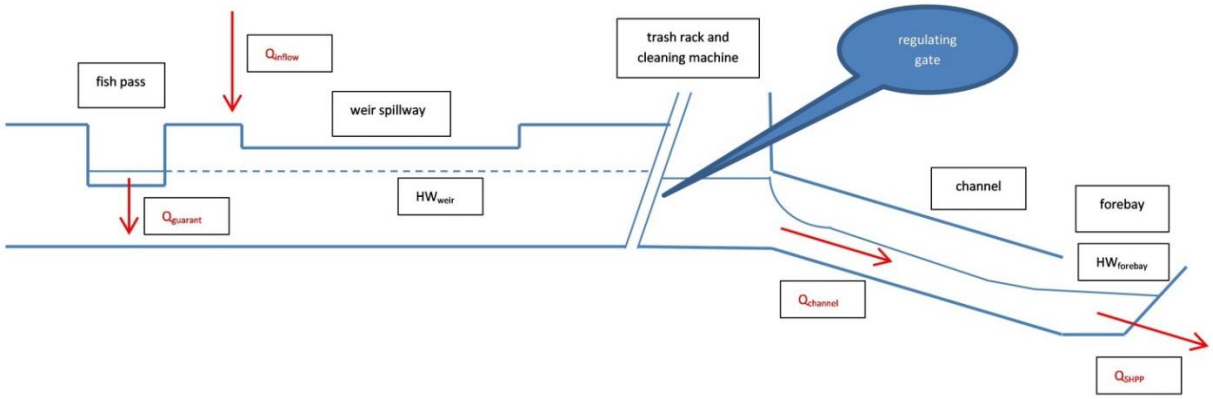

Figure 1. Schematic presentation of a SHPP which comprises weir and non-selfregulating headrace channel – two governing loops for headwater level governing (at the weir/reservoir and at the forebay)

Due to relatively huge length of non-selfregulating channels and significant difference in elevations of channel bottom at its upstream and downstream ends, there is no possibility to influence water level at the channel upstream side (at weir/reservoir) solely by manipulation of water level at its downstream side (i.e. at SHPP forbay). Therefore, two separate, mutually independent regulating systems are necessary.

The first one, for governing of the weir/reservoir water level, comprises regulating gate (with actuator of electric or hydraulic type), located at the joint of the weir and the channel, with appurtenant level metering device and automatic governing device. Its bloc-diagram scheme is presented at Fig. 2.

The second one, for governing of the SHPP forebay water level, comprises turbines, located at the SHPP powerhouse, with appurtenant level metering device and automatic governing device. Its bloc-diagram scheme is presented at Fig. 3.

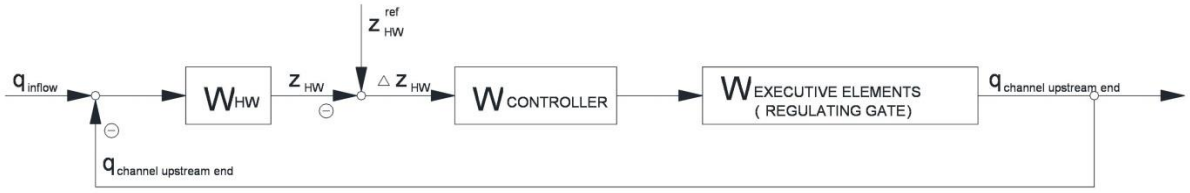

Figure 2. Bloc-diagram scheme of AHLG for SHPPs with headrace channel of non-selfregulating type. Governing loop 1 (weir/reservoir water level)

Figure 3. Bloc-diagram scheme of AHLG for SHPPs with headrace channel of non-selfregulating type. Governing loop 2 (forebay water level)

Hereafter, results of headwater level governing analysis for a case study SHPP (SHPPs with weir and derivation channel of non-selfregulating type) are presented.

4. CASE STUDY

Brief data of the plant:

- name, location	SHPP Moravica, Serbia,
- year of initial commissioning and reconstruction	1911. and 2019,
- dam type	concrete weir, with spillway,
- average annual river inflow	6.7 m³/s,
- guaranteed discharge	0.69 m³/s,
- type of conveyance waterway	open-air non-selfregulating channel,
- length of the channel	90 m,
- SHPP installed discharge	9 m³/s,
- turbine rated head	9 m,
- SHPP installed power output	700 kW,
- average annual energy generation	2.23 GWh/year,
- number of units	1,
- type of governing controller for loop 1 (reservoir)	PI-controller with local feed-back,
- type of governing controller for loop 2 (forebay)	PI-controller with local feed-back.

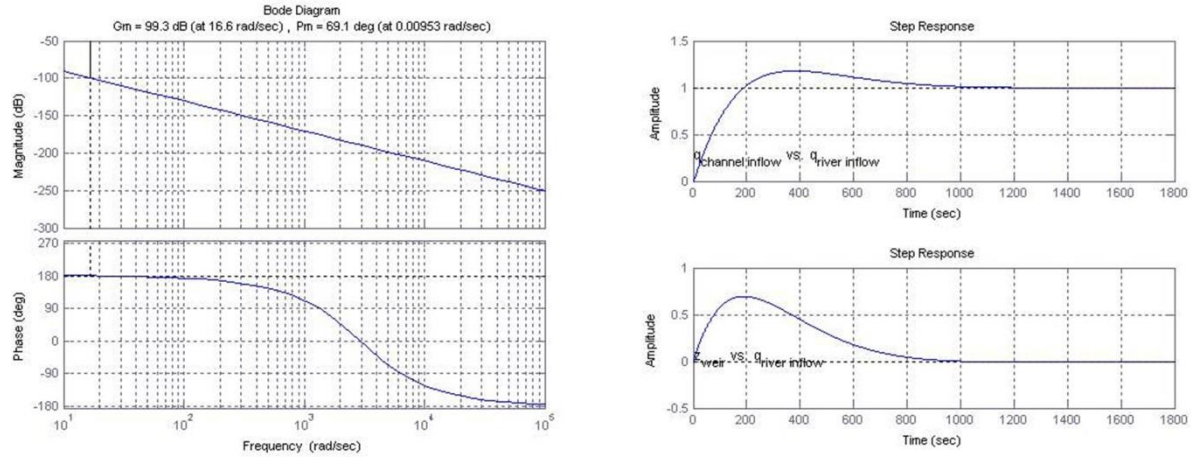

Figure 4. Governing loop 1 (reservoir water level). Bode chart of the open-circuit governing loop and time histories of step-responses (channel inflow vs. river inflow disturbance and reservoir water level vs. river inflow disturbance)

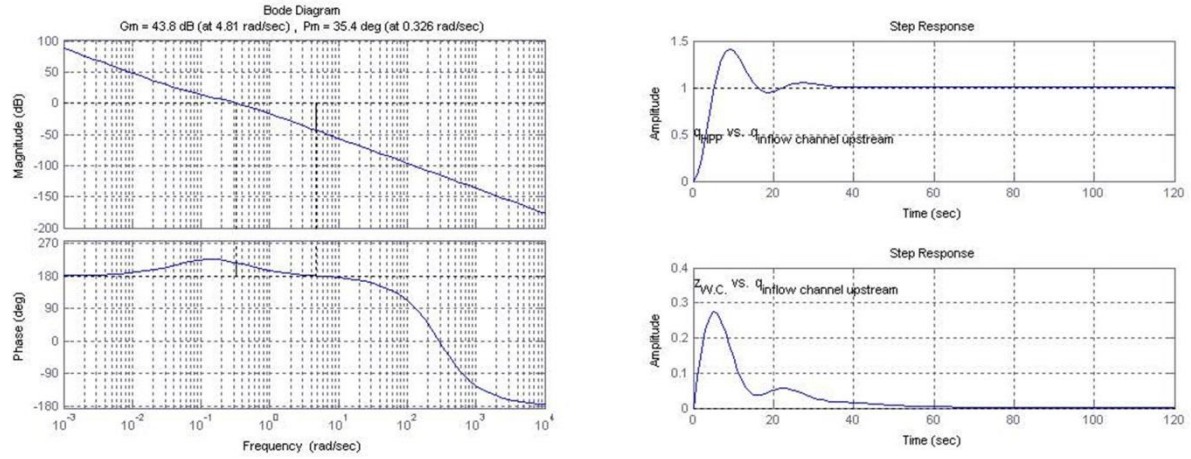

Figure 5. Governing loop 2 (forebay water level). Bode chart of the open-circuit governing loop and time histories of step-responses (SHPP discharge vs. channel inflow disturbance and forebay water level vs. channel inflow disturbance)

As can be seen from the obtained numerical simulation results, both governing loops avail with stable and quality transient behaviour (favourable value of relative overshoot and short restitution times), thanks to appropriate adoption of governor architecture and the setting values of the controllers. Bode charts (logarithmic amplitude- and phase- frequency characteristics) evidence on sufficient stability reserve margins, whereas time histories of step-responses evidence smooth elimination of disturbance effect and transition onto new steady-state conditions. Reservoir transient process attenuates within 15 minutes, whereas forebay transient process attenuates within approx. 1 minute. This assures precise governing of the water levels at reservoir (weir) and forebay, thus adequately fulfilling both ecological and energetic requirements set forth for this SHPP.

5. CONCLUSIONS

It is of utmost importance to clearly identify all necessary hydrotechnical functions which are to be fulfilled during exploitation of a SHPP and to implement them by installation of appropriate hydromechanical and auxiliary equipment. Implementation of automatized systems for headwater level governing of adequate architecture and setting parameter values allows for precise maintaining of necessary value of reservoir water level. In long term, this assures fulfilment of both ecologic and energetic requirements of SHPPs.

For the existing SHPPs which undergo refurbishment (reconstruction, upgrading, modernization of power generating equipment), implementation of automatized systems for headwater level governing leads to increase of energy generation and revenues.

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APPLICATION OF 2D DIGITAL IMAGE CORRELATION METHOD ON THREE-POINT BENDING IN MATERIAL TESTING

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Abstract: *The three-point bending test is a widely used and important method for evaluating the mechanical properties of materials. Its versatility, applicability, and ability to provide valuable information on flexural strength, stiffness, and fracture toughness make it a valuable tool in materials science, engineering, and biomedical research. Digital Image Correlation (DIC) provides a high-resolution and full-field measurement of deformation during the bending process. DIC also allows for the calculation of strain fields, which can be used to determine material properties such as Young's modulus and Poisson's ratio. This is particularly important in understanding the strain distribution and identifying potential failure mechanisms in the material. In this paper, the potential application of the 2D Digital Image Correlation method on three-point bending tests is presented.*
Keywords: 2D Digital Image Correlation method, three-point bending, material testing, 3D printing,

1. INTRODUCTION

Three-point bending testing is a widely used method for evaluating the mechanical properties of materials. This test involves applying a load to a specimen at two points, while a third point acts as a support. The specimen is subjected to bending stress, allowing the measurement of important parameters such as flexural strength, stiffness, and fracture toughness [1].
The three-point bending test has a variety of use cases in different fields. In the field of materials science, it is commonly used to assess the mechanical behaviour of various materials, including ceramics, metals, polymers, and composites[1, 2]. For example, in dental stress analysis, the three-point bending test is used to evaluate the bond strength between ceramics and titanium in dental prosthetics [1]. In the study of fabrics, a modified version of the three-point bending test is used to evaluate the bending properties of textiles [3]. Additionally, the three-point bending test has been applied to study the mechanical behaviour of cancellous bone, providing valuable information on the structural support and flexibility of this tissue [4].
The importance of the three-point bending test lies in its ability to provide valuable information about the mechanical properties of materials. By subjecting a specimen to controlled bending stress, this test allows the determination of key parameters that are crucial for material characterisation and design. Flexural strength, for example, indicates the ability of a material to withstand bending loads without failure, making it an important parameter for structural applications [2]. On the other hand, stiffness reflects the resistance of a material to deformation under bending stress and is essential for understanding its load-bearing capacity [5]. Fracture toughness, another important parameter,

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measures the resistance of a material to crack propagation and is crucial for assessing its resistance to failure [6].
The applicability of the three-point bending test extends to a wide range of materials and testing conditions. It can be performed at various temperatures, including extremely high temperatures, allowing the evaluation of material behaviour under different environmental conditions [7]. Furthermore, the test can be adapted to different specimen geometries and sizes, making it versatile and adaptable to specific research needs [5]. The three-point bending test is also applicable to both quasi-static and dynamic loading conditions, enabling the assessment of material behaviour under different loading rates [2].
Digital image correlation (DIC) is a non-contact optical measurement technique that has gained significant popularity in material and structure testing [8–13]. It involves analysing the displacement and strain fields of a specimen by tracking the movement of unique patterns or markers on its surface. DIC provides a high-resolution and full-field measurement of deformation, making it a valuable tool for understanding the mechanical behaviour of materials. In the application of three-point bending tests, DIC offers several advantages. Firstly, it allows for the measurement of both global and local deformations during the bending process. This is particularly important in understanding the strain distribution and identifying potential failure mechanisms in the material. DIC can capture the deformation of the specimen in real time, providing valuable insights into the behaviour of the material under load [14].
Furthermore, DIC enables the calculation of strain fields, which can be used to determine material properties such as Young's modulus and Poisson's ratio. By analysing the strain distribution along the length of the specimen, researchers can assess the material's stiffness and its ability to withstand bending stress. This information is crucial for designing and optimizing structural components [15]. DIC also allows for the visualization of stress concentrations and the identification of potential failure locations. By tracking the displacement and strain fields, researchers can identify regions of high stress or strain, which can help in understanding the failure mechanisms and improving the design of materials and structures [15].
The aim of this paper is to present the potential application of the 2D Digital Image Correlation method on three-point bending testing.

2. MATERIALS AND METHODS

The three-point bending specimens used in this study were fabricated in SolidWorks CAD software, with dimensions of 10 × 5 × 5 mm, Fig. 1. A total of 5 specimens were made. The specimens were printed using the RepRap X400 (Rep Rap, Germany) 3-D printer. The infill pattern for all samples was concentric with 30% of the infill density. The layer height was 0.2 mm, with 2 layers on top, 2 on bottom, and 2 on both sides. In this study, the commercially available thermoplastic polymer PLA (RepRap, Germany) was used. PLA is a biodegradable, non-toxic organic polymer derived from biobased resources.
All experiments were carried out on the Shimadzu AGS-X tensile testing machine (Shimadzu, Japan) with a maximum load of 100 kN. The surface of the specimen must have a pattern to clearly allocate the pixels in the camera images (facets). Consequently, the pixel area of the reference image can be assigned to the corresponding pixel area of the target image. The surface of a sample was coated with a black paint point to generate a random high-contrast stochastic pattern. All images were recorded using a 35 mm lens and acA-2500 Basler camera (Basler, Germany) with 5 MP camera resolutions. Continuous specimen lighting was provided by an LED lamp (Fig. 1).

3. RESULTS AND DISCUSSION

2D-DIC is a non-contact and full-field measurement technique used extensively in material testing. This method tracks the movement of the markers placed on the surface of the specimen during

deformation. The resulting displacement data can be used to calculate the strain and stress in the specimen.
The results of the displacement in the Y direction are presented in this paper. The displacement field was analysed using 3 sections (Sections 1, 2 and 3), two points (Points 1 and 2) and one point-point distance, as shown in Fig. 1. Experimental data are also represented in graphics as time and section length functions. Figure 1 shows a representative image of the Displacement Y field results for the maximum force before the break.
The highest displacement values in the Y direction of around 10 mm are recorded below the grip of the tensile testing machine, on the lower part of the specimen where Section 3 is located. The tests revealed a slight displacement difference between the upper and lower parts of the specimen, as can be seen in the Section Diagram in Figure 1. What is interesting here is that the point-point distance change represents the thickness reduction of the specimen of around 0.25 mm. Overall, these results suggest that DIC can be used for localized displacement and strain field analysis and improvement in the standard three-point bending testing of material.

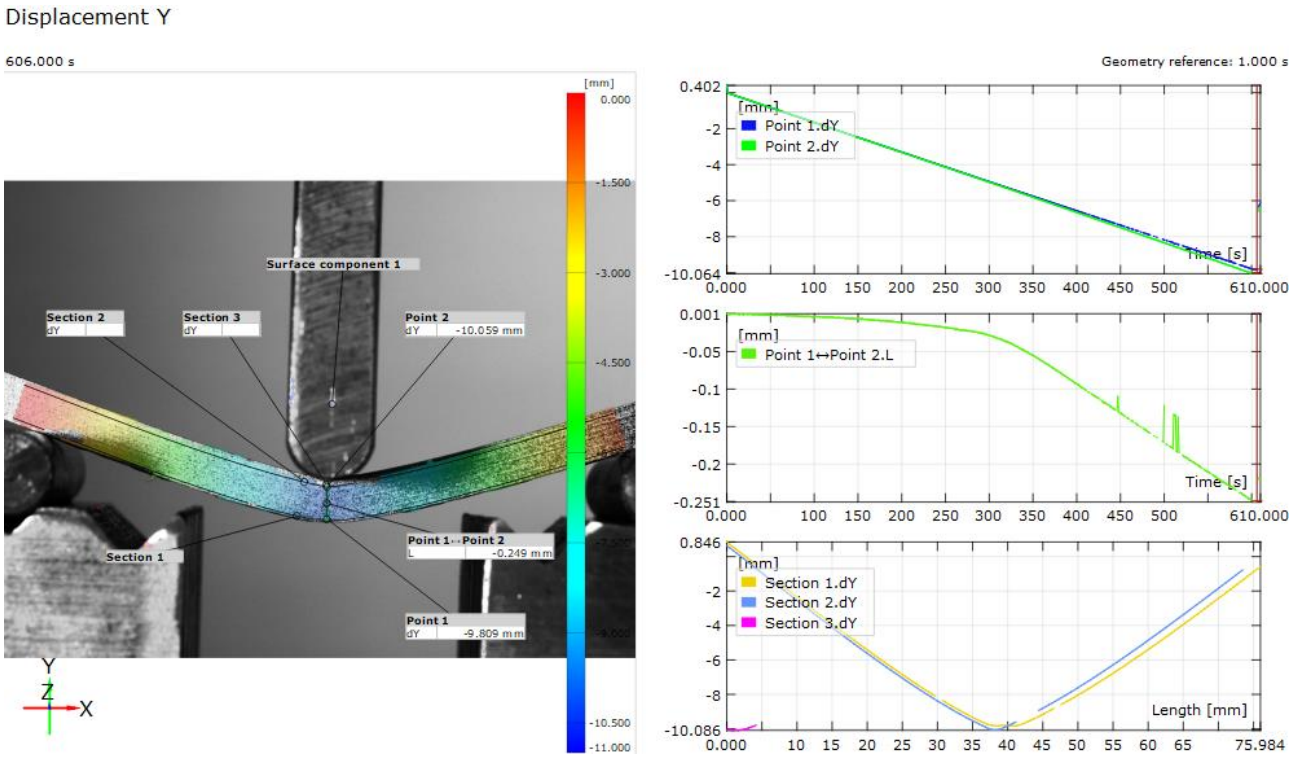

Figure 1. Displacement Y before the specimen brake

4. CONCLUSION

In conclusion, the three-point bending test is a widely used and important method to evaluate the mechanical properties of materials. Its versatility, applicability, and ability to provide valuable information on flexural strength, stiffness, and fracture toughness make it a valuable tool in materials science, engineering, and biomedical research.
The use of DIC in three-point bending tests offers a comprehensive and detailed analysis of the behaviour of the material. It provides a full-field measurement of deformation, allowing for a more accurate assessment of the mechanical properties of the material. DIC can capture global and local deformations, providing information on the distribution of strains and potential failure mechanisms. Additionally, DIC enables the calculation of strain fields, allowing for the determination of material properties such as stiffness. In general, DIC is a valuable tool in material testing, particularly in the application of three-point bending, as it enhances our understanding of material behaviour and aids in the development of more reliable and efficient materials and structures.

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APPLICATION OF SMART PRODUCTION SYSTEMS IN VOCATIONAL EDUCATION

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Abstract: *In this paper an application of smart production systems in vocational education is described. The goal of this project is the industrial automation of the production process, which is based on the fusion of CNC (Computer numerical control) machines and industrial robots, the application of artificial intelligence in the production of machine parts with the use of CNC simulators, the increase in the use of information technologies, new software and hardware platforms in teaching, especially in order to raise the quality of practical work teaching, through the creation of functional realizations of assemblies, devices and systems - Project Based Learning, as well as Work Based Learning. It is planned to introduce modern digital techniques of design, analysis and synthesis of practical, functional realizations of technical assemblies, devices and systems, in the syllabus of the subjects related to the above-mentioned knowledge items. In other words, the goal is to introduce new opportunities, primarily in the domain of practical exercises, such as hardware and software environments for the development of digital devices, automation of production processes, reduction of production time, increase in productivity, and elimination of scrap and support for Industry 4.0.*
Keywords: Smart production system, Industry 4.0, Robotics, CNC machine, CAD/CAM

1. INTRODUCTION

The assertion of world economists, that automation, computerization and application of robots are the first three things that developing and countries in transition should approach in order to bridge the gap between themselves and developed countries is fully justified [1,2,3]. In the future, the development of human civilization will depend more and more on the position of science and its application, and less and less on the amount of work invested and the simple amount of resources that increase its strength [4,5,6,7]. With the development of Industry 4.0, the application and therefore the production of automated and computerized machine tools, automatic management and control systems, transport systems and robots increases, while the production using classic machines and systems decreases [7,8,9]. The implementation of this project would involve the application of smart production systems with the application of the CAD/CAM/CNC concept (Computer Aided Design/ Computer-Aided Manufacturing/ Computer Numerical Control) and support for the fourth digital revolution in vocational education [9, 10].
This research paper presents project proposal "Application of smart production systems in vocational education" that aims to innovate existing subjects - more precisely, a group of subjects on accredited study programs, in master professional and basic vocational studies, which are implemented in the Computer-Mechanical Engineering Section (CME Section), of the Academy of applied technical studies Belgrade. The three subjects are selected from the master's vocational

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studies (MVS) and three subjects from the basic vocational studies (BVS), which are implemented in study programs (SP) in the technical and technological field, namely: Computer Mechanical Systems (MVS level), Mechanical Engineering (BVS level) and Mechatronics (BVS level).
The subjects included in the project proposal are, in the master's vocational studies (at SP MVS CME): Mechatronic systems (implemented in the autumn-winter semester), Industrial plants and automation, and Artificial intelligence methods (both implemented in the spring-summer semester). From the basic professional studies, the courses CNC System Programming (implemented in the autumn-winter semester), Sensors and actuators, and Basics of Industry 4.0, are included for which classes take place in the spring-summer semester, in the CME Section in Belgrade and at the same time in the Higher Education Unit in Valjevo.
Apart from the six subjects mentioned, the proposed innovations would have a positive and favourable impact on other subjects from study programs of the CME Section (e.g., Machine Learning, Automatic Control and Digital Electronics, all at BVS level).

2. PURPOSE AND DESCRIPTION OF THE PROJECT PROPOSAL

Real-time machine CAM (computer-aided manufacturing) programming represents a fundamental change in the way the tool path moves, resulting in extended tool life, shortened cycle times and better machine utilization. Unlike traditional CAM software, by applying advanced software that has been developed in recent years, information about machine kinematics and dynamics is used for setup, programming, optimization and simulation. In this way, CAM programmers make better tool path choices, resulting in improved machining performance [6,7,8].
The purpose of innovating subjects for master's and undergraduate studies is to enable students to acquire and assimilate knowledge of complex concepts, through experience gained in practice and acquire competencies, useful or necessary for the automation of the production process and the application of smart production systems with the support of Industry 4.0 [10,11,12]. The expected result of innovation of the mentioned courses is that students develop skills and competencies in all levels of Bloom's Taxonomy: in addition to remembering, understanding and applying knowledge, analysing and evaluating technical solutions, students will also be able to create this way. The idea of this proposal is to awaken the need for experimentation in students, develop entrepreneurial ideas and overcome limitations in the process of designing and building specified technical solutions.
Description of selected subjects in undergraduate vocational studies:

- Sensors and actuators: Introducing students to the basic types and characteristics of sensors and transducers, which are used in mechanical engineering and the process industry. The goal of the course is for students to gain an understanding of the basic principles of measurement and control, basic notion regarding the servo drive: measurement of motion parameters and variables, dimensions or position, types of drives that are used in practice and understanding the operational correlation of measurement and motion control. This course provides a solid foundation for understanding automation;
- Programming of CNC (Computer numerical control) systems: The aim of the course is to acquire knowledge about modern CNC machining systems and learn about the basic differences in the design of technology for CNC machining systems compared to classical ones in terms of application, productivity, costs and overall processing efficiency;
- Basics of Industry 4.0: The aim of the course is to acquire knowledge regarding the concept of the flexible production systems - FPS as well as to become able to develop, improve and organize the production in FPS, to reach the desired level of automation, and the management of FPS.

Description of subjects from the master professional level study:

- Mechatronic systems: Gaining in depth theoretical and practical knowledge regarding mechatronic systems and a mechatronic approach to design, developing a multidisciplinary approach in solving engineering tasks, in product design or physical realization, through a

combination of courses in the fields of modelling mechanical and electrical systems, system management, electronics, computing and computer controlled and monitored systems;

- Industrial plants and automation: Familiarization with advanced concepts in the field of automatic control and training for application and verification of acquired knowledge on concrete physical processes, objects and systems, mastering methods for synthesis, design and adjustment of control systems (through the design and tuning of the regulators);
- Methods of artificial intelligence: Acquisition of applied knowledge and skills in the field of artificial intelligence. Application of artificial intelligence methods such as expert systems, neural networks, fuzzy logic, as well as machine learning algorithms in diagnostics in operation and decision making regarding the condition of machines in production.

Work and teaching methods to be implemented to achieve learning goals are:

1. Lectures are oral, explanation, presentations using computers, dialog, and interactive methods;
2. Simulation - programming methods (simulation of examples from practice, practical work on the computer, writing and testing of programs);
3. Laboratory - experimental methods: creating software models and exploring modes of operation of various systems varied by adding regulator or parameter tuning (using Matlab and Simulink), making experiments in physical programming i.e. building simple electronic projects controlled by microcontroller board (e.g. Arduino Uno) or single board computer (Raspberry Pi), creating exercises using software to support Industry 4.0 and applying smart production systems using simulators for numerical control, in programming industrial controllers, such as Step 7, Logo Siemens, Fatek, Trilogy; in visualization and control of technological processes the software systems are used (e.g. Promotic Scada, Delphi Scada, braumSistems); in robotics the software Robotics Studio, Robot Simulation Software, Robot programming software are implemented, and in artificial intelligence and machine learning examples in practice are derived using Matlab and Python software;
4. Taking the exam.

Evaluation of learning outcomes and monitoring of teaching quality:

- At the end of the semester, students will perform an online evaluation of the lessons and practical exercises in the context of using multimedia techniques. Based on the processed evaluation results, corrections and additions will be made to the course content for the following years of study, creation of on-line surveys, questionnaires, which students would fill out, to rate their satisfaction with the new way of teaching.

3. GENERAL AND SPECIFIC COMPETENCES

Description of goals acquired after taking these innovative subjects, namely Sensors and actuators, Programming of CNC systems, Basics of Industry 4.0, Mechatronic systems, Industrial plants and automation, and Methods of Artificial Intelligence states that all will contribute to the development of students' digital competencies, as well as the following general and specific competencies.

General competences that students should develop during practice oriented teaching are:

- Ability to learn;
- Ability to analyze and synthesize;
- Ability to apply knowledge in practice;
- Ability to adapt to a new situation;
- To successfully plan and perform troubleshooting;
- Obtaining high level of quality, maintaining it and assessing the quality;
- Information management skills;
- Ability to work independently and in a team;
- The ability to have a creative approach to solving practical problems;

- The ability to evaluate one's own and others' work through comparisons;
- Ability to create technical solutions for development of products and services;
- Cooperation, communication and problem solving in teamwork;
- Knowledge of using the computer programs and computer equipment (understood in the broadest sense).

Specific competencies that students should develop during practice oriented teaching are:

- Knowledge of design elements and principles;
- Integrating the principles of design and adhering to legal requirements and relevant standards;
- Ability to design using digital tools and hardware;
- Ability to create and design from an idea or conceptual sketch to a functioning prototype and a finished device, system or service;
- Ability to work on adequate software and hardware platforms (Arduino Uno, Raspberry Pi, programmable logic controllers - PLCs, supervisory control and data acquisition – SCADA systems);
- Simulation of CNC machine and robot levelling procedure using a special digital levelling device. Levelling the machine means setting machine up and aligning it - bringing its horizontal axes into a parallel position with the horizontal plane (or bringing its vertical axis to a perpendicular direction to the horizontal plane). This device has the ability to connect to mobile devices and computers via Bluetooth connection. Information about the position of the work table, or some other reference part of the machine, is sent in real time to the mobile phone of the service technician who performs the adjustment. In this way, the service technician does not need to go to the machine after setting each foot of the machine to check the angle, nor there is a need for another service technician who would constantly read the data during levelling;
- Simulation of robot and CNC machine communication via CNC simulator. If the robot would receive information when the protective door of the machine is open, i.e. for the machine to have information that the robot is outside the working area and can close the door, they need to communicate with each other over an interface and protocol, which can be successfully simulated through additional M-functions such as options for working with peripheral devices;
- Using the CNC simulator, and to display the communication between the machine and the computer or server via the ETHERNET network interface;
- Support for Industry 4.0 by simulating an application for remote machine monitoring. The machine must be connected to the Internet over the cabled (Local Area Network – LAN) or wireless (e.g. WiFi) network. The WiFi option on the machine’s side provides a wireless connection between the control unit and the LAN. The status of the machine can be monitored from a computer or mobile phone. Notifications, warnings, and alarms and can be generated for the start of the cycle, the end of the program, as well as possible alarms on the machine, or any changes to the program, number of revolutions, or rapid movements. All notifications are sent to
  a mobile device or an email account;
- Simulation of the calibration of the CNC machine, i.e. the correction of the movement of the axes of the CNC machine as a whole, which directly influence the precision of the produced part. Testing is performed using Windows-based software that guides the operator through each step.
  A useful option is the so-called "Generator of NC programs" which helps in writing programs for the machine tool. In many cases, existing test templates are used. Quick access to templates is done by simply searching for existing files;
- Connecting all the elements of the flexible production cell into one simulation unit;
- After composing the simulated flexible production cell using a CNC simulator with the generation of NC programs in the ESPRIT CAM software [13];

- Simulation of the installation of the Vision Sensor, which can be installed on the support above the box with work-pieces, and on the robot arm itself. The digital image is converted into a symbolic description that is in machine-readable format and that the device can 'understand' and use. From the point of view of connection to other sciences and engineering fields, Machine Vision represents a combination of areas as: Machine Learning, Robotics, Optics, Digital Signal Processing, Image Processing, Video Processing, Geometry, and others;
- The ability to perceive the technological tasks of industrial robots, manifested through the robotic manipulation with objects, performing pick-and-place and/ or the assembling tasks that the robot performs in several stages, such as: recognizing an object, approaching a recognized object, grasping the object with the appropriate orientation of the grasper's fingers and with right intensity of grasp**, moving the object to another location, and the like.**

Description of the use of digital technologies in teaching:

- The introduction of digital technologies, new methods and techniques into the content of these courses would improve students' competencies in designing, programming and testing. Students work independently in consultation with professors during lectures and exercises. Practical exercises within the course would involve solving specific tasks, and deriving solutions in laboratory for problems arising in specific situations or taken from practice.

By implementing innovations in this group of subjects, students will master working with modern technologies and a real-world equipment that the current course content did not cover. Conditions will be created for students to independently reflect, evaluate, communicate, collaborate, and analyze, test and simulate devices, machines, and technological systems.

4. CONCLUSION

The aim of the project is, in addition to innovating existing subjects, to improve the competences of professors and teachers as well as students in the domain of digitization and Industry 4.0, information communication technologies and entrepreneurial competences for the purpose of providing higher quality of teaching. The result of the implementation of the project should be: ability to work on CNC machines using a simulator, understanding of a flexible production cell consisting of two units - a CNC machine and an industrial robot in order to master production processes related to Industry 4.0, creating greater autonomy and increasing the productivity of the system, application of advanced machine learning techniques, digital literacy of students, development and installation of a smart production system with the application of artificial intelligence methods and the cybernetic model, improving the quality of the teaching process and increasing the use of information communication and other contemporary/ modern technologies in the educational process.

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ENVIRONMENT AND SUSTAINABLE DEVELOPMENT. MECHATRONICS. OCCUPATIONAL SAFETY AND HEALTH AND FIRE SAFETY. SMART MANAGEMENT SYSTEMS. GRAPHIC ENGINEERING. DESIGN. TRAFFIC ENGINEERING. BIOTECHNOLOGY AND HEALTHCARE. MECHANICAL ENGINEERING. ECOTOURISM AND RURAL DEVELOPMENT.

A STUDY ON THE ENVIRONMENTAL AND HEALTH IMPACT OF HAZARDOUS SUBSTANCES DURING WELDING

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Abstract: *Welding is a major joining process in modern manufacturing, primarily used for creating metal structures and components, as well as maintenance and repair operations. Welding, compared to other production processes, is regarded as a hazardous procedure that can have long-term detrimental consequences for persons and the environment. It's critical to be aware of these consequences and consider the possibility of employing environmentally friendly methods. Each welding process has distinct risks and pollutant exposures, thus choosing the proper technique for a given application with the lowest risk of hazards is critical. This article includes a technical and environmental overview of welding operations, as well as information on the major pollutants and their estimations. The effect of welding conditions, parameter optimization, operation, and materials on the formation of key contaminants is investigated and analyzed. The purpose of this study is to raise awareness of the dangers of welding contaminants to the environment and human health. It also suggests ways to mitigate these risks and promotes the development of green welding technology.*
Keywords: fumes, gases, health dangers, welding processes

1. AIMS AND BACKGROUND

Welding plays a significant role in manufacturing, particularly in industries that use complex metal components and structures. It is a metal-joining fabrication process that employs high heat, pressure, or a combination of the two, with or without filler material, to create a strong and permanent connection between the assembling metal parts. The solidification of the molten metal at the interface of the joining parts results in metallurgical bonding, which forms a solid welded joint with improved properties over the base metal [1]. Today, there are numerous welding processes available for a wide range of applications, which can be divided into two categories: fusion welding and pressure welding. Fusion welding processes use electric arc, gas, electrical resistance, and high energy to generate heat at the location of the joint. Pressure welding also known as solid-state welding uses mechanical pressure to achieve coalescence through friction or explosion. Welding technologies also differ in terms of their economic performance and environmental impact, because of this, selecting a technology for a specific application is crucial for welding costs and environmental burdens [2]. In the manufacturing sector, there is no clear preference for welding technologies; however, basic material properties and other conditions that arise from the specific case of application, such as the number of joints, shape, and dimensions, loading, connection purpose, and so on, are important considerations. Electricity, radiation, heat, flames, fire, explosion, noise, welding fumes, fuel gases,

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inert gases, gas mixtures, and solvents are the most dangerous aspects of welding. However, it is considered that the most dangerous welding byproducts are fumes and gases. Welding processes generate a complex mixture of fine and ultrafine aerosols and gaseous harmful substances that are due to the intensive heat that vaporizes the base metal, and the electrode coating condenses into small particles [3, 5]. These chemical agents are fumes and particulates with aerodynamic diameters of less than 1 μm and can be easily inhaled and attached to human lungs causing serious illness to the affected individual [4, 5]. The welding fume and particulate matter mainly consist of particles from the evaporated electrode and a little part of the basic material with chemical compositions that depend on the welding technique, parameters, electrode, basic metal, and flux composition [6]. Metal oxides with chemical particulates such as lead, nickel, zinc, iron, oxide, copper, cadmium, fluorides, manganese, chromium, and gases such as carbon monoxide, nitrogen oxides, and ozone are the main components of the emissions [6, 7]. A summary of all the chemical, physical, and radiation hazards are shown in Table 1[8]. The gaseous by-products originate from chemical reactions, ultraviolet irradiation of atmospheric elements, or shielding gases. Together with welding nanoparticles, they represent a significant source of air pollution, and their size and distribution should be monitored and evaluated. Several factors influence the volume of fumes and gases produced (welding parameters, arc length, electrode, shielding gas, welder experience, humidity, welding technique). As a result, there are compelling reasons to address the type and methodology used during these processes to ensure a working environment with the least amount of air pollution possible.

Table 1. Common hazardous byproducts during welding
Source: National Institute for Occupational Safety and Health, 2022 [8]

Fume	Aluminum, Cadmium, Chromium, Copper, Fluorides, Iron, Lead, Manganese, Magnesium, Molybdenum, Nickel, Silica, Titanium, Zink
Gases	Carbon Dioxide, Carbon Monoxide, Nitrogen oxide/dioxide, Ozone
Radiant energy	Ultraviolet, Visible, Infrared
Other Hazards	Heat, Noise, Vibration

The purpose of this article is to provide an overview of the major pollutants that affect worker health and the environment during welding. The results of several experimental studies on various welding processes are summarized to broaden knowledge and raise awareness of the potentially toxic effects of welding emissions.

2. RESULTS & DISCUSSION

2.1 Air pollution from welding

The hazardous air pollutants present at high temperatures during metal vaporization are the main source of concern in the welding process. As a result, electric arc welding is thought to emit these pollutants in substation quantities. Other welding processes, such as pressure welding, produce fewer fumes and are thus considered green welding technologies due to their lower operating temperatures Friction stir welding (FSW) and magnetic pulse welding (MPW) produce less pollution and emit no hazardous fumes because they do not require flux or fillers. Outgassing is also eliminated with diffusion welding. When compared to standard shielded metal arc welding (SMAW) and gas metal arc welding (GMAW), other techniques, such as laser arc hybrid welding (LAHW), have the lowest direct environmental impact. However, because the composition of the used wire is directly related to the composition of the fumes, gas tungsten arc welding (GTAW) emits fewer fumes than SMAW and GMAW. SMAW is considered a process that has negative health effects because there is a tendency to form hexavalent chromium [7]. Furthermore, high rates of toxic compound emissions are generated during SMAW stainless steel welding [7]. Plasma arc welding (PAW) is like the GTAW process and emits similar levels of air pollutants [7]. GMAW welding of aluminium produces more ozone than GTAW welding. Despite these environmental advantages, some of these techniques are

impractical for specific applications or large jobs, so fusion welding processes remain the preferred method among manufacturers.

2.2 Polluting components

The chemical elements found in fumes are complex and highly dependent on the metal mixtures that evaporate at different rates and at different temperatures. Because most steels contain iron, silica, chromium, and nickel in varying amounts, the rates at which the alloying elements evaporate are also affected by element concentration. The fumes are primarily composed of manganese (Mn), nickel (Ni), chromium (Cr), cobalt (Co), and lead (Pb). Gaseous pollutants or greenhouse gases such as carbon dioxide (CO_2), carbon monoxide (CO), nitrogen oxides (NO_x), and ozone (O_3) are also present. The precise level of risk is determined by fume composition because each of these chemical elements and gases has a unique toxic effect that must be effectively controlled. Some of the chemical components in fumes and glass byproducts are discussed in the following paragraphs. When welding stainless steel or high alloy steel, chromium is measured in significant quantities. The concentration of hexavalent (Cr+6) depends on the shielding gas, and it is a dangerous toxic compound with mutagenic potential that can cause lung cancer [8]. Nickel is commonly found when welding stainless steel and nickel alloys. It is a human carcinogen, and some studies show that the cancerogenic potency of different materials can vary significantly [8]. Dermatitis, pneumoconiosis, asthma-like lung disease, renal dysfunction, and respiratory tract irritation are also at increased risk [3, 4, 8]. Iron, in the form of iron oxide, can also be found in fumes. It is considered irritant dust with a low risk of causing chronic lung disease after inhalation, but these particles have been observed to accumulate in alveolar macrophages and the lung interstitium [8]. Welders develop pneumoconiosis known as siderosis because of long-term exposure to arc welding fumes [4]. Manganese can be found in most welding fumes, particularly when it is used as a flux agent in the coatings of SMAW electrodes, flux-cored electrodes, or as an alloying element, or when it is present in high concentrations in the base material [8]. As a symptom of chronic manganese poisoning, it affects the eyes and nose, and the central nervous system, and causes chemical pneumonitis and kidney damage [4]. The coatings of metal electrodes and flux-cored electrodes contain silica and fluorides. The silica is amorphous and non-cytotoxic, as opposed to the highly cytotoxic and crystalline form associated with silicosis [8]. Inhaling fluorine-containing gases has been shown to irritate the eyes, nose, and throat as well as harm the lungs, and occupational pulmonary exposure to particulate fluorides has been linked to occupational lung disease [3]. In addition, there is bone and joint damage, gastrointestinal symptoms, fluid in the lungs, and kidney dysfunction [3]. Long-term fluoride fume exposure can cause skeletal or dental fluorosis [4]. Exposure to zinc or zinc oxide in fumes is mostly caused by heated galvanized coatings on the base metal, which can cause acute respiratory illness [14]. Aluminum is found in fumes because it is used as an additive in many steels and nonferrous alloys, as well as welding electrodes, coatings, paint, electro-plated or sprayed elements, and filler wires [8]. Welding with aluminum encourages the formation of the pneumo-toxic gas Ozon, which can irritate the lungs. When welding copper and its alloys or using copper-coated GMAW electrodes, high concentrations of copper are possible. Vaporized copper and cadmium are metals known to cause metal fume fever [3]. Cadmium is an element that is used in the production of fluxes found in flux-cored electrodes on occasion [8]. Cadmium in welding fumes has been linked to acute chemical inhalation lung injury, and it is one of only a few welding-related exposures that can be fatal [8]. During arc welding processes, a large quantity of gases such as ozone, nitrogen oxides, carbon monoxide, and carbon dioxide are released. The airborne vapors around the arc undergo oxidation, which is aided by ultraviolet radiation from the welding arc, to produce phosgene, a pulmonary irritant gas [9]. Arc welding gases can be produced by shielding gases, decomposition of electrode coatings and cores, arc reaction with atmospheric constituents, ultraviolet light reaction with atmospheric gases, and decomposition of degreasing agents and organic coatings on the metal welded [9, 15]. Ozone is an allotropic form of oxygen produced by arc welding's UV radiation, which ionizes oxygen. The rate of ozone formation is determined by the wavelengths and intensity of ultraviolet light produced in

the arc, which is influenced by the material being welded, the type of electrode used, the shielding gas, the welding process, and welding variables such as voltage, current, and arc length [9]. Ozone is a severe respiratory irritant that can cause extreme discomfort, nausea, coughing, and bronchitis at levels above 0.3 ppm, and pulmonary edema at levels above 10 ppm for several hours [8]. Nitrogen oxides are produced during welding processes because of direct oxidation of atmospheric nitrogen at high temperatures [8, 9]. When inhaled, nitrogen oxides have been shown to irritate the eyes, mucus membranes, and lungs [4]. Excessive pulmonary irritation and edema can result from exposure to extremely high concentrations [8]. Carbon monoxide is a toxic and dangerous gas produced during welding because of the action of UV radiation on carbon dioxide [8, 9]. Carbon dioxide and carbon monoxide are produced because of the decomposition of organic compounds in electrode coatings and cores, as well as the decomposition of inorganic carbonates in coatings [8]. It impairs the blood's ability to absorb oxygen, resulting in headaches, nausea, dizziness, confusion, death, cardiovascular symptoms, and carbon monoxide poisoning [4]. In a recent study, carbon monoxide, sulfur dioxide, and nitrogen gases were detected and measured in the air at the same time, resulting in significant negative effects, as shown in Table 2 [12].

Table 2. CO_2, SO_2, and NO_x emissions during welding
Source: G. Amza and D. Dobrotă in Metalurgija, 51, 2012[12]

Welding process	**CO_2**		**SO_2**	**NO_x**
	Min	**max**	**SO_2/t seam**	**NO_x/t seam**
SMAW	0.280	0.5	0.64	0.154
Submerged automatic arc welding (SAAW)	0.175	0.21		
GMAW and GTAW	0.205	0.24		
Oxyfuel welding	0.312	0.55		

According to the data presented, industrial activity for manufacturing welded constructions can be considered an environmental pollutant, particularly to the atmosphere, as evidenced by air quality monitoring results. The emissions are strongly influenced by the diameter and composition of the electrodes, the workpiece composition and coatings, travel speed, voltage, current, arc length, welding position, and deposition rates, so fumes can be reduced or increased depending on the choice [10]. The weight of fumes generated is a percentage of the weight of deposited metal or the length of the electrode used. It is found that 95 % of the welding fumes are generated from the additional material and only about 5 % from the base material [13]. Table 3 shows typical ratios of different welding processes and metals, the maximum rate of welding fume is achieved if the GMAW continuously welds on the carbon steel with 10lb/h or 0.09 lb/h (0.9%) [11]. The situation is different for stainless steel, the generation of fume with the same welding process is 0.7lb/h. If the welding processes last for half an hour, then the values of the fumes are going to be divided by two.

Table 3. Welding fume ratios
Source: Source: *Welding fume control: regulations and processes, 2008 [11]*

Welding	**Metal Type**	**Range Weight of Fumes/ Weight of Deposited Material**
FCAW	Carbon Steel	0.9-2.4%
	Stainless Steel	0.9-2.4%
SMAW	Carbon Steel	1.1-5.4%
	Stainless, High Alloy	0.3-1.4%
GMAW	Carbon Steel	0.3-0.9%
	Stainless Steel	0.6-7%
	Copper/Aluminum	0.5-1.6%

Emission amount and variations in the fume formation rate (FFR) are heavily influenced by the type of welding and the operating conditions, as shown in Fig. 1 for various processes based on electrode type [10].

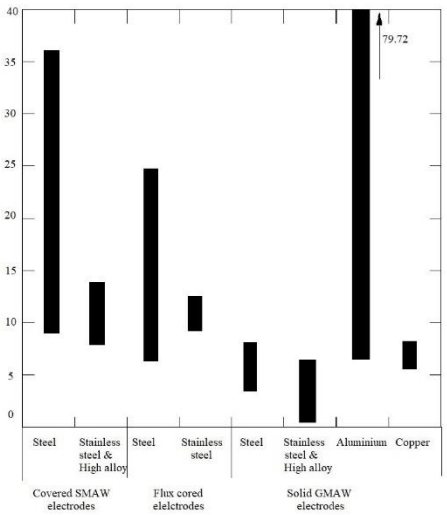

Figure 1. Particulate emissions from various arc welding processes
Source: Development of particulate and hazardous emission factors for electric arc welding, Final Report, 1994 [10]

The GMAW uses a shielding gas to protect the molten metal from the atmosphere to reduce oxidation and other reactions and provide a better quality of the weld. Usually, this gas is an inert gas mixture of argon, helium, or carbon dioxide and can intensify the production of toxins such as nitrogen oxides and ozone. Flux-cored arc welding uses flux with a high level of fluorides and silicates that vaporize and produce gases that protect the liquid melt from impurities.

2.3 Parameter considerations and operational conditions

The mechanisms that cause fume formation are complex, but changes in process parameters and operational conditions can help to reduce fume emissions and provide a healthier working environment. A recent investigation on fume emission when welding mild steel (MS) and stainless steel (SS) with the GMAW process at various current and voltage settings revealed that heat input and FFR are directly connected, meaning that with higher current or voltage there will be higher FFR so to lower the amount of fume generated welders should use the lowest current intensity as possible [16]. Also, it is concluded that the use of MS as base metal produces more fume when compared to SS, so there is a strong connection between fume rate generation and the chemical composition of the metal to be welded. Welding voltage and current both affect fume generation. The length of a welding arc can also influence fume generation. A longer arc gives the droplet more time to react and emit fumes. As the voltage increases, so does the amount of welding fume produced. The current levels in solid wire GMAW rise as current levels rise, depending on the shielding gas used. Metal transfer changes from short-circuiting to globular to fine droplet spray as the electrode current density increases. This change also has an impact on arc stability, which in turn has an impact on fume levels.

3. CONCLUSION

There is an urgent need to reduce air pollutants to protect the environment and workers' health. The composition of the consumable electrode alloy, the base metal being joined, and the presence of any surface materials or coatings on that base metal, all influence the substances found in the welding environment. When it comes to keeping fume exposures to very low levels, the challenges are significant. The only way to achieve and maintain low levels of exposure is to carefully select consumables and welding processes, as well as to use proper ventilation and personal protective equipment. Also, a study of various base materials revealed that stainless steel produces a greater quantity of nanosized particles than carbon steel, therefore the proper choice of base metal is crucial. When selecting a base metal, consider choosing the one that emits less fume and can be welded with a low fume emitting process, considering the type of electrode and, if necessary, the type of shielding

gas for emission control. Fume levels in gas-shielded processes are influenced by the reactivity of the gas blend as well as its influence on the type of metal transfer required. When high percentages of argon are used, it is possible to achieve stable, finer droplet transfer at moderate current levels. When shielding gases contain more than 20 percent carbon dioxide, transfer remains globular within these same current ranges. Welding fume levels rise as the percentage of CO_2 in the shielding increases. Prior to deciding on a specific welding process, the amount of fume must be considered; whenever specifications and conditions allow, the process generating the least amount of fume should be chosen. Overall, all welding processes can result in a significant concentration of nanosized particles being deposited in the lungs of exposed welders, but according to data from various studies, the lowest level of airborne particles transferred in the alveolar region of the lungs was associated with FSW, followed by TIG and metal active gas welding (MAG) [7]. While FCAW produces the most fumes, submerged arc welding (SAW) produces the least. To reduce fume emissions, the proper current, arc voltage, arc length, travel speed, and welding electrode angle should be chosen by the operator to ensure quality welds.).

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ANALYSIS OF RESEARCH ON OPTIMIZATION MODELS AND ALGORITHMS FOR PLANNING PREVENTIVE MAINTENANCE OF MACHINE SYSTEMS

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Abstract: *The paper presents a complete overview of various optimization models and algorithms related to preventive maintenance planning. An overview of works that use models and given applications of preventive maintenance planning in production systems, service systems and special purpose systems is presented.*
Keywords: Model, Preventive maintenance, Algorithm.

1. INTRODUCTION

Modern organizational systems for maintenance are oriented towards achieving efficient and effective procedures and work processes in order to satisfy the needs of their customers - consumers of services for which they are competent in the maintenance of technical systems. The effectiveness and efficiency of maintenance is very precisely dictated by the requirements of clients - customers. Most organizational maintenance systems are capable of offering quick repairs at low prices, all thanks to the knowledge economy. The basis of the knowledge economy is the knowledge industry, which is supported by planning, production equipment, production methods, maintenance methods, science and technology. Modern maintenance systems start processes with maintenance planning, which interacts with the knowledge economy and industry. They mutually create incentives (causes and effects) for more efficient and effective maintenance processes.
That is the reason why optimization models and algorithms in the field of maintenance have been dealt with by many world researchers and authors. Special interest was directed to the planning of preventive maintenance of technical systems, where various optimization deterministic and stochastic models and algorithms were used.

2. EXACT ALGORITHMS

For the maintenance of technical systems in semiconductor production, Yao et al. [1] optimized preventive maintenance planning by means of the Analytical Hierarchy Process (AHP) method, which was developed by Thomas and Maatu in the early seventies of the last century. They proposed different approaches in defining the problem of optimal maintenance periodicity of technical systems. They developed a Markov decision process and optimized this model via a mixed integer linear programming model. They defined a profit maximization from the production of a group of tools, as an objective function, and took a time dimension for the preventive maintenance activities by introducing a limitation of assets that can be out of use during maintenance interventions. In doing so, they defined an optimization model by means of non-linear functions. In order to achieve the global optimum, they transformed non-linear functions into linear ones. In doing so, they used the optimization software EasyModeler and OSL (Open Software License). In addition, they used the AutoSched AP as a simulation software to create a simulation model to evaluate the realization of the

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proposed optimization model. In their analysis of the operational problem of preventive maintenance in a planned time period of one week, with 11 constraints, they compared the obtained results with the actual preventive maintenance plan. Later, Yao and a group of scientists extend their earlier optimization model to make it more general and show its application through numerical examples.

Jayakumar and Asgarpoor, [2], presented a linear programming model to optimize the maintenance policy for system elements with reduced quality, reduced reliability and uncontrolled failures. They determined the optimal average time for small and large overhauls of preventive maintenance based on maximizing the readiness of a certain technical element, assembly or aggregate. They used MAPLE and LINGO software to solve linear programming models utilizing Markov decision processes.

Duarte et al., [3], presented a model and algorithm for the optimization of system maintenance with a series of elements - components. In their research, they assumed that all components have a linearly increasing failure rate, with a constant failure growth factor, thus making it difficult to manage the maintenance of technical systems. In addition, they assumed that the objective function is cost minimization, subject to individual and total downtime/failure constraints. In terms of maintenance activities, they defined preventive and corrective maintenance for each component. Finally, their algorithm optimizes the time interval between maintenance activities for each component during the planned period. Canto, [4], presented an optimization model for planning preventive maintenance of the power plant through planned periods. He considered the total cost of various operations as an objective function and used Bender decomposition to solve mixed-integer linear programming models.

Budai et al. [5], presented two mixed-integer linear programming models for preventive maintenance planning problems. These authors take the objective function for both models to be total costs, including depreciation costs, maintenance costs, and costs of unscheduled maintenance activities. They present and solve preventive maintenance planning problems using GAMS software to execute optimization models. They use CPLEX as optimization software to find the optimal preventive maintenance plan. They apply their model to a railway maintenance planning case study. In addition, they develop four heuristic optimization algorithms, two for each model, and compare the research results obtained from the exact algorithms and state the methodological advantages of each solution.

Nonlinear optimization models have also been developed for this purpose. Thus, Tam et al., [6], developed three well-known nonlinear optimization models based on: a) minimization of total costs with the targeted achievement of reliability, b) maximization of reliability for a certain financial expenditure or budget and c) minimization of total costs if the risk of occurrence is accepted expected costs due to the termination of operation of technical systems and maintenance costs on which elements of reduced reliability have been identified. They use MS-Excel Solver as the optimization software that uses the generalized reduced gradient (GRG) algorithm to solve nonlinear optimization models. Using these models, the optimal maintenance intervals for a multicomponent system can be determined, however those models only consider maintenance activities for components and do not consider replacement activities.

Alardhi et al.,[7], presented a binary integer linear programming model to find the best preventive maintenance plan in the separate and coupled cogeneration plants. These researchers defined equipment readiness maximization as an objective function, taking maintenance timelines, maintenance process execution duration, logistics operations, asset constraints, maintenance personnel availability, efficiency measures, and demand as a set of constraints. They were implementing this model in Kuwait in two factory plants with seven units and 42 pieces of equipment, during the 52 planned weeks. In doing so, they used LINGO as an optimization software for model optimization. In addition, they performed a sensitivity analysis on this model to assess efficiency and analyse the impact of moving the planned time limit in operation, reducing assets and increasing the need for maintenance strategies.

Panagiotidou and Tagaras [8], by applying nonlinear programming (NLP) methods, developed an optimization model that optimizes preventive maintenance plans in the production process. These authors considered two different states of components of technical systems, controlled and

uncontrolled, before total failure. They use time to change and time until cancellation as random variables and express it with the help of Weibull and Gamma distributions. In addition, in order to maintain the optimal preventive maintenance plan, they combine the concepts based on the lifetime and condition of the equipment in the optimization model, while realizing the minimum total cost, solving it by applying the Karush-Kuhn-Tucker (KKT) optimality conditions. Finally, they presented several numerical examples to demonstrate the effectiveness of their methodology. Shirmohammadi et al., [9], developed a nonlinear lifetime-based optimization model to determine the optimal preventive maintenance plan for single-component systems. They defined two types of decision variables: the time between preventive replacements and the lifetime of the element (until complete failure). They predicted expected maintenance costs, replacement costs, and total maintenance costs as the cost function, taking the cost per unit time as the objective function. To solve the optimization model and show the effectiveness of the proposed model, they used the MAPLE software.

In solving engineering problems, dynamic programming, as a frequently used optimization technique, has a wide application for obtaining optimal maintenance and replacement activities. Canfield, [10], studied optimization models of preventive maintenance focusing on various aspects of the failure function related to system reliability. He stated that preventive maintenance activities do not change or affect the failure rate increase, so the developed failure function is constant with maintenance activities. For his study, he considered the increasing failure rate, based on the Weibull distribution and determines the optimal maintenance costs, defining the average amount of system operating costs and applying dynamic programming as a solution approach.

Robelin and Madanat, [11], developed a maintenance optimization model for bridge decks through a Markov chain process. In this paper, optimization models are classified into two categories: (1) optimization models for systems with physically based deterioration (deadlocks), and with a limited number of decision variables, and (2) simpler optimization models for deterioration systems with a larger number of decision-making variables. They applied Markov chain methodology with the states based on the history of increasing failure rates and maintenance activities and used a dynamic programming as a solution and business decision-making approach.

3. HEURISTIC AND META-HEURISTIC ALGORITHMS

The genetic algorithm, as the main optimization approach, has been presented in several research papers. Usher et al, [12], presented an optimization model for maintenance and replacement of parts in small component systems. The authors determined the optimal preventive maintenance plan for the new system depending on the increase in failure frequency, considering time as the value of money for all future costs, the increasing failure rate over time, and the use of improvement factors to improve maintenance workflows. In addition, they performed a comparison of results between random search, genetic algorithm, as well as the known algorithms and constraints.

One of the most significant studies in the field of reliability and maintenance optimization for multi-component and multi-state systems was performed by Levetin and Lisnianski, [13]. The authors defined a multi-state system as a system in which all or some components have different levels of states, from adequate functioning to a complete failure, and system reliability as its ability to satisfy certain level of operation. They formulated an optimization model to determine preventive maintenance activities that affect the effective lifetime of components. Their model is based on a cost minimization depending on the required level of reliability. They applied a universal generating function technique and used a genetic algorithm to determine the best maintenance strategy. Levetin and Lisnianski presented additional research in which an optimization model is developed to determine optimal scheduling and switching in multi-state, parallel-connected systems. They considered an increasing frequency of failures based on the expected number of failures over time intervals and defined the sum of the costs of maintenance activities together with the costs of insufficient operation due to component failures. They used a universal generating function approach and applied a genetic algorithm to find the optimal maintenance strategy.

Wang and Handschin, [14], developed a new genetic algorithm by modifying, by crossover and permutation, the basic operators of the standard genetic algorithm based on the specific characteristic of the preventive maintenance planning problem for power supply systems. They improved the time complexity of genetic algorithm research by considering an integrated coding method, with specific code and transparent constraints. Thus, they ensured faster convergence in solving problems and prevented the creation of unresolved issues. As an implementation methodology, an object-oriented programming approach is applied. In doing so, the effectiveness of the new genetic algorithm is shown through theoretical analysis and simulation results, all in order to make a comparison with the traditional genetic algorithm. Tsai et al., [15], in their optimization model of preventive maintenance considered two activities: imperfect maintenance and replacement of parts. They designed the imperfect maintenance activities based on the concept of improvement factors, which are determined by a quantitative assessment procedure. They used a genetic algorithm to find optimal preventive maintenance activities while taking system lifetime per unit cost as the objective function. As a case study, they tested a mechatronic system to demonstrate the effectiveness of their model and algorithm. Cavory et al., [16], presented an optimization model to plan the best preventive maintenance tasks for all machines in a single product production line. The authors assumed that each machine should be assigned to each operator and that the overall throughput of the line should be considered as an objective function to bring it to the perfect operation. As the first step, they formulated an optimization model and analysed it using an analytical approach. Then, these researchers used C++ for some programming and applied a genetic algorithm to find the best variant of preventive maintenance. In addition, to confirm the results they designed an experimental design to establish and analyse the parameters of the genetic algorithm and used the Taguchi method and statistical analysis. Finally, this approach was applied to an actual automotive engine production line. Leou, [17], showed an optimization model to find the optimal preventive maintenance plan for a multi-component system. It considers the total costs of operations and maintenance work processes together with reliability as system criteria and transfers them to an objective function, defining the degree of impairment in relation to the required reliability. In addition, it defines maintenance personnel and maintenance duration as system constraints. He applied this optimization model to a case study with six electric generators and used a genetic algorithm as an optimization methodology to determine the best preventive maintenance plan.

Han et al., [18], considered the recursive nature of failure rates between preventive maintenance cycles and developed a nonlinear optimization model based on repair costs, preventive maintenance costs, and production loss costs in a production system. They applied a genetic algorithm as an optimization technique and stated that their model can be considered in decision support systems for maintenance of technical systems.

Brice et al., [19], considered cost and readiness as system criteria in their research. They optimized the model including cost as an objective function and availability as a constraint using a genetic algorithm to find the best preventive maintenance plan. They used a time-dependent Birnbaum importance factor to generate an ordered sequence of first control periods and used MATLAB to calculate system readiness via a Monte Carlo simulation approach.

Limbourg and Kochs, [20], proposed several techniques to represent decision variables in preventive maintenance planning models using heuristic and meta-heuristic optimization algorithms. The authors tested various non-standard approaches and compared them to the binary representations with the help of a heuristic algorithm, and the research results demonstrated the effectiveness of their approaches. In addition, they implemented certain modified crossover and permutation procedures in the genetic algorithm and showed improvements in the performance of their algorithm in terms of search time and accuracy. Another study of the application of genetic algorithms for maintenance optimization was conducted by Lapa et al., [21]. They considered flexible maintenance intervals and stated the advantage of this assumption over conventional methodologies. They developed a model that includes preventive and corrective maintenance activities and their associated costs, number of losses, system reliability and failure probability. Since their model is a large-scale nonlinear optimization model, they used a genetic algorithm as the solution procedure. Additionally, and as a

case study, they applied their model to technical systems - high pressure plastic injection machines, in order to measure the effectiveness of their methodology.
Verma and Ramesh, [22], grouped the systems and subsystems of a large construction plant into higher modular assemblies (HMA) and applied the multi-objective preventive maintenance planning method. They modelled this problem as a constrained nonlinear multi-objective mathematical program, where reliability, cost, maintenance period discrepancy, and initial maintenance time factor are the elements of the objective function and use a genetic algorithm to solve this model.
Shum and Gong, [23], presented the application of a genetic algorithm to optimize the planning of preventive maintenance of production machines. They assumed that the frequency of maintenance and replacement of parts, together with the purchasing strategy and the volume of maintenance manpower, are the decision variables, and the total cost is an objective function. They examined the impact of these costs on the optimal maintenance plan under realistic conditions.
Other meta-heuristic algorithms have been used as combinatorial optimization techniques to solve maintenance planning problems. Samrout et al., [24], used the ant colony algorithm or ant theory to optimize a problem that was previously optimized with the help of a genetic algorithm. They defined a series of maintenance and control periods for the components and used MATLAB for the simulation.

4. HYBRID ALGORITHMS

Kim et al., [25], combined a genetic algorithm with simulated effects for the optimization of the problem of scheduling large-scale and long-term preventive maintenance and parts replacements. In their research, the probability of acceptance of the simulated effects method was taken as a measure of individual survival in the genetic algorithm. Using this approach, they achieved a near-optimal solution in a short period of time compared to the exploration time of a simple genetic algorithm. As a case study, they optimized the long-term maintenance planning problem of a thermal system.
Tan and Kramer, [26], developed a general framework for optimizing preventive maintenance in chemical process operations. They used the Weibull distribution for failure rates and considered different maintenance activities that could be implemented. They developed a methodology that combines Monte-Carlo simulation with a genetic algorithm to solve opportunistic maintenance problems with a non-deterministic objective function. They applied their approach to two case studies to compare the results obtained from the proposed model with the results obtained from an analytical approach and a Monte-Carlo simulation with a neural network. Finally, they stated the advantages of their approach over other approaches.
Marseguerra et al., [27], developed a condition-based maintenance model (CBM) for the multi-component systems and used a Monte-Carlo simulation model to predict the level of degradation in a continuously observed system. They applied a genetic algorithm to optimize the degradation level after maintenance activities in a multi-objective optimization model where profit and completion are the objective functions. In addition, they considered a simulation model to explain the dynamics of the load-dependent degradation process in components with different loads. Considering the obtained research results, they stated that the combination of genetic algorithm with Monte-Carlo simulation is an effective approach for solving combinatorial optimization problems.
Shalaby et al., [28], developed an optimization model for preventive maintenance planning of multi-component and multi-state systems. They defined a series of preventive maintenance activities as the decision variables, and the sum of preventive maintenance costs, minimum repair costs, and downtime costs as an objective function. In addition, they considered system reliability, minimum intervals between maintenance activities, and personnel availability as constraints of their model. Finally, a combination of genetic algorithm and simulation was used to optimize this model.
Allaoui and Artiba, [29], presented a combination of simulation and optimization models in order to solve a hybrid job flow scheduling problem with maintenance constraints and multiple objective functions, based on flow duration and due date. In addition, they considered a set-up time, clean-up time and transport time in this model and stated that the implementation of the algorithm can be

affected by numerous dead time intervals. Finally, they proved that the efficiency of the simulated process effect algorithm is better than the heuristic algorithms with the same conditions.
Suresh and Kumarappan, [30], developed an optimization model and used a combination of genetic algorithm with the simulated effects. These authors applied their method to determine the preventive maintenance plan in the power supply system. They stated that this method can create better conditions if certain changes and modifications are made in the procedure of this solution. As a case study, they tested this method on 62 units of the state electricity system of Victoria.
Samrout et al., [31], presented yet another paper on the combination of the ant colony algorithm and the genetic algorithm for the optimization of the large-scale preventive maintenance problem. They divided the objective function of their problem into two parts and then used each algorithm to improve those parts separately. They note that using a hybrid algorithm for a large-scale problem is more efficient in comparison to a simple algorithm.

5. MULTI-OBJECTIVE ALGORITHMS

Multi-objective models of preventive maintenance optimization are presented in several works. Kralj and Petrović, [32], introduced a new approach in planning preventive maintenance in thermal systems. These authors developed a large-scale multi-objective combinatorial optimization model with three objective functions and a set of constraints. They considered the minimization of total fuel costs, the maximization of reliability in terms of expected unused energy, and the minimization of technological uncertainties as the objective functions. In addition, they defined the duration of maintenance, continuity of maintenance, period of maintenance, sequence of maintenance of thermal units of the same class, limitation of simultaneous maintenance of thermal units, and limitation of total maintenance capacity depending on manpower and resources for limitations. They developed a software for multi-objective preventive maintenance planning based on a multi-objective branch-and-bound algorithm implemented in FORTRAN. Finally, these researchers applied their method to a real system of 8 power plants with twenty-one thermal units and with 11 maintenance classes, all for a planned time period of 31 weeks.
Chareonsuk et al., [33], developed a multi-criteria preventive maintenance optimization model to find the optimal preventive maintenance intervals for the components in a manufacturing system. In this study, the authors considered the failure frequency based on the lifetime of the components by fitting the Weibull distribution to the data, and defined the expected total cost per unit time and the reliability of the production system as the main criteria. Furthermore, they used PROMETHEE (Preference ranking organization method for enrichment evaluations) as a solution approach, and defined alternative decisions as preventive maintenance intervals. Using this approach, they can prepare decisions by combining the importance of priority functions for the entire set of criteria. As a case study, they applied their methodology in a paper mill and used PROMCALC as the optimization software. Finally, they stated the advantage of their approach in which decision makers and managers can include different criteria in this model and perform sensitivity analysis on optimal solutions.
Konak et al., [34], presented an extensive study on multi-objective genetic algorithms and their applications in reliability optimization problems. They conducted 55 research papers and demonstrated solving techniques and methodologies.
Quan et al., [35], developed a new multi-objective genetic algorithm for optimizing preventive maintenance scheduling problems. They defined the problem as a multi-objective optimization problem considering the minimization of manpower idle time and the minimization of maintenance time, as well as stated that there is a trade-off between the objective functions. As a solution procedure, they used the utility theory instead of the dominance-based Pareto search to determine non-inferior solutions and demonstrate the advantage of this method through a numerical example.
Taboada et al., [36], presented a new study in this area. They developed a multi-objective genetic algorithm to solve multi-state reliability plan problems. These authors used a universal moment generating function to measure reliability and completeness criteria in a system. They applied their approach to two examples: the first is a system of five units connected in series, in which each

component has two states, functioning properly or with failure, and the second is a system composed of multiple subsystems with three units connected in series. In this system, each component has multiple states with different levels of realization, ranging from normal operation to the complete failure. They used MATLAB and demonstrated the efficiency of their approach in terms of research time.

6. CONCLUSION

Preventive maintenance planning is widely used in manufacturing and production systems. Most of the research focuses on single-component systems or simple and specific systems. That's why these researches are not always applicable to real and general systems. There is not enough research in the field, which relates to life expectancy reduction models with an improvement factor. The presented models of preventive maintenance planning, which deal with multi-component systems, can be applied to a wide range of systems. Progress in research represents the development of mathematical and statistical models that are presented as an improvement factor for ineffective preventive maintenance activities.

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ENVIRONMENT AND SUSTAINABLE DEVELOPMENT. MECHATRONICS. OCCUPATIONAL SAFETY AND HEALTH AND FIRE SAFETY. SMART MANAGEMENT SYSTEMS. GRAPHIC ENGINEERING. DESIGN. TRAFFIC ENGINEERING. BIOTECHNOLOGY AND HEALTHCARE. MECHANICAL ENGINEERING. ECOTOURISM AND RURAL DEVELOPMENT.

EXPERIMENTAL INVESTIGATION ON THE USE OF OF JIC FOR A HSLA STEEL WELDED JOINT

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Abstract: *The structural and mechanical heterogeneity of a welded joint affects its resistance to cracking in both the elastic and plastic regions. Therefore, it is important to define the test method and the position of the fatigue crack. The behavior of an elasto-plastic material during stable crack growth can be described by the J-Δa diagram. As the crack propagates, a point is defined on the curve that represents the critical value of the J-integral. The aim of this experiment is to determine JIC value and the procedure is reflected in the determination of the R-curve, i.e. the J–Δa curve, which consists of the value of the J-integral for uniform crack increments Δa. In this paper, two SEN(B) specimens with the fatigue crack in the parent material (PM) and weld metal (WM) were tested according to standard ASTM E1820 at room temperature (RT) as well as three specimens with the fatigue crack in the weld metal (WM) at RT, -20 0C, -30 0C.*
Keywords: J-integral, J-R curve, HSLA steel, welded joints

1. INTRODUCTION

NIOMOL 490K belongs to the class of molybdenum microalloyed steels, of yield strength min. 490 MPa and specified nil-ductility transition (NDT) temperature of –60 ºC, produced by Slovenian Steel work company ACRONI Jesenice. This steel grade is designed for welded pressure vessels exposed to dynamic loads, operating at temperatures below zero, and that is why it must have acceptable toughness. The successful application of this steel depends on the grade deterioration of the properties of the base metal during welding [1].
The impact of plastic strain around the crack tip is very important for materials with pronounced plasticity, which include high-strength low-alloy steels used for welded structures. That is why it is necessary to introduce parameters that are not limited by the linear-elastic behavior of the material: crack tip opening displacement CTOD (δ) and - J-integral. The analysis of fatigue parameters must be possible even after the occurrence of significant plastic strains [2].
Procedure for determining J_{Ic} using the J-R curve (J-Δa dependence) consists of the value of the J-integral for uniform crack increase Δa, which for each load /unload point can be defined based on the total of elastic and plastic components [3,4]:

$$J(i) = J_{el}(i) + J_{pl}(i) \tag{1}$$

Elastic component of J-integral from the Eq 1

$$J_{el(i)} = \frac{K_i^2 \cdot (1 - v^2)}{E} \tag{2}$$

where are E - elasticity modulus, K_i - stress intensity factor and v - Poisson's ratio.

Plastic component of J-integral from the Eq 1:[5]

$$J_{el(i)} = \left[J_{pl(i-1)} + \frac{\eta_{1-i}}{Bb_{i-1}} A_{pl}^{i-1,1}\right]\left(1 - \frac{\gamma_{i-1}}{b_{i-1}}(a_i - a_{i-1})\right) \quad (3)$$

here are: $A_{pl}^{i-1,1}$- the increment of plastic zone under a load-displacement record from step i – 1 to i, b and η are constants.
Based on the calculated data, *J-R* curve can be created (*J-Δa* curve) using a fitted regression line, Fig. 1. Using the regression line, the J_{Ic} was obtained. After determining the J_{Ic}, the K_{Ic} can be determined very easily.

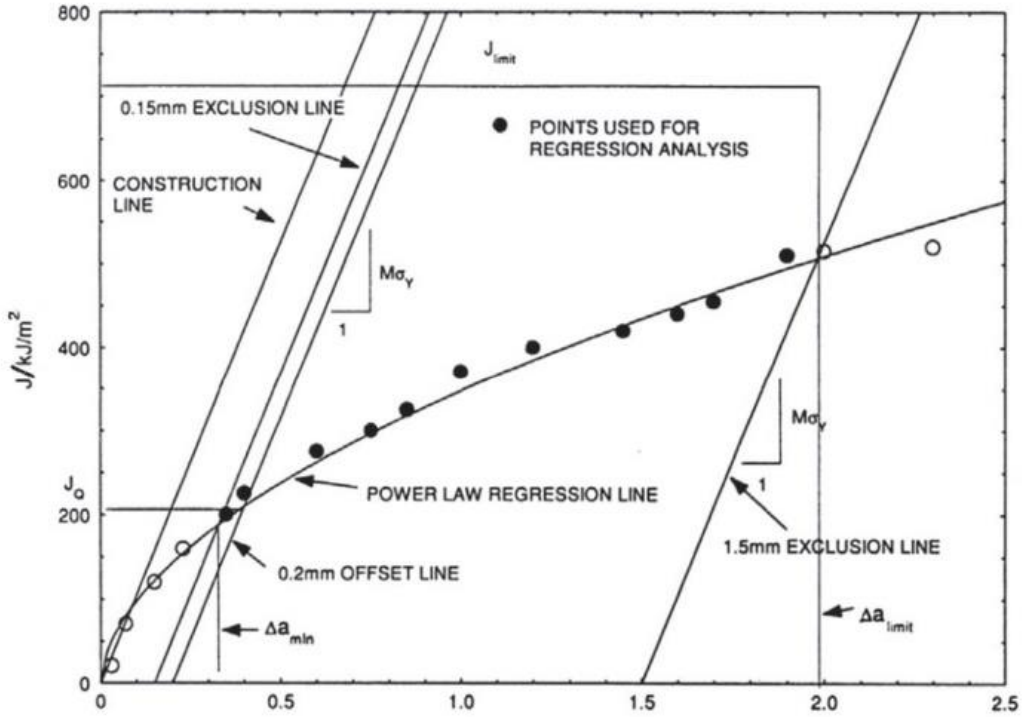

Figure 1. Standard procedure for selecting relevant points for determining J_{Ic}
Source: Zhu, X. & Joyce, J., Review of fracture toughness (*G*, *K*, *J*, CTOD, CTOA) testing and standardization, *Engineering Fracture Mechanics* Vol 85, pp 1-46, ISSN: 0013-7944, 2012

2. MATERIAL AND EXPERIMENTAL PROCEDURE.

The investigated material is micro-alloyed high strength steel, commercial mark NIOMOL 490K steel, of yield strength min. 490 MPa and specified nil-ductility transition (NDT) temperature – 60°C, produced by Slovenian Steel work company ACRONI Jesenice. It is primarily applied for dynamic loading conditions and at low temperatures.
The results of the chemical composition of the investigated steel used for fabrication of butt-welded plates of 30 mm thickness are given in Table 1. The results of tension tests obtained at RT of the parent material (PM) and the welded joint (WJ) are shown in Figs. 2 and 3 respectively, and their tensile properties (mean values) were determined using 3 PM specimens and 3 WJ specimens, are listed in Table 2.

Table 1. Chemical composition of NIOMOL 490K, wt. %
Source: original copyright

C	Si	Mn	P	S	Cr	Cu	Al	Sn	Ni	Mo	As	Nb	N	O
0.09	0.34	1.06	0.009	0.002	0.12	0.17	0.41	0.005	0.9	0.26	0.008	0.06	0.0082	0.0075

Table 2. Mean tensile properties values at RT of the investigated specimens PM and WJ.
Source: original copyright

Material	Yield strength $R_{p\,0.2}$, MPa	Ultimate strength R_m, MPa	Fracture strain, %
PM	544	610	26.47
WJ	620	650	25.5

The influence of the heterogeneity of the structure and mechanical properties of the welded joint is primarily reflected in the position of the fatigue cracks tip as well as the properties of the area through which the fracture propagates. The experiments were conducted on fatigue precracked single edge notched bend SEN(B) specimens, Fig 4., extracted along the length of the welded seam, using single specimen elastic compliance method according to ASTM E1820 standard. Plane-strain fracture toughness KI were determined in order to evaluate the behaviour of the welded joint in the presence of a crack-type fault, as the most dangerous of all structural faults.[6]

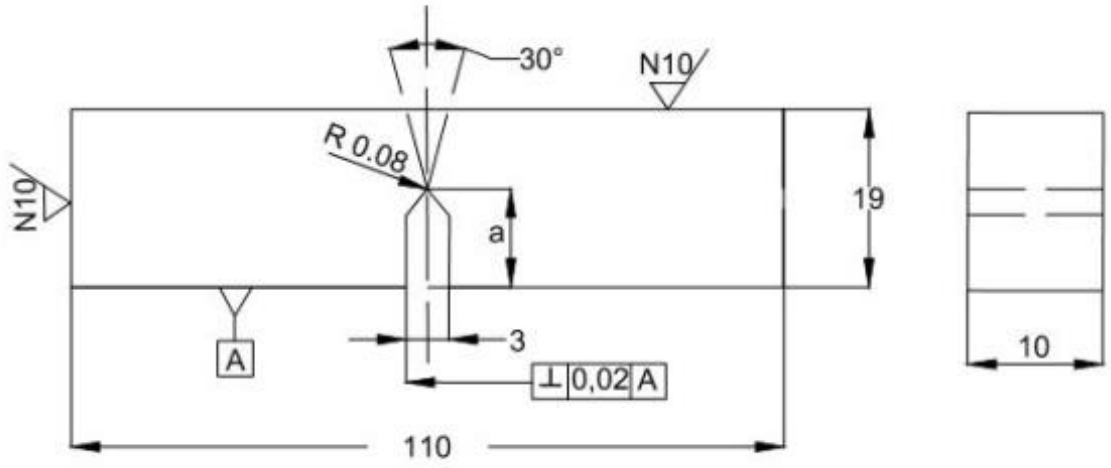

Figure 4. Fracture mechanics test specimen (SEB)
Source: ASTM E399-06 (2006). Standard test method for linear elastic plane-strain fracture toughness K_{Ic} of metallic materials. West Conshohocken: ASTM, Pennsylvania, USA.

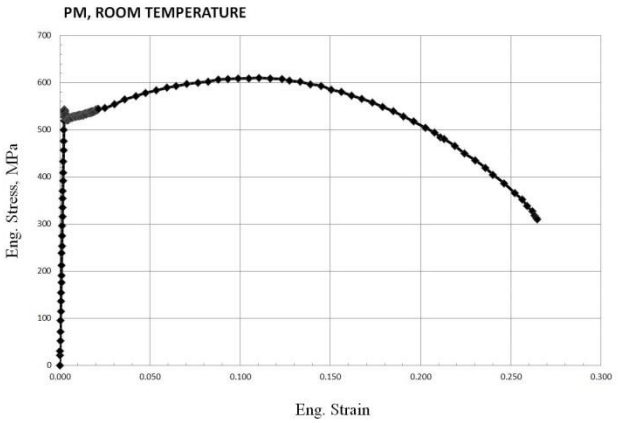

Figure 2. Engineering stress-engineering strain diagram for PM tested at room temperature
Source: original copyright

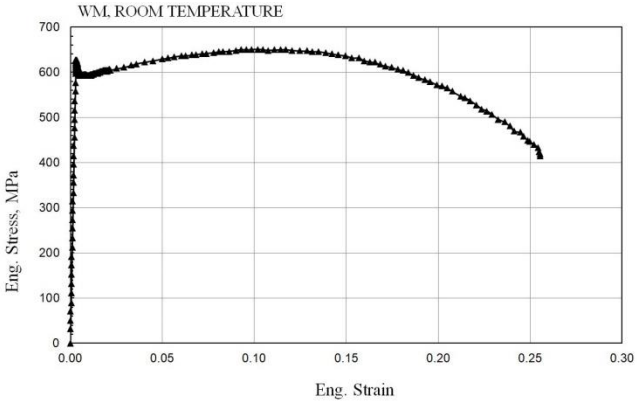

Figure 3. Engineering stress-engineering strain diagram for WM tested at room temperature
Source: original copyright

The test was performed at three different temperatures (RT, -20°C and -30°C) on an electromechanical testing machine, SCHENCK TREBEL RM 100, Fig. 5. The crack tip opening is obtained by special extensometer, with a measuring accuracy of ± 0,001 mm.

Figure 5. SCHENCK TREBEL RM400 testing machine
Source: original copyright

Based on the data collected from the testing machine, diagrams load F – crack tip opening CTOD was drawn and then the J–Δa dependence is constructed, Fig 6. The critical J-integral value, J_{Ic}, is obtained from the regression line. After obtaining J_{IC} values, values of the critical stress intensity factor (SIF) K_{Ic} were determined using Eq 4. [3]

$$K_{Ic} = \sqrt{\frac{J_{Ic} \cdot E}{1 - \nu^2}} \tag{4}$$

where E denotes elasticity modulus of the investigated steel and ν its Poisson's ratio. Results of critical J-integral and SIF values, J_{Ic} and K_{Ic}, are presented in Tab. 3.

Table 3.Valuesof the J_{IC} and K_{IC}
Source: original copyright

Temperature, °C	a, mm	Δa, mm	J_{Ic}, kJ/m^2	K_{IC}, MPa m$^{1/2}$
RT	11.617	0.414	222	226
-20	10.519	0.391	147	184
-30	10.982	0.312	118	165

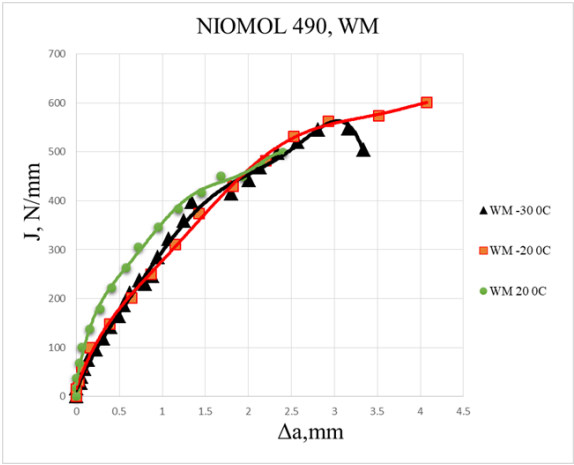

Figure 6. J – R curves of NIOMOL 490K welded joints tested at different temperatures
Source: original copyright

3. RESULTS AND DISCUSSION

The structure and mechanical heterogeneity of the welded joint influence the crack development in the elastic and plastic regions. Therefore, it is necessary to define the position of the fatigue crack when examining fracture mechanics.[2]
The obtained values for WM are within the limits of the linear values for this type of steel and are reported in Tab.3.
We can see that values for WM obtained by testing specimens at the RT are $J_{Ic} = 222$ kJ/m^2, $K_{Ic} =$ 226 MPa m$^{1/2}$, at the temperature -20^{0}C, obtained values are $J_{IC} = 147$ kJ/m^2, $K_{Ic} = 184$ MPa m$^{1/2}$ and at the temperature -30^{0}C, values are $J_{Ic} =$118 kJ/m^2, $K_{Ic} = 165$ MPa m$^{1/2}$.

4. CONCLUSION

Great interest in the application of fracture mechanics testing of welded joints encountered limitations already at the beginning, because at least 10 specimens should be examined to determine some of the fracture mechanics parameters of the welded joint. The application of fracture mechanics to the examination of welded joints is large, and the reason is, first of all, a better and more complete understanding of the behaviour of a welded joint with a crack based on data analysis is obtained in those tests.[8]

Acknowledgements
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LANDING OPTIMIZATION OF A SMALL SOUNDING ROCKET

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Abstract: *Sounding or research rockets are able to carry with them special containers in which it is possible to place various scientific instruments. The purpose of these instruments can be to perform scientific experiments or measure the desired parameters of the atmosphere during suborbital flight. Small sounding rockets, depending on the purpose, are able to reach heights of several thousand meters. Their advantage is reflected primarily in low manufacturing and exploitation costs, the possibility of quick preparation and conducting experiments. Also, it is possible to work with them in research areas that are not accessible by stratospheric balloons or orbital satellites.*
Keywords: sounding rocket, streamer, parachute, descent time, landing speed.

1. INTRODUCTION

Due to constant changes in the lower layers of the troposphere, which are most often caused by many pollutants, as well as disrespect with standards and regulations that control the release of harmful substances, large and frequent climate changes occur and these affect many aspects of humane lives. That is why there is a need for constant control of this space and continuous monitoring of all important parameters in it, such as: temperature, pressure and air humidity, content of harmful substances, intensity of UV radiation and the like. These tests can be performed using small sounding rockets.

2. SMALL SOUNDING ROCKETS

A small sounding rocket can be used to analyze the lower layers of the troposphere up to a height of 2000-5000 m. Its construction contains three basic systems, namely:

- The propulsion group, i.e. the solid fuel rocket engine, which will ensure that during operation (combustion in the chamber) a sufficient total impulse and the amount of energy that will enable the successful execution of the flight are created.
- The sounding module, which contains all the necessary electronic equipment, instruments and sensors for precise measurement of the desired parameters during descent. It must have sufficient strength to ensure safe operation and prevent any damage during flight. Collected data can be stored in the module's memory or sent directly using the transmitter. The sounding module should also have its own power source, and preferably a GPS.
- A descent system that should ensure reliable and safe activating the parachute or streamers and safe descent and landing of equipment.

According to flight technical requirements (flight up to 2000-5000 m height), a small sounding rocket should have a maximum mass of 15-18 kg, a mass of the sounding model of several kilograms and a body diameter of about 100 mm. A suitable commercially available solid fuel engine is also required. The flight course of a sounding rocket can be divided into three phases.

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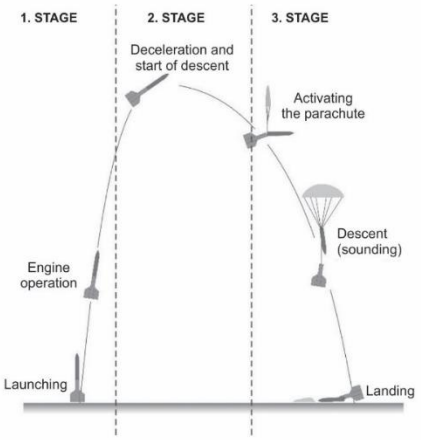

Figure 1. Phases of sounding rocket flight
Source: original copyright

During the first phase, while the rocket is on the launch pad, the engine starter is activated, which ignites the rocket fuel (propellant charge) and on that occasion, in the combustion chamber, the chemical energy of the fuel is converted into the kinetic energy of the burned gases, which, thanks to the nozzle, create thrust that drives rocket. The operation of the engine lasts only a few seconds, during which the rocket has a high acceleration [1, 2].
In the second phase, after the engine stops working, the rocket continues to move by inertia and slows down to the maximum altitude and speed v=0. Then it starts to descend. In the third phase, at a certain altitude and safe speed, the parachute is activated, which ensures a slow descent and time to make all the necessary measurements. At the end of this phase is landing with a sufficiently low speed rate that prevents unwanted damage to the equipment [3, 4]. Next chapter shows the calculation for determining the parameters during the third phase of the flight of a small sounding rocket.

3. DESCENDING AND LANDING OF THE ROCKET

The start of the descent is the moment the parachute (or streamer) is activated, which takes place slightly below the maximum flight altitude, at a relatively low speed, which enables correct opening and prevents the ropes or connections from breaking upon activation. The activation system can be mechanical or using a timer.
The distance of the rocket landing from the launch site can be large, which is usually affected by unplanned atmospheric elements such as wind speed or the formation of vertical thermal currents. That's why a streamer (rectangular strip) is often used instead of a parachute, which ensures a closer landing of the rocket but has a higher decay speed.
The two most important parameters in this flight phase are:

- t time from parachute activation to landing (sounding time). It is defined by the required time during which all necessary measurements will be performed.
- v speed of landing that ensures the safety of the equipment during the impact on the surface of the earth.

4. CALCULATION OF DESCENT TIME AND LANDING SPEED

The results obtained by the calculation differ from the actual values. The reason is the participation of several atmospheric parameters, horizontal and vertical currents, which are variable in a short period of time and cannot be predicted in advance. As the streamer gives more approximate results, it will be used in further analysis [5]. A rocket on a streamer can be viewed as a rigid body of mass m moving vertically downwards with speed v.

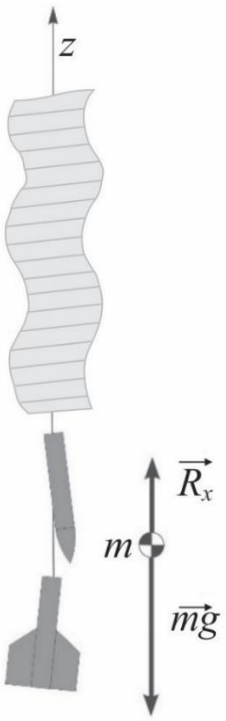

Figure 2. Distribution of forces acting on the rocket during descent.
Source: original copyright

According to Newton's second law is:

$$ma = mg - R_x \tag{1}$$

The force of air resistance acts vertically upwards and is proportional to the square of the instantaneous velocity *v*:

$$R_x = \frac{1}{2}\rho v^2 c_x S = Nv^2 \tag{2}$$

Where are: ρ - air density, c_x - drag coefficient and *S*- characteristic surface. [6, 7]

$$ma = mg - Nv^2 \tag{3}$$

$$m\frac{dv}{dt} = mg - Nv^2 \tag{4}$$

so it is:

$$dt = \frac{m \cdot dv}{mg - Nv^2} \tag{5}$$

The integral of the previous equation is:

$$\int_0^t dt = \frac{m}{N} \cdot \int_{v_0}^{v} \frac{dv}{\frac{mg}{N} - v^2} \tag{6}$$

so it's descent time: [8]

$$t = \frac{m}{N} \cdot \left[\sqrt{\frac{N}{mg}} \cdot \operatorname{arctanh}\left(v \sqrt{\frac{N}{mg}} \right) \right]_{v_0}^{v} \tag{7}$$

Since the functions tanh and arctanh are inverse, it can be written:

$$t = \sqrt{\frac{m}{Ng}} \cdot \left[\tanh^{-1}\left(v \cdot \sqrt{\frac{N}{mg}} \right) - \tanh^{-1}\left(v_0 \cdot \sqrt{\frac{N}{mg}} \right) \right] \tag{8}$$

The total mass of the system can be seen as the mass of the rocket (mass of the structure, engine without fuel, equipment) and the mass of the streamer, that is:

$$m = m_r + m_s \tag{9}$$

So equation (8) can be written in the form:

$$t = \sqrt{\frac{m_r + m_s}{\frac{1}{2}\rho c_x S g}} \cdot \left[\tanh^{-1}\left(v \cdot \sqrt{\frac{\frac{1}{2}\rho c_x S}{(m_r + m_s) g}} \right) - \tanh^{-1}\left(v_0 \cdot \sqrt{\frac{\frac{1}{2}\rho c_x S}{(m_r + m_s) g}} \right) \right] \tag{10}$$

Since hyperbolic functions are inverse, the descent speed can be obtained from equation (8) or (10):

$$v = \sqrt{\frac{mg}{N}} \tanh\left[t \cdot \sqrt{\frac{Ng}{m}} + \tanh^{-1}\left(v_0 \cdot \sqrt{\frac{N}{mg}} \right) \right] \tag{11}$$

With increasing time *t*, the tangent-hyperbolic function tends to 1, so the landing speed is:

$$v_{pr} = \sqrt{\frac{mg}{N}} \tag{12}$$

5. OPTIMIZATION OF STREAMER PARAMETERS

The main goal of such a system is definitely minimization of the mass. Like the masses of the rocket base, propulsion group and equipment are defined by the requirements of the structure itself, it is necessary to define the parameters of the rocket descent system. As mentioned earlier, in this case, the streamer will be considered due to the smaller deviation of the calculated and actual values. In this case, the condition is that the system provides the necessary descent time with the condition of minimum mass, as well as its dimensions. It is recommended that the aspect ratio of a rectangular streamer be 1:10. For financial reasons and legal regulations, optimization and tests were not performed on real sounding rockets, but on rockets of smaller dimensions. Their dimensions are 0.350 m high and 0.03m in diameter, with a mass of 0.025 kg. For the propulsion unit, a rocket motor with solid fuel of total impulse I_t=1.5 Ns and with a working time of 0.75 s was used. According to the calculation, with this rocket it is possible to reach a height of about 150 m.
In order to optimize, the BOX method according to the complex algorithm was used, for which it was created. [9]

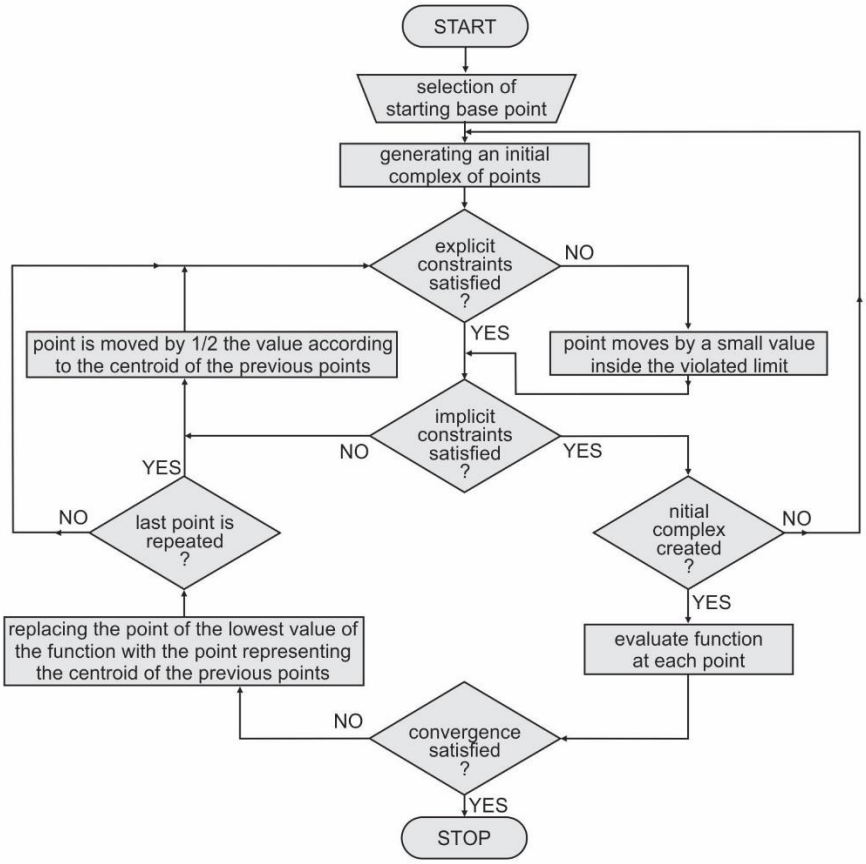

Figure 3. Optimization algorithm according to BOX's method.
Source: original copyright

In the given problem, it is necessary to find the maximum of the objective function, which is represented by equation (10). It is dependent on two variables with given constraints in the form:

$$t = f(m_s, S) \rightarrow max \tag{13}$$

$$0{,}005 \leq m_s \leq 0{,}01 \tag{14}$$

$$0{,}15 \leq S \leq 0{,}3 \tag{15}$$

The results obtained are: descent time t=55.03 s, streamer mass m_s=0.0075 kg and streamer area S=0,173 m^2 (1,32x0,132 m).

During the test, ten launches were performed with the same rocket with the same streamer. This was performed in calm weather and in the early morning hours when the currents in the atmosphere are minimal in order to minimize the unwanted effects of horizontal and vertical currents. Achieved descent times ranged from t=51 sec to t=62 sec, and only one time was below the calculated value of 55.03 sec.

6. CONCLUSION

Small sounding rockets are, among other things, practical for measuring the physical and chemical parameters of the lower layers of the atmosphere, the pollution of which significantly affects both human life and the entire flora and fauna. Due to their low cost of production and exploitation, simple use and quick production, they can have a great usage in specific research of air quality in endangered environments. The paper deals with the parameters of the final phase of the rocket's flight, descent and landing, which were confirmed by experiment.

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ENVIRONMENT AND SUSTAINABLE DEVELOPMENT. MECHATRONICS.
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TRAFFIC ENGINEERING. BIOTECHNOLOGY AND HEALTHCARE.
MECHANICAL ENGINEERING. ECOTOURISM AND RURAL DEVELOPMENT.

SYSTEM SCALING RENORMALIZATION PROBLEMS IN BIO-THERMODYNAMICS: I) Yeast cell colony size scaling, as an opportune model

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Abstract: *The existence of scaling relations between components of cell growing colony i.e. the production of proteins, single cell- and complete colony- growth, is considered in theoretical aspects and applying to yeast as an opportune model. The relations of methods applied with bio-thermodynamics principles accepted nowadays, are expound.*The *growth of each yeast wild type colony considered, is scaling regularly, with protein production in its cells, and with practically the same exponent, although the size of cells varies due to division. It indicates that the system expansion gradient at those two levels is the same, and wall coordinated and balanced by thermodynamics energy, and entropy parameters. It is very important for further bioengineering system design, especially in the frame of the new industrial trends.*
Keywords: Bio-thermodynamics, scaling principles, universality theory, yeast, Industry 4.0 concept

1. INTRODUCTION

The **scaling properties** of some objects in nature have been recognized very long time, as can be seen from some writings of Euclid, Archimedes, some members of Pythagorean School and through centuries and millennia, up to Galileo, Reynolds and present day papers. But, the research of deep logics of rules, relating scaling lows into common theoretical core, started with the rise of modern thermodynamics, and the new mathematical areas, as well [1-10]. In a similar way, the first ideas about problems of **nowadays bio-thermodynamics** rose already in writing of Schrodinger, Krebs, and Monod but, it waited with growth until polymer science came to enough high level of understanding of macromolecular structure and properties [5-15].That research has been founded on Paul Flory's thermodynamics theories on macromolecular systems, and Linus Pauling's quantum mechanical theories of peptide bond, α-helix, etc., and on their initiative of founding the new sciences related to bio-polymers (i.e. molecular biology, bio-medicine),what also lead to e.g. recognition of essential role of protein-chlorophyll conjugates in conversion of sun light to bio-energy (what makes even 65 TW from about 10 PW of the radiation energy coming from sun to the earth) [11-17].The interest grow at that time also, due to new developments of satellite technology, and planning for human traveling to the Moon, what raised in 1970s a numerous issues on human body response to thermodynamically completely different conditions, ever faced (where polymers also are important, as bio-protecting materials). It supported further the development of cryobiology but, also research on cell dehydration properties. Naturally, it generated also high interest of food and beverages industrial producers for more efficient work and conservation, with its help, as it was in First Ind. Revolution for classical thermodynamics help, for efficient use of heat, and recently for preservation of vaccines and medical samples [3, 11-14].The issues of climate changes and other environment impacts to life processes also supported development of bio-thermodynamics in the next period. Additional impact came from bio-medicine by cell engineering developments, and

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discovering stem cells generation in adults, what followed with creations of the whole organs, out of them [12-14],
The research of genetics, developed in parallel with disciplines mentioned, then naturally establish close relations with those polymer-based sciences, but all of that generated also the whole set of interdisciplinary research fields, even more than 30 new disciplines, with names ending with - omix (e.g. proteomics, genomics [17,18]). Nowadays quite obvious is the need that those research results, abundant but, each focused on some narrow aspects, should be connected all together, and make available for some broad engineering, practical, purposes in modern bioengineering. Bioengineering is included, in that sense, into 3 main holders of Industry 4.0 concept, together with artificial intelligence and robotic production [11, 18].
To be able to fulfill such tasks, nowadays bio-thermodynamics also tries to make unified theoretic background connecting 3 fields of research: on bio-polymers, on living cell cultures and tissues, and on metabolic functions at all levels of cell systems. For example, temperature (T), pressure (P), acidity (pH), additives and solutes etc., influence a protein molecule performance in the cell, but that all influence also the following activity of that cell, and clusters of those cells, and living systems as a whole e.g., activity of medical-lab culture, or cells in a bio-reactor, but also cells in tumors-to be cured. Besides that applicative approach, bio-thermodynamics considers fundamental issues as cell growth, division, aging and human organism aging as a whole [18-27]. All those mechanisms must follow basic thermodynamic lows, but their balancing at different system levels, from a macromolecule to the organism, is a complex problem. For example, what are relations between three fundamental processes of living systems grow and development: protein production in a cell, the cell growth, and the corresponding cell cluster growth (not to extend for now the cell growth mechanism to the mechanisms of organism growth and cell replacement issues). Only recent years are available relevant experimental techniques to study and compare those processes in parallel, thanks to AI with modern cytometric and spectroscopic arrangements [3, 18, and 22] in complete agreement with **Industry 4.0 concepts**, causing significant advances in medicine and agronomy last years. In both of them appears the problem of coordination system processes, at different levels. In particular, in agronomy it starts with molecular activity of plant cell, up to huge systems outputs, from large surface plantation. The **smart management** here is needed, to provide efficient use of robot work in variety of conditions recently made by manual work and now requires adjustment to appropriate **technological operations** with plenty of details, what requires help and control of some AI center. The activates of such kind are still in development, but as a promising support from bio-thermodynamics aspect can be the application or rarefaction theory, with modified OUT method e.g. S16 rRNA sampling, modified now to cell colony levels relations, all with possibilities of the help from **nucleic acids sequencing AI platforms** (active nowadays or adapted to the new tasks in the future). (See section 2.3). In other words, bio-thermodynamics in involved in numerous nowadays activates but one of the main problems common to all is quantification of level relations. For illustration of that, we consider here the growth of cell colony from macromolecular production inside a cell, till change of colony size, using scaling as appropriate method for all levels and baker yeast as an opportune model, been of extensively studied, and best known system in microbiology.

2. THEORETICAL BACKGROUND

2.1 Scaling lows of Landau and Flory and foundations of modern thermodynamics

This year passed exactly 200 years since baron Cagntard de la Tour as the first, detected a critical point, measuring transition temperatures at high pressures, by lucid combination of experimental methods from several fields. Interestingly, he was interest for fermentation production of alcohol and the first critical temperature T_C, he found for alcohol, so bio-thermodynamics may origin from the same roots as criticality?! But, the both where not appropriately understood than, in modern management terms, although the interest for evaporation methods, and steam engine was very high.

But, it encouraged T. Andrews in further measurements of pressure-volume relations and making liquid-vapor coexistence curves and so the first, but very useful, phase diagrams. In 1873 (50 years after de la Tour) showed J.D. van der Waals that Andrews diagrams can be explained theoretically by equation of state, that he formulated based on mean field approach. The deviations of van der Waals theoretical curves from Andrews experimental, in the biphasic area, soon explained Maxwell in qualitative and quantitative manner, using the second law of thermodynamics and his theories on molecular motions. So in 1870s emerged new approach to thermodynamics, based on direct description of thermal molecular dynamic, as through the fundamental papers of Maxwell in 1971 (naming such mathematical description of system particle thermal motions, The Statistical Mechanics), papers of Boltzmann in 1875 (with his formula on entropy as a measure of systems ordering) and of Gibbs, in 1876 (with his description of thermal equilibrium of particle systems). Still, the behavior of systems close to critical point staid mysterious, e.g. all basic parameters of state, when approaching the critical point T_C, were observed to follow the scaling lows, with the same exponent for each kind of parameter, no matter what is the chemical structure of a liquid substance used, and with diverging behavior at the critical point [15]. For example, the change of the heat capacity is described by characteristic scaling exponent α with:

$$C_P \propto |T - T_C|^{-\alpha} \tag{1}$$

The new approach to the problem, and also to unusual behavior of liquid helium transitions, especial its superconductivity and magnetic properties, started Lev Landau in 1937. But for the magnetic properties, the fundamental influence has head also, the theoretical model of Ising, published in 1924, who considered magnetic dipole moment orientation changes with the field [3,4] through magnetic spin vectors **S** orientations. Landau used both, Gibbs thermodynamics and Ising models for the start [15]:

$$C_P = -T\left(\frac{\partial^2 G}{\partial T^2}\right)_P \tag{2}$$

But, Landau assumed that Gibbs free energy density (G_{dns}) change, with spin ordering, can be represented by power series of spin density field variable $\mathscr{S}$ (**X**),what is later called the order parameter, and where **X** represents the space coordinates:

$$G_{dns}(T,\mathscr{S}) = \mathrm{G}_0 + a(T)\mathscr{S}^2 + \frac{1}{2}b(T)\mathscr{S}^4 + \ldots \tag{3}$$

For thermodynamic equilibrium, Gibbs free energy tends to minimum, so:

$$\frac{\partial G_{dns}}{\partial \mathscr{S}} = 2\mathrm{a(T)}\mathscr{S} + 2\mathrm{b(T)}\mathscr{S}^3 = 0 \tag{4}$$

Likewise can be expended the parameter $a(T)$ around the critical point $a(T) = a_0 (T\text{-}T_C) + \ldots$so we obtain in the first approximation two solutions for order parameter: the trivial $\mathscr{S}=0$ and the relation:

$$\mathscr{S}_0^2 = -\frac{a}{b} = -\frac{a_0}{b_0}(T - T_C) \tag{5}$$

That gives values for $C_P = (a_0^2 / b_0)\ T$ for $T<T_C$ and $C_P = 0$ for $T > T_C$, and results with scaling exponent $\alpha = 0$. In addition, it leads to scaling of order parameter that can be related for helium to magnetic susceptibility (that can be measured) and indicate the change of particle ordering as reason to special properties. In thermodynamics it is analogy to compressibility, and leads to introduction of a new kind of universal exponent, related to system ordering, assigned β:

$$\mathscr{S}(\mathrm{T}) \propto |T - T_C|^{\beta} = |T - T_C|^{\frac{1}{2}} \tag{6}$$

Landau continued work on those problems till 1953 collaborating with Ginsburg and introduced, for better description of ordering, a new kind of scaling, described by correlation length ξ, very useful parameter, to quantify cooperative coupling in the system, with scaling exponent assigned ν :

$$\xi \propto |T - T_C|^{-\nu} \tag{7}$$

In the next 1954 year, published M. Gell-Mann with F.E. Low the paper on electromagnetic coupling in molecular systems under photon propagator at high energies, and described it with the

coupling parameter $g(\boldsymbol{\mu})$ at the energy scale $\boldsymbol{\mu}$ and reference scale M. They also realized that the effective scale can be taken at arbitrarily $\boldsymbol{\mu}$ and vary following theory results at that other scale [16]:

$$g(\kappa) = G^{-1}\left[\left(\frac{\kappa}{\mu}\right)^{d} G_W(g(\mu))\right] = G_W^{-1}\left[\left(\frac{\kappa}{M}\right)^{d} G_W(g(M))\right] \tag{8}$$

where G is Wegner's scaling function. They elaborated further this rescaling problem, in the range of infinitesimal transformations, but later a number of authors focused on deeper understanding of its physical meaning and possible generalizations of the process: B. Windom, A. Patashinski, V. Pokrovsky, L. Kadanoff, M. Fisher, K. Wilson and some others. So in 1971 Ken Wilson succeeded in formulation of rigorous mathematical procedure for renormalization of critical phenomena named Renormalization Group, and with only a couple of papers published on the subject, deserved The Nobel Prize for physics in 1982, what is probably, the unique case for the theory work, in the history of The Prize, but was for results of fundamental importance and such a complex task [10] Meanwhile, but after Landau published his first theory, developed Lars Onsager analytical procedure for solution of Ising model in two dimensions, what provide possibilities for verification of all results mention above, in two dimension cases (the analytical solution of three dimensional Ising model, nobody succeeded to solve, till now) [1,27].Those verifications confirmed the value Landau obtained for α=0, and also experimentally determined value (recently in satellite) α=0.0127. But the correct value for β is (1/8) and not (1/2) what Landau obtained. Also other exponents from the universality class, calculated in the mean field approach, differ from rigorous, analytical solution e.g. scaling exponent γ of isothermal compressibility close to critical point is (7/4) and not 1, and corresponding scaling exponent for system density is δ =15, not 3 -from mean field approach Polymer networks and percolation scale in 0.56 to 1.29 range [1, 26, 27] With exact values of scaling exponent values was possible to develop functional relations between them. It indicates special importance of correlation length exponent ν and scaling exponent related to volume η, while all others can be derived from them, with help of Renormalization Group.

In parallel with scaling universality theory foundation in theoretical physics and in the same period of time, Flory developed in polymer science the theory on interactions dominated by the large chain structure. It provides possibilities to obtain scaling exponents independently and staring from completely different aspects. Moreover, it gives directly the correct value of the 3D universal exponent ν=3/5=0.6 (from Universality approach is now 0.62± 0.02), what is here of special interest for bio-thermodynamics [1,5]. Because of restricted space available here, we can describe it only in short, but we shall point here to possible derivation in analogy steps to the methods above. The essential difference between those approaches is in Landau development for model with large number of particles in agreement with classical thermodynamics principle and Flory development for the model of single polymer chain, but with large number of conformations, in agreement with the Concept of Macromolecular Statistical Mechanics, he introduced in science [6-9]. According to that, we can describe the coiled polymer molecule states, with Gibbs free energy:

$$G_{coil} = U - TS \cong N_m k_B T B_V \frac{N_m}{\frac{4}{3}\pi R^3} + \frac{3k_B T R^2}{2N_m a^2} \tag{9}$$

Here N_m is number of chain links, k_B the Boltzmann constant, B_V thermodynamic second virile coefficient, $\boldsymbol{R}$ radius of the coil with a describing link dimensions. According to equilibration principles: $\partial G_{\text{coil}} / \partial \boldsymbol{R} = 0$ so we obtain:

$$-\frac{k_B T B_V N_m^2}{R^4} + \frac{k_B T R}{N_m a^2} = 0 \tag{10a}$$

Solving for $\boldsymbol{R}$ gives explicitly the scaling of the size, that macromolecule takes in space, by excluding the other particles from that volume, according to **Flory's Theory of excluded volume,** and complementary to **Einstein's model of the thermal vibration**s in thermodynamics [1,7,15].

$$R \propto (B_V a^2)^{1/5} N_m^{3/5} \tag{10b}$$

2.2 Nucleic acid thermodynamics

Flory contributed also with first theoretical papers on DNA and RNA thermodynamics, considering interactions inside the volume excluded, and the volume opened, to other molecules. Now it is a large field, growing fast due to both, hybridization reactions and sequencing methods, that are managed today up to commercial level, and in number of disciplines.

2.3 Extension of the scaling principles and AI support of it

First established in thermodynamics, the Scaling Universality Theory extended to number of other sciences, from classical and quantum electrodynamics, nuclear structure, all up to cosmology, **giving to thermodynamics again leading position** in Ind.04 concept of 3 holders(as it had in The first Industrial Revolution) but now further progress is not possible to manage without help of AI. Such extension into bio-sciences started with **bio-thermodynamics**. We try to illustrate it, in this short contribution, by cell bioengineering issues, both theoretical and practical, using yeast model.

3. EXPERIMENTAL DATA, MATERIALS AND METHODS

Baker yeast cells have been cultivated very long time through human history for production of food, beverages, conservation some of the products by fermentation, but also present time fundamental scientific research e.g. in genomics [17-27]. In the course of time, is accumulated a huge amount of data in the literature on its colony grow, cell grow, and cell structure to properties [18-25].The relations between colony size and number of cell at some stage of development are nowadays quite obvious, but for management of design, or activity predictions, in cell engineering, medical control of tissue growth, and many agricultural tasks, is of special interest the scaling with time. In particular could be useful, relating cell systems grow, to present level of polymer scaling in science, and AI tools. So we analyzed data on the increase of colony, cell and polymer content size, of yeast as an opportune model. Here, we related time properties of sampling from the same system, or systems grown at identical conditions, media and temperature (YEP+2%glucose, 30 ^{0}C). In the next paper of this series of investigations, will be compared the system grow at different temperatures. Data presented are from Beckman Counter Multisizer or Coulter Electronics Counter and protein content from flow fluorescent cytometer and some obtained by cell lysing and polymer characterization [22].

4. RESULTS AND DISCUSSION

First we made qualitative analysis of the numerous data as described in the previous section making correlations of a system size with time during growth looking for self-similarity that Saccharomyces crevisiae strains expose, both of wild type (WT) and natural and synthetic generated mutants, by nowadays methods (many controlled, in addition, by hormones and/or inhibitors). Keeping in mind that those correlation represent averaged effects, because some cells decrease due to division, but other grow, with protein production, at the same time, 3 different system scaling behavior can be isolated (a) average size of cells is the same, and system grow dominantly by increasing the number of cells e.g. for WT (b) some cells size is high but, growing number is lower (c) dominant number of buds is 1 or 2 or 3 (what has influence upon actin skeleton orientation, and protein order, changing density, according to recent papers). So we restricted further research on WT strains cell number growth, with low budding, and obtained similarity coefficient 1,22 (with coefficient of determination R^2=0.993) and for proteins in a cell 1.1 (R^2=0.991) with scaling exponents for both of 1.2±0.1. Those results are in agreement with theoretical, for network directed percolation scaling [1-4], and polymer polarity [7-9], but restricted for now to wild type yeast behavior, and for other systems are needed more data, from phosphorescent flow cytometer with AI support.

5. CONCLUSION

Scaling and Renormalization Group are among most important theoretical methods now, for relating structure and properties from nano- to macro-levels, established in modern thermodynamics and extended to classical and quantum electro-dynamics, nuclear structure, field theory, etc., but still not enough in bio-sciences. For that is bio-thermodynamics the most convenient way, as can be seen from modern AI applications to cell system analysis, as we illustrated in yeast case, obtaining both, practical parameters for comparison between strains colonies behavior, and the scaling of protein production. Results indicate indicates that the system expansion gradient at those two levels is the same, and wall coordinated and balanced by thermodynamics energy and entropy parameters.

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INFLUENCE OF LAMINATE STACKING AND FIBER VOLUME FRACTION ON NATURAL FREQUENCIES OF COMPOSITE KEVLAR 49 ARAMID – 3501 – 6 EPOXY PLATES

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Abstract: *This research addresses the influence of the material design of Kevlar 49 Aramid – 3501 – 6 Epoxy on the natural frequencies of composite plates. The goal of the research is to obtain direct functionality of natural frequencies on material design, that can be used in engineering practice when designing composite flight vehicle components, such as aircraft stabilizers and missile fins. The modal analysis represents the desired dynamic behavior of elastic bodies and therefore it must be performed in the initial design of these components. Material design is varied with variations of symmetric lay-up and fiber volume fraction. Natural frequencies and normal modes of an investigated plate are obtained using a numerical approach.*
Keywords: Natural frequencies, Modal analysis, Composites, Finite element method

1. INTRODUCTION

In the present paper, the dependency of natural frequencies of thin, non-tapered composite plates on the type of layup and ratio of individual components in the composite is investigated. Every dynamic aeroelastic phenomenon, such as flutter, aeroservoelasticity, buffeting, gust, etc., is in direct correlation with normal modes of flight vehicle structure. Since it is well-known that all of the aeroelastic effects can have disastrous and catastrophic effects on aircraft structures, it is of paramount importance to investigate its natural frequencies, even in the initial design, and therefore tailor the composite to sustain external loads. The first two mode shapes are analyzed, which describe the dynamic behaviour of composite plates as first bending and first twisting.
Modal analysis is a primary engineering tool for the prediction of the dynamic behavior of flexible structures and its application can be found in solving numerous various engineering problems [1]. Within the scope of modal analysis, natural frequencies, normal modes, and shapes are studied, to obtain a mathematical model that describes the potential dynamical behavior of the mechanical system. Natural frequencies directly represent the rate of oscillations of elastic bodies in a state of free vibrations. Modal analysis provides a set of simple harmonic motions of the structure, while each harmonic is described with one natural frequency, and combines them in one linear set. Since a flexible structure can have infinite mode shapes, while studying modal analysis of a structure, one must observe only those modes that influence a large portion of the mass of the structure.
The effect of material design, in terms of laminate stacking and fiber volume fraction on normal modes of composite structures used as missile fins is investigated. These structures are, because of their flexible design, inclined to structural stability loss. For this research, it was arrogated for the composite to be formed from two individual components: Kevlar 49 Aramid – 35016 – 6 epoxy.

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The design of material is analyzed by varying laminate, with a variation of the individual lamina, and by varying volume fraction of fiber in the composite. The usage of composite materials in the aerospace industry is shown in Figure 1. Composite materials have a high contribution in the share of materials used in the aerospace industry because of their unique possibility to tailor to a specific engineering requirement.

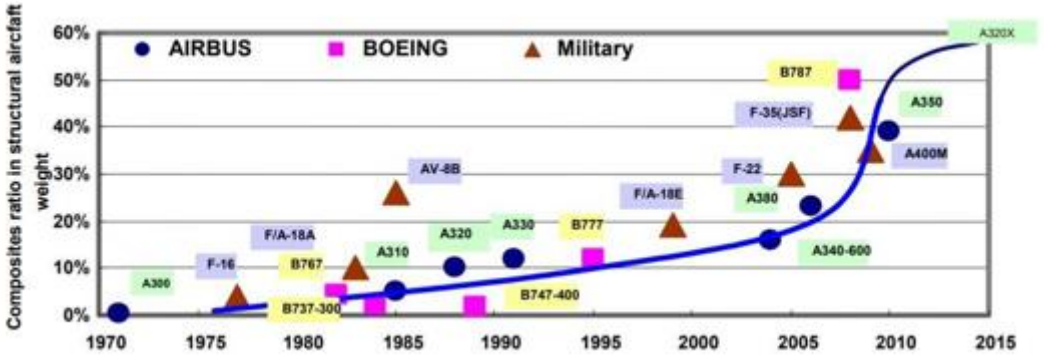

Figure 1. Application of composite materials in aerospace [2]

2. INTRODUCTION

2.1 Material Model

Design and manufacturing of composites is far more expensive and demanding than of conventional materials. Today, composites can be designed using numerous analytical and numerical theories. In the scope of this research, popular Classical Laminate Theory (CLT) was used in material design for the analysis of laminate, because it determines complex stress–strain fields with high accuracy. CLT's foundations rely on Kirchoffs research of thin plates and expand it in terms of stacking individual plates (laminas) into integrated lay-up [3].

Bearing in mind the goal of this research to determine the effect of layup type and share of fiber in composite, different types of composite Kevlar 49 Aramid – 3501-6 Epoxy are analyzed. Since the dynamic behaviour of a structure depends on its natural frequencies, which depend on inertial and stiffness of a structure, material properties are of significant importance in modal analysis. It was arrogated to analyze three types of this material, which was achieved with varying fiber volume fractions, and six types of symmetric laminate, with the aim that inside the lamina doesn't occur shear-coupling effect.

Mechanical properties of laminae can be obtained with the application of micromechanics, or with various experiments of test tubes on tensile strength tester. In this research, methods of micromechanics were performed on individual material components in the composite for determination of mechanical properties of the specially orthotropic lamina are listed here:

$$E_1 = E_f^1 V_f + E_m V_m$$

$$\nu_{12} = V_f \nu_f + V_m \nu_m \tag{1}$$

$$E_2 = \frac{E_m}{1 - \sqrt{V_f}\left(1 - \frac{E_m}{E_2^f}\right)}$$

$$G_{12} = \frac{G_m}{1 - \sqrt{V_f}\left(1 - \frac{G_m}{G_2^f}\right)}$$

Individual phase mechanical properties in above relation (E_m, E_f, G_m, ν_{12}) are obtained from material datasheet, found in literature [4]. Each composite phases are designed to be in range of $60 - 40\ \%$ for V_f, as this composite is used as missile airframe. Obtained mechanical properties of material analyzed in current paper are presented in Table 1.

Table 1: Kevlar Aramid 49 – 3501 – 6 Epoxy mechanical properties

$V_f[/]$	$\rho[g/c\ m^3]$	$E_1[MPa]$	$E_2[MPa]$	$G_{12}[MPa]$	$\nu_{12}[MPa]$
0.4	1.358	54980	5687	3849	0.338
0.5	1.384	67650	5913	4614	0.337
0.6	1.402	80320	6132	5625	0.336

The mentioned approach is applicable to the design of unidirectional laminae (UD), which are the subject of this research. Laminate is designed to be quasi-isotropic (QI) and symmetric to the neutral surface. The mentioned approach of designing a laminate is often used in the preliminary design of missile fins, because this approach disables shear – coupling effect and maintains in-plane stiffness independent of laminae orientation [5].

The laminates that are analyzed within this research are described with following layup models: $[0_4, 0_2]_s$, $[0_4, 10_2]_s$, $[0_4, 22.5_2]_s$, $[0_4, 45_2]_s$, $[0_4, 60_2]_s$, $[0_4, 75_2]_s$, $[0_4, 90_2]_s$, $[10_4, 0_2]_s$, $[22.5_4, 0_2]_s$, $[45_4, 0_2]_s$, $[60_4, 0_2]_s$, $[75_4, 0_2]_s$, $[90_4, 0_2]_s$. Mechanical properties of analyzed laminates are obtained following forms:

$$E_x = E_y = 2(1 + \nu_{xy})G_{xy}$$
$$G_{xy} = \frac{1}{2}G_{12} + \frac{1}{8}E_1\frac{(E_1 + E_2 - 2\nu_{12}E_2)}{E_1 - 2\nu_{12}^2 E_2} \quad (2)$$

2.2 Modal Analysis

Various approaches can be carried out for determination of dynamical behaviour of flexible body – analytical, numerical and experimental. Analytical methods are of great importance for mechanical systems that can be described with simple mechanical-mathematical model [7], due to their great accuracy. Experimental modal analysis is quite expensive and tedious and it requires additional equipment depending on intensity of frequencies, such as mechanical excitation systems, electromagnetic exciters (shakers) and acoustic systems [8].

A thin clamped laminate, representing a missile fin, has infinite number of degrees of freedom, and therefore its governing equation of motion can be described with second type of Lagrange's equation:

$$\frac{d}{dt}\left(\frac{\partial E_k}{\partial \dot{q}_j}\right) - \frac{\partial E_k}{\partial q_j} = -\frac{\partial E_p}{\partial q_j} + Q_j \quad (3)$$

Since overall energy of the described system is a function of generalized coordinates, if the expressions for kinetic and potential energy were included in equation (3), the following system of equations would become non-linear and extremely demanding for analytical solving. Therefore, a method of linearization is implemented to the equation (3), and keeping in mind the phenomenon of free-vibration, the dynamic behavior of the mentioned system becomes described in reduced matrix form:

$$[M]\{\ddot{u}\} + [K]\{u\} = 0 \quad (4)$$

In relation (4), $[M]$ and $[K]$ are used to represent mass and stiffness matrix of the system, respectively. It is common to assume harmonic particular solution to equation (4):

$$\{u\} = \{\varphi\}\sin(\omega t - \alpha) \tag{5}$$

In relation (5), ω represents natural frequency of the oscillating system, φ represents a harmonic function of mode shapes and α is a phase difference. The natural frequencies are determined by solving the characteristic equation of the system described with relation (4), which follows as:

$$([K] - \omega^2[M])\{\varphi\} = 0 \tag{6}$$

Natural frequencies of a cantilevered plate, representing a missile fin clamped to the missile body, can be determined with the application of Rayleigh-Ritz theory for cantilevered beam. In the following relation, modes of a plate are represented in terms of material and geometrical properties and type of boundary condition:

$$\omega_n = \frac{\lambda_n}{b^2}\sqrt{\frac{D}{\rho t}} \tag{7}$$

In the previous relation n represents number of natural frequencies, λ_n is a function of geometry of a plate, ρ is material density, t is material thickness, D represents flexural rigidity of a plate, and for composite plates it can be computed as:

$$D = \frac{E_x t^3}{12(1 - \nu_{xy})} \tag{8}$$

For the purpose of this research modal analysis was performed using the finite element approach. Plate is modeled with four-node quad elements. Lancoz algorithm was used for calculation of real solutions, due to its speed, simplicity and accuracy [9]. Geometry of a clamped plate used to represent missile fin is given on Figure 2, with all units in millimeters. Commercial software Femap/Nastran was used for numerical modal analysis. The fineness of the mesh was examined until the results converged. Size of all elements equals to *4* millimeters. FEA model has *1875* elements with *1976* nodes. Boundary condition that is applied to the root edge of a plate is commonly used to represent missile fin clamped to the missile body.

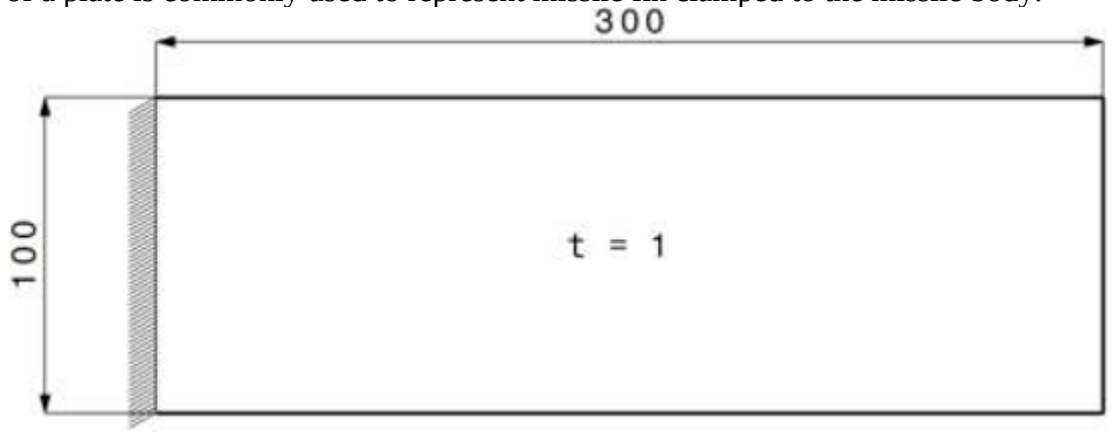

Figure 2. Geometry model

3. RESULTS AND DISCUSSION

Based on the results of numerical modal analysis, the polynomial functionality between fins natural frequency and type of laminate was found. The error of polynomial approximation in regression model is described with a statistical measure R^2, which represents the percentage of a dependent variable that is described with independent variable. Shape of first two modes are presented in Figure 3.

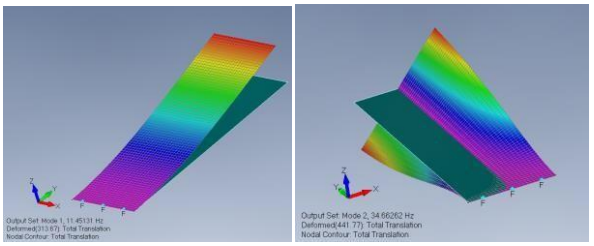

Figure 3. First two mode shapes (first bending – left, first twisting – right)

Analyzing the obtained results, in terms of the first two modes, it was observed that an appropriate QI stack must be designed for laminate to have required bending and torsional stiffness. In accordance with that, divergence in bending and torsional stiffness between contrary types of symmetric QI laminates can reach up to 62% and up to 30%, respectively. Such changes in stiffness are extreme, and they can induce disastrous effects on the airframe structure.

In the following text, the obtained numerical results, with appropriate polynomial approximation are shown graphically in Figures 4 and 5, and afterward, the formed polynomial functionality of natural frequencies compared to the type of laminate and fiber volume fraction is tabulated in Table 2.

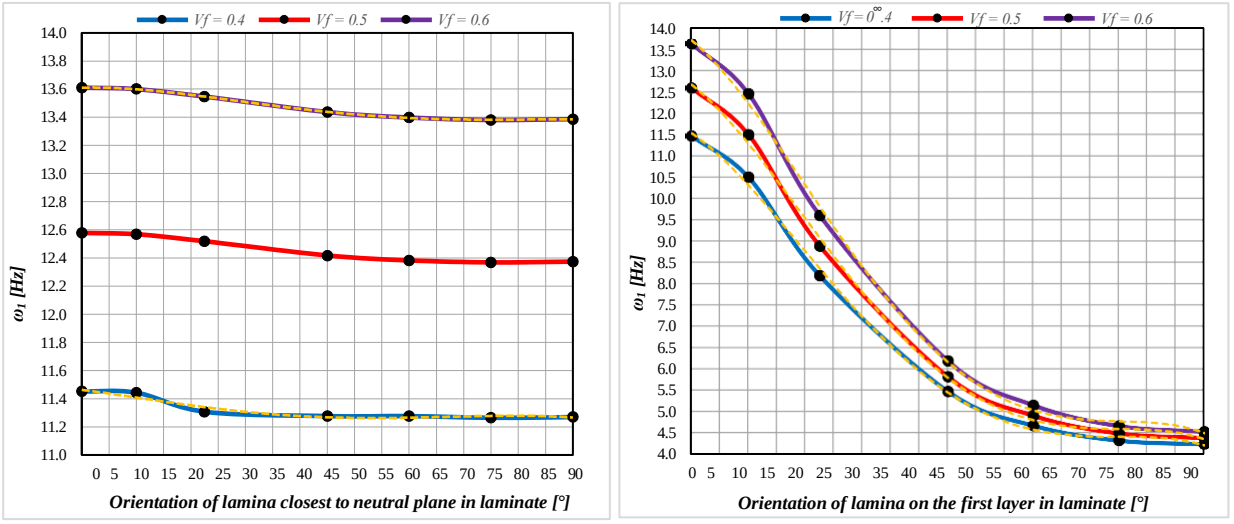

Figure 4. First mode natural frequency as a function of laminate lay-up and fiber volume fraction

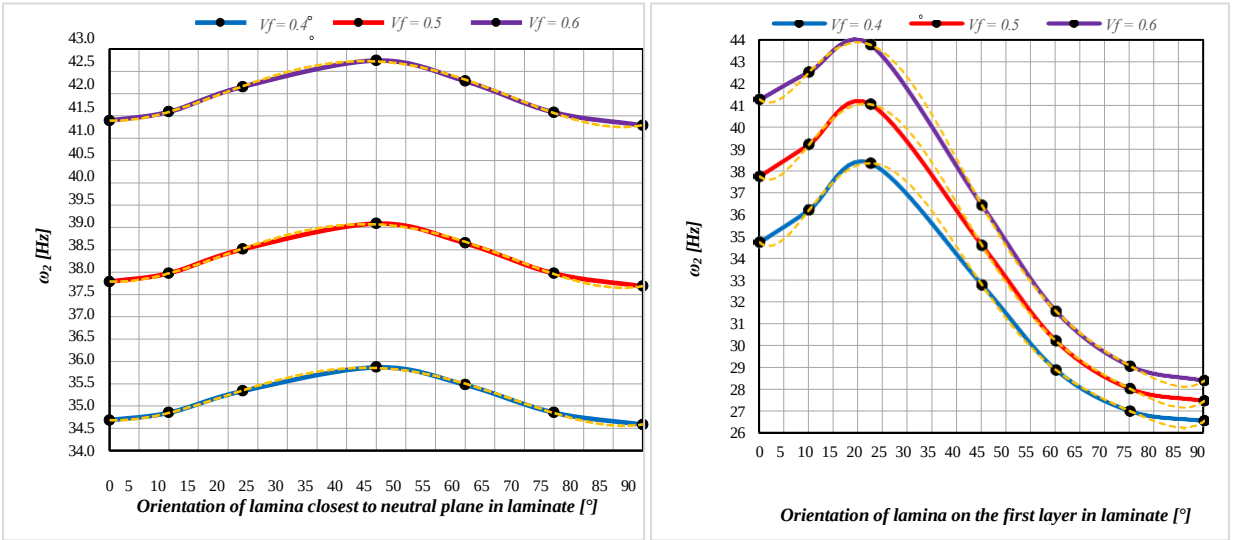

Figure 5. Second mode natural frequency as a function of laminate lay-up and fiber volume fraction

Table 2: Obtained polynomial functionality of first and second mode natural frequency on laminate lay-up and fiber volume fraction

x [°]	*Layup*	$\omega = f(x, V_f)$
0 ÷90	$[0_4, x_2]_s$	$\omega_1 = \begin{Bmatrix} -2\cdot10^{-8}x^4 + 3\cdot10^{-6}x^3 - 7\cdot10^{-5}x^2 - 5\cdot10^{-3}x + 11.5;\ V_f = 0.4;\ R^2 = 0.93 \\ -2\cdot10^{-8}x^4 + 4\cdot10^{-6}x^3 + 12.5 \quad ;V_f = 0.5;\ R^2 = 0.999 \\ -2\cdot10^{-8}x^4 + 4\cdot10^{-6}x^3 + 13.61 \quad ;V_f = 0.6;\ R^2 = 0.999 \end{Bmatrix}$
		$\omega_2 = \begin{Bmatrix} 4\cdot10^{-7}x^4 - 6\cdot10^{-5}x^3 + 0.002x^2 - 0.006x + 34.7; \quad V_f = 0.4\ ;\ R^2 = 0.999 \\ 4\cdot10^{-7}x^4 - 7\cdot10^{-5}x^3 + 0.002x^3 - 0.006x + 37.7\ ;\ V_f = 0.5;\ R^2 = 0.999 \\ 4\cdot10^{-7}x^4 - 7\cdot10^{-5}x^3 + 0.003x^3 - 0.006x + 41.1\ ;\ V_f = 0.6;\ R^2 = 0.999 \end{Bmatrix}$
0 ÷90	$[x_4, 0_2]_s$	$\omega_1 = \begin{Bmatrix} -4\cdot10^{-7}x^4 + 8\cdot10^{-5}x^3 - 0.003x^2 - 0.092x + 11.5;\ V_f = 0.4\ ;\ R^2 = 0.998 \\ -5\cdot10^{-7}x^4 + 9\cdot10^{-5}x^3 - 0.004x^2 - 0.105x + 12.6\ ;\ V_f = 0.5;\ R^2 = 0.998 \\ -6\cdot10^{-7}x^4 - 0.004x^2 - 0.110x + 13.69 \quad ;\ V_f = 0.6;\ R^2 = 0.998 \end{Bmatrix}$
		$\omega_2 = \begin{Bmatrix} 6\cdot10^{-5}x^4 - 0.002x^3 + 0.055x^2 - 0.176x + 34.7;\ V_f = 0.4\ ;\ R^2 = 1 \\ 6\cdot10^{-5}x^4 - 0.002x^3 + 0.055x^2 - 0.170x + 37.7;\ V_f = 0.5;\ R^2 = 1 \\ 5\cdot10^{-5}x^4 - 0.002x^3 + 0.050x^2 - 0.156x + 41.2;\ V_f = 0.5;\ R^2 = 1 \end{Bmatrix}$

4. CONCLUSION

Within the scope of this research it was found that laminate stacking and fiber volume fraction of Kevlar 49 Aramid – 3501-6 epoxy have significant influence on natural frequencies and modal shapes of rectangular plate. Based on the results collected within this work, when designing aircraft components made of Kevlar 49 Aramid – 3501-6 epoxy, engineers can use obtained dependencies of natural frequencies on laminate design, in order to achieve satisfactory composite material that can withstand calculated aerodynamic loads. In the further research, laminate stacking and fiber volume fraction of Kevlar 49 Aramid – 3501-6 epoxy on static and dynamic aeroelastic effects will be analyzed.

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FIRE RESISTANCE OF BOILER ROOM THE BUILDING STRUCTURE

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Abstract: *This A significant limitation of the methodology for determining the class of fire resistance, defined by the group of standards DIN 18230, is the inapplicability to industrial facilities in which energy is produced or distributed. The aim of this paper is to define a new methodology for determining the necessary fire resistance of the building structure of a boiler room.*
Keywords: fire risk; fire load; fire resistance time of structures.

1. INTRODUCTION

W. Halpaap was developed methodology for determining the necessary fire resistance class for industrial building structures based on the previous research for metal constructions made by Gellinger and Boe in the period from 1959 to 1964. A historical overview of the methodology and more references can be found in paper [1]. This methodology was standardized in the form of German technical standard DIN 18230 [2], which was modified several times in the period from 1964 to 2010.
Two methods for fire risk assessment were standardized based on the research of the Swiss engineer Gretener (references can be found in paper [3]) which were carried out in the period from 1961 to 1968: (1) The Swiss Society of Engineers and Architects (SIA) published SIA81 method in 1981 and SIA2007 in 2007; (2) The Austrian Fire Brigade Association published TRVB 100 Technical Recommendation in three versions issued in 1975, 1987 and 2010. Using the results of Gretener's research, author Purt [4] recommended a new methodology in 1972, which was standardized by the European Fire Alarm Manufacturers Association (Euroalarm).
A significant limitation of the DIN18230:2010 standard is its inapplicability to facilities in which energy is produced or distributed. In paper [5] a new approach is presented in order to determine the necessary fire resistance of the building structure of a boiler room where liquid or gaseous fuels are used. This results was extended to boiler room where solid fuels are used in [6].
The aim of this paper is to determine the necessary fire resistance of the building structure (FR) of a general boiler room. The analysis will include boiler rooms with boilers that use gaseous fuels such as mixtures of methane and other gases (i.e. natural gas, city gas or landfill gas) or LPG, liquid fuels such as oil fuels and alcohol-based fuels, solid fuels and cases in which one type of fuel is primary and the other is alternative. The proof of the adequacy of the class of fire resistance for building structure will be given independently using the Purt methodology (according to the Euroalarm standard) while the obtained results will be verified by using the Gretener methodology (according to the TRVB 100:2010 recommendations).
Assumed fire prevention and protection measures include:

1.1. Installation of an automatic fire alarm system;
1.2. Constant presence of the person on duty next to the fire control panel;
1.3. Sufficient number of fire extinguishers before the arrival of the fire brigade;

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1.4. Existence of appropriate fire hydrant installation;

1.5. Professional fire brigade located up to 5 km from the building;

1.6 Access to the boiler room is provided from three sides for the purpose of fire-fighting, i.e. there is at least one opening that can be used for fire-fighting purpose on every 20 m of the walls that border the fire sector.

Other assumptions include:

2.1. Mechanical ventilation system is applied, which provides adequate explosion protection, but without smoke and heat control system;

2.2. The boiler room is rectangular shape with single fire compartment, which is less than 40 m wide, and with an area of less than 3000 m^2 in which there are no other facilities;

2.3. The boiler room is located on the ground floor;

2.4. There are no other floors below and above the boiler room;

2.5. The building in which the boiler room is accommodated is free-standing or it is part of an industrial building;

2.6. No combustible materials are built into the boiler room construction;

2.7. Installed boiler heating duty is less than 1 GW;

2.8. No fuel is stored in the boiler room.

2. SPECIFIC FIRE LOAD AND FIRE RISK CLASS FOR BOILER ROOMS WITH LIQUID OR GASEOUS FUELS

In Euroalarm tables, only boiler rooms that use solid fuels are considered. Tables given in TRVB 126:1987 do not define which type of fuel is used in the boiler room, but based on the adopted coefficient of fire risk class S = 1, it can be concluded that these are fuels of class IV fire hazard, i.e. solid fuels. Since no combustible materials are built in the construction of the fire sector in which the boiler room is accommodated, it follows that the fixed specific fire load is $Q_i = 0$. It also can be assumed that fuel amount that can be found in the boiler room is sufficient for no more than 15 minutes of operation and that the boiler efficiency is higher than 50%. Based on the above assumptions, the total specific fire load can be calculated using the following equation:

$$Q = Q_m = \frac{P \cdot t_w}{A} \tag{1}$$

where Q is specific fire load [MJ/m^2], Q_m is movable specific fire load [MJ/m^2], P is installed boiler heating duty [MW], t_w is total combustion time and A is boiler room area [m^2]. Hence

$$t_w = 2 \cdot 15 \cdot 60 \text{ s} = 1800 \text{ s}. \tag{2}$$

In this study the fire hazard class I (for gaseous fuels), is adopted because this is the most unfavorable case.

3. PURT METHOD.

3.1 Purt method for boiler rooms with liquid or gaseous fuels

For the application of Purt method it is necessary to determine two parameters: fire risk of the structure construction and fire risk of the structure contents. The fire risk of the structure contents is a coefficient that qualitatively shows the harm to people and equipment. It is calculated using the equation:

$$R_S = H \cdot D \cdot F \tag{3}$$

Where H is the harm to people coefficient, D is the harm to property coefficient and F is the smoke effectiveness coefficient.
In this case study, H equals to 1 because there is no expected harm for people, D equals to 2 because expensive equipment is installed in the boiler room and because interruption of the boiler operation causes stoppage of the supply of thermal energy to consumers, and F equals to 1, because there is no danger of smoke and corrosive gases.
Hence, the fire risk of the structure contents (R_s) equals to 2, which means that installation of fire alarm system, is necessary in the boiler room, except in the case of installation of the fire extinguishing system, which is a technically unacceptable solution due to the large area and height of boiler rooms.
Fire risk of the structure construction is a coefficient that qualitatively shows the hazard for the building construction and is calculated using the form:

$$R_0 = \frac{[(P_0 \cdot C) + P_k] \cdot B \cdot L \cdot S}{W \cdot R_i} \tag{4}$$

where P_0 is the structure content fire burden coefficient; C is the structure content combustion coefficient; P_k is the structure construction material fire burden coefficient; B is the size and position of the fire sector coefficient; L is the extinguishing start delay coefficient; S is the fire sector width coefficient; W is the structure's carrier construction fire resistance coefficient; and R_i is the fire risk reduction coefficient.
Based on the introduced assumptions, it follows that S equals to 1.6, because of the adopted fire hazard class I; P_k equals to 0, because Q_i equals to 0; B equals to 1, because the boiler room is located at the ground floor and with area less than 3000 m^2, L equals to 1.1 because the nearest professional fire brigade is 5 km away. If the width of the boiler room is less than 20 m, S equals to 1, otherwise S equals to 1.1. For the margin of safety in this paper the following values are adopted: $S = 1.1$ and $R_i = 1$.
Since the installation of a fire extinguishing system is not a technically acceptable solution, it is necessary to choose the coefficient W so that $R_0 < 2$ as follows:

$$\frac{P_0 \cdot 1.94}{W} < 2, \tag{5}$$

that is

$$P_0 \cdot 0.97 < W. \tag{6}$$

Based on the previous inequality, the results are shown in the table 1, in which the last raw gives the values of the necessary fire resistance of the building structure (FR).

Table 1. Fire resistance of the building structure with width more than 20 m

Source: [5]

Q_m [MJ/m^2]	0÷ 251	252÷502	503÷ 1004	1005÷ 2009	2010 ÷4019
P_0	1.0	1.2	1.4	1.6	2.0
W	1.0	1.3	1.5	1.6	2.0
FR [min]	<30	30	60	90	240

If we assume that the boiler room is less than 20 m wide, S equals to1. Thus, from equation (6) one can derive results given in table 2.

Table 2. Fire resistance of the building structure with width equal or less than 20 m
Source: [5]

Q_m [MJ/m^2]	0÷ 251	252÷502	503÷ 1004	1005÷ 2009	2010 ÷4019
P_0	1.0	1.2	1.4	1.6	2.0
W	1.0	1.3	1.3	1.6	1.8
FR [min]	<30	30	60	90	180

3.2 Purt method for boiler rooms with solid fuels

From tables given in EUROALARM standard P_0 equals to 1, because movable specific fire load Q_m equals to 251 MJ/m^2 for boiler rooms and C equals to1.2 because the fire hazard class III (for solid fuels) is adopted. Since no combustible materials are built in the construction of the fire sector in which the boiler room is accommodated, it follows that the fixed specific fire load is $Q_i = 0$ thus P_k equals to 0. Coefficient L equals to 1.1 because the nearest professional fire brigade is 5 km away. If the width of the boiler room is less than 20 m, S equals to 1, otherwise S equals to 1.1. For the margin of safety in this paper the following values are adopted: $S = 1.1$ and $R_i = 1$.
Since the installation of a fire extinguishing system is not a technically acceptable solution, it is necessary to choose the coefficient W so that $R_0 < 2$ as follows:

$$\text{for } R_i = 1: \frac{1{,}45 \cdot B}{W} < 2, \text{ for Ri = 1,2: } \frac{1{,}2 \cdot B}{W} < 2 \text{ and for Ri = 1,3: } \frac{1{,}12 \cdot B}{W} < 2, \tag{7}$$

which implies

$$\text{for } R_i = 1: 0{,}725 \cdot B < W, \text{ for Ri = 1,2: } 0{,}6 \cdot B < W \text{ and for Ri = 1,3: } 0{,}56 \cdot B < W. \tag{8}$$

From equation (8) it can be concluded than fire resistance of the building structure (FR) depends only on the area and height of the boiler room. The previous condition is met when W equals to 1, which is a case for all boiler rooms with area less than 10 000 m^2, from which it follows that it is sufficient to provide the supporting structure of the boiler room that is fire resistant for 30 minutes.

4. GRETENER METHOD

4.1 Gretener method for boiler rooms with liquid or gaseous fuels

The decision on the necessary fire-fighting measures is made on the basis of the calculated value of the factor of preventive fire-fighting measures ($S_G \cdot F_G$) and the estimated value of the fire resistance of the building structure (F_G). The following equation is used to determine the $S_G \cdot F_G$ factor:

$$S_G \cdot F_G = \frac{(G + 4.42) \cdot B_G}{6.25} \tag{9}$$

because there are no installed smoke and heat control systems in the building, where G is the geometry factor of the fire sector. Since the boiler room is provided with fire extinguishing access from three sides, i.e. there is at least one opening on the walls that limit the fire sector on every 20 m, G is calculated according to the equation:

$$G = \frac{A \cdot b}{10^5} \tag{10}$$

Where A is area of the fire sector [m^2] and b is width of the fire sector [m]. In this case the most unfavourable scenario is assumed: A = 2000 m^2 and b = 40 m when G = 0.8 it follows that

$$S_G \cdot F_G = 0.84 \cdot B_G \tag{11}$$

where B_G is specific fire hazard factor calculated from the equation:

$$B_G = Q_G \cdot C_G \cdot R_G \cdot K_G \cdot A_G \cdot P_G \cdot E_G \cdot H_G \tag{12}$$

where E_G is fire brigade intervention factor, A_G is the factor of fire activation, P_G is people harm factor, Q_G is specific fire load factor, C_G is factor of combustibility, R_G is smoke hazard factor, K_G is corrosion hazard factor and H_G is building height factor.
Based on the assumptions, in this case C_G equals to 1.6, because of the adopted fire hazard class I, $R_G = K_G = P_G = A_G = 1$. Factor H_G equals to 1 because the boiler room is located on the ground floor and E_G equals to 0,83 because the nearest professional fire brigade is 5 km away.
As mentioned before, the decision on the necessary fire protection measures is made on the basis of the calculated value of the factor of preventive fire-fighting measures ($S_G \cdot F_G$) and the estimated value of the estimated value of the fire resistance of the building structure (F_G).
Therefore, in this case specific fire hazard factor can be calculated as:

$$B_G = Q_G \cdot 1.6 \cdot 1 \cdot 1 \cdot 1 \cdot 1 \cdot 1 \cdot 0.83 = 1{,}328 \cdot Q_G \tag{13}$$

The results of equation (13) are shown in table 3.

Table 3. Fire resistance of the building structure based on Gretener's method

Source: [6]

Q_m [MJ/m^2]	200 <	300 <	< 400	< 600	< 800	<1300	<1700	<2500
Q_G	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7
B_G	1.33	1.46	1.59	1.73	1.86	1.99	2.12	2.26
$S_G \cdot F_G$	1.12	1.23	1.34	1.45	1.56	1.67	1.78	1.90
FR [min]	<30	<30	<30	<30	<30	F30	F30	F30

4.2 Gretener method for boiler rooms with solid fuels

Based on the assumptions, in this case $Q_G = C_G = R_G = K_G = P_G = A_G = 1$. Factor H_G equals to 1 because the boiler room is located on the ground floor and E_G equals to 0,83 because the nearest professional fire brigade is 5 km away.
Therefore, in this case specific fire hazard factor can be calculated as:

$$B_G = 1.6 \cdot 1 \cdot 1 \cdot 1 \cdot 1 \cdot 1 \cdot 0.83 \cdot 1 = 0.83 \tag{14}$$

It follows that:

$$S_G \cdot F_G = 0.90 \cdot 0.83 = 0.75 \tag{15}$$

From the results it can be concluded that it is sufficient to provide the supporting structure of the boiler room that is fire resistant for 30 minutes.
If boiler room is with installed capacity lower than 500 kW or with area smaller than 150 m^2, factor G can be calculated from equation (10). In this case the most unfavourable scenario is assumed as A = 150 m^2 and b = 40 m when G = 0.06 it follows that

$$S_G \cdot F_G = 0.72 \cdot B_G \tag{16}$$

Based on previous result from equation (16) B_G = 0.83 and equation (14) follows that:

$$S_G \cdot F_G = 0.72 \cdot 0.83 = 0.6 \tag{17}$$

From the results it can be concluded that it is sufficient to provide the supporting structure of the boiler room that is fire resistant for 30 minutes, even in case where automatic fire alarm system is not installed in the boiler room.

5. CONCLUSION

Standardized Purt's and Gretener's procedures were used to assess fire risks. The differences between the applied methods are that Purt's procedure does not consider the approaches of fire engines and the probability of fire activation while Gretener's procedure does not consider the consequences of fires other than human losses. Considering the initial assumptions from the results it can be concluded that for boiler rooms where solid fuels are used for generating energy it is sufficient to provide fire resistance of the building structure of 30 minutes.

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ENVIRONMENT AND SUSTAINABLE DEVELOPMENT. MECHATRONICS. OCCUPATIONAL SAFETY AND HEALTH AND FIRE SAFETY. SMART MANAGEMENT SYSTEMS. GRAPHIC ENGINEERING. DESIGN. TRAFFIC ENGINEERING. BIOTECHNOLOGY AND HEALTHCARE. MECHANICAL ENGINEERING. ECOTOURISM AND RURAL DEVELOPMENT.

EFFECTS OF TEMPERATURE ON FATIQUE CRACK GROWTH RATE OF A LOW CARBON MICROALLOED STEEL

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Abstract: *The influence of temperature on fatigue crack growth parameters was analysed by testing a new generation of unalloyed chromium-molybdenum steel additionally alloyed with vanadium intended for elevated temperature applications. The paper contains a comparison of the fatigue threshold ΔK_{th} and the fatigue crack growth rate da/dN of the untreated steel specimens taken from the pipe tested at room temperature (RT) and working temperature (HT) of 540 °C .*
The microscopic fracture surfaces of the test specimens are shown. The results of the fatigue crack growth parameters correspond to the SEM micrographs of the fracture surfaces.
Keywords: Fatique treshold, Crack Growth Rate, SEM.

1. INTRODUCTION

Analysis of the state of stress and deformation at the tip of a growing fatigue crack using linear elastic fracture mechanics methods led to the formulation of the Paris equation for all metals and alloys, which relates the fatigue crack growth rate to the stress intensity factor (SIF) range at the crack tip [1-5]:

$$\frac{da}{dN} = C \cdot (\Delta K)^m \tag{1}$$

Although the Paris equation of crack growth is not valid in the entire region, between low rates near the fatigue threshold ΔK_{th}, and higher rates K_{Ic}, the large linear middle part of the curve covered by the Paris equation turns out to be by far the most important from a practical point of view, as it allows at the same time to contrast between creation and growth of a fatigue crack. The application of the Paris equation has proven to be particularly fruitful in the field of fatigue of structures made of materials of elevated and high strength [6].
As the structure under certain conditions will not be endangered until the crack reaches a critical size, it is possible, with previous analyses, to allow the exploitation of the structure with the crack during the crack growth period. Knowing the speed of crack growth and its dependence on the acting load is important information for the decision on further exploitation. Standard ASTM E647-15e1, "Standard Test Method for Measurement of Fatigue Crack Growth Rates" prescribes the measurement of the fatigue crack growth rate *da/dN*, which develops from an existing crack, and the calculation of the SIF range, ΔK, which means that the specimen should have a fatigue crack.

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2. EXPERIMENT

Research for this work was done on a virgin pipe with an outer diameter of ∅270 mm, length of 275 mm and a wall thickness of ≠34 mm, obtained from the Nikola Tesla B thermal power plant. The chemical properties of analyzed chrome-molybdenum alloy steel of the new generation additionally alloyed with vanadium designed for elevated temperatures application, are given in Table 1 [7].

Table 1. Chemical composition of as-received steel, % wt.
Source: original copyright

C	Si	Mn	P	S	Al	Cr	Mo	V
0.12	0.37	0.65	0.01	0.01	0.004	1.042	0.24	0.16

Mechanical properties of material tested at RT and HT are shown in Tables 2.

Table 2. Mechanical properties of tested material at RT and HT
Source: original copyright

Temperature	Elasticity modulus E, GPa	Yield stress $R_{p0.2}$, MPa	Tensile strength R_m, MPa	Elongation A, %	Poisson's coefficient v
RT	197	363	458	26.8	0.3
HT	138	214	300	29.4	0.3

2.1 Determination of crack growth rate

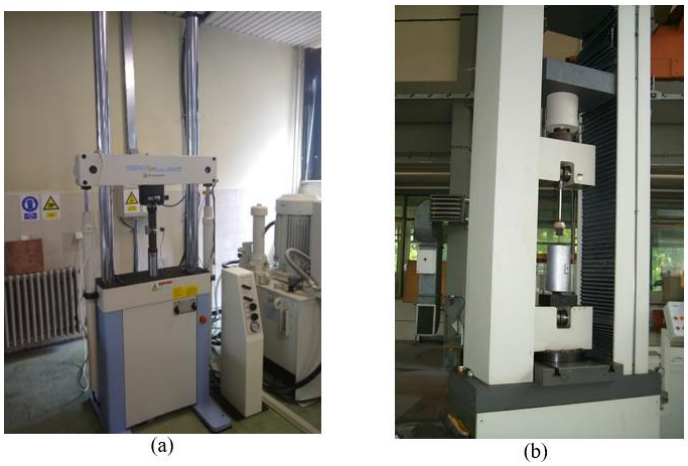
To determine the fatigue crack growth rate da/dN and the fatigue threshold ΔK_{th} at RT, the standard CT-50 specimen was used, Fig.1 (a), while the test at HT was performed on the modified C(T) specimens shown in Fig.1 (b).

(a)

(b)

Figure 1. CT-50 specimens for fatigue crack growth rate testing at room temperature (a) and modified C(T) specimens for fatigue crack growth rate testing at elevated temperature(b)
Source: original copyright

The tests for the fatigue crack growth rates da/dN as well as the fatigue thresholds ΔK_{th} determination at RT were performed on the servo-hydraulic test machine shown in fig. 2(a). The test was performed in crack growth control. This servo-hydraulic system realizes a sinusoidal variable load in the range of - 100 to + 100 kN.
Testing at HT was done on an electromechanical testing machine shown in Fig.2 (b). The test was performed in position control. Because of the more complete assessment of the behavior of the material under the effect of variable load, and taking into account the dimensions of the specimens, the critical case of the effect of variable load was performed, variable load with stress ratio $R = 0.1$.



(a) (b)

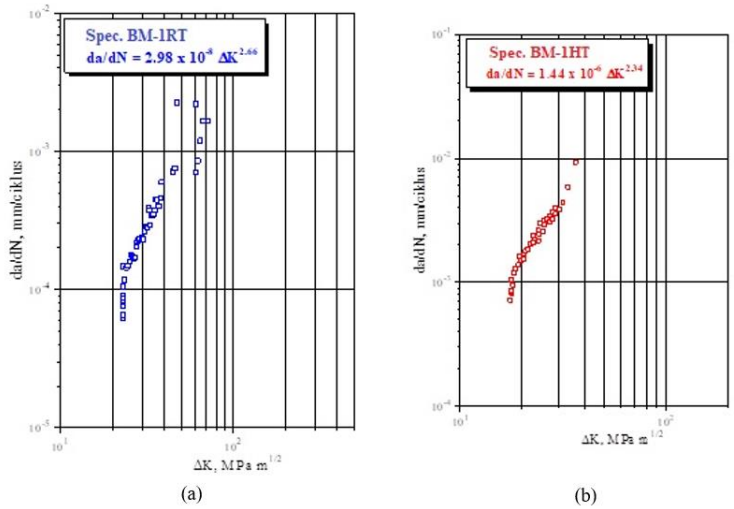
Figure 2. SHIMADZU SERVOPULSER (a) and electromechanical test machine for dynamic tests (b)
Source: original copyright

Depending on the applied variable load expressed through the change in the range of SIF, ΔK, curves are drawn in double logarithmic coordinates (log da/dN - log(ΔK)). Testing of precracked specimens, the values of the following parameters of the Paris equation were obtained: coefficient C and exponent m, fatigue threshold ΔK_{th}, and fatigue crack growth rate, da/dN, at the value ΔK = 25 $MPa\ m^{1/2}$. Those results are shown in Table 3.

Table 3. Fatigue crack growth parameters for specimens with a notch in BM
Source: original copyright

Specimen	Test temperature °C	Fatigue threshold ΔK_{th}, MPa√m	Coefficient C	Exponent m	da/dN, µm/cikl, at ΔK=25 $MPa\sqrt{m}$
Spec. BM-1RT	20	23,2	$2{,}98 \cdot 10^{-8}$	2,66	$0{,}253 \cdot 10^{-3}$
Spec. BM-2RT		20,4	$2{,}02 \cdot 10^{-7}$	2,15	$0{,}303 \cdot 10^{-3}$
Spec. BM-3 RT		19,7	$7{,}33 \cdot 10^{-7}$	1,85	$0{,}396 \cdot 10^{-3}$
Spec. BM-1 HT	540	16,3	$1{,}44 \cdot 10^{-6}$	2,34	$2{,}69 \cdot 10^{-3}$
Spec. BM-2 HT		15,5	$7{,}51 \cdot 10^{-6}$	1,89	$3{,}29 \cdot 10^{-3}$
Spec. BM-3HT		15,1	$4{,}77 \cdot 10^{-6}$	2,05	$3{,}50 \cdot 10^{-3}$

Characteristic diagrams of fatigue crack growth rates, da/dN - ΔK, for specimen tested at RT and at a HT are shown in Fig. 3.



(a) (b)

Figure 3. Diagram of da/dN - ΔK dependence of the specimen tested at (a) RT and (b) HT
Source: original copyright

3. ANALYSIS OF RESULTS

The influence of the notch position and the initiation of the crack, as well as the test temperature, have a decisive influence on the values of the fatigue threshold ΔK_{th}.
The fatigue threshold values, ΔK_{th}, range from 21.1 $MPa\sqrt{m}$ at RT and decrease to 15.6 $MPa\sqrt{m}$ at HT, Table 3.

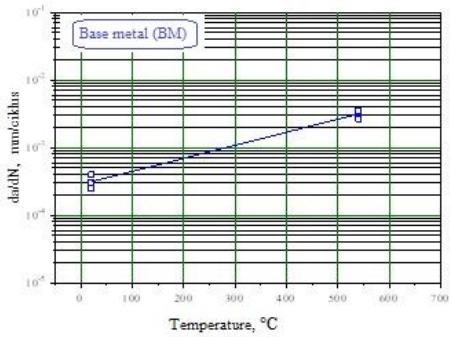


Figure 4. Change in *da/dN* value with increasing test temperature
Source: original copyright

The influence of the test temperature on the rate of fatigue crack growth, *da/dN*, is shown graphically in Figure 4. We can see that with increasing temperature, the rate of fatigue crack propagation, *da/dN,* also increases. The average obtained value of fatigue crack growth rate at RT is 0.317 *μm/cycle*, while at HT it is ten times higher and is 3.16 μm/cycle.

4. CONCLUSION

Fatigue crack growth parameters are the basis for assessing the safety of the operation of structural elements containing a crack that will not lead to failure in the time period between two consecutive inspections. A comparison of the fatigue crack growth rate at room and operating temperatures shows that the fatigue crack growth rate of chrome-molybdenum alloyed steel of the new generation additionally alloyed with vanadium for elevated temperatures application, increases with increasing operating temperature.

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LARGE-SCALE THREE-DIMENSIONAL PRINTERS IN INDUSTRY 4.0

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Abstract: *The emergence of Industry 4.0 has brought forth transformative technologies with the potential to revolutionize manufacturing processes. Among these, large-scale three-dimensional printers have gained significant attention due to their ability to fabricate complex and customized objects on an unprecedented scale. This paper presents an overview of the applications, benefits, challenges, and future prospects of large-scale three-dimensional printers in the context of Industry 4.0. It explores the advancements in additive manufacturing techniques, materials, and software solutions that enable the realization of large-scale printing. Additionally, the paper discusses the integration of these printers within smart factories and the impact on supply chains, production flexibility, and sustainability. Through a comprehensive analysis, this paper highlights the potential of large-scale three-dimensional printers to drive innovation and efficiency in the manufacturing landscape of Industry 4.0.*
Keywords: large-scale 3D printing, additive manufacturing, Industry 4.0, smart factories, emerging trends.

1. INTRODUCTION

Industry 4.0 represents a transformative shift in manufacturing, driven by the integration of advanced technologies and digitalization. This paradigm revolutionizes traditional production methods by interconnecting cyber-physical systems, artificial intelligence, data analytics, and automation. Industry 4.0 enables intelligent and autonomous manufacturing processes, leading to unparalleled levels of efficiency, productivity, and customization. It builds upon earlier industrial revolutions, but uniquely merges the physical and digital realms, creating the so-called smart factories and value chains. Within this context, large-scale three-dimensional printers, also known as additive manufacturing systems, play a pivotal role. These printers have the potential to revolutionize production, offering advantages such as improved efficiency, reduced lead times, enhanced customization, and increased sustainability.

In the era of Industry 4.0, large-scale three-dimensional printers play a crucial role in transforming the manufacturing landscape. These advanced printers, also known as additive manufacturing systems, have the capability to fabricate complex objects with precision and efficiency. By utilizing a layer-by-layer approach and a variety of materials, including metals, polymers, and composites, large-scale three-dimensional printers enable manufacturers to achieve unprecedented levels of design freedom and customization. They offer benefits such as reduced production time, cost savings, and the ability to produce intricate and personalized products. Furthermore, these printers facilitate the integration of smart factories and the optimization of supply chains by enabling on-demand production and reducing reliance on traditional manufacturing processes. As a key enabler

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of Industry 4.0, large-scale three-dimensional printers are driving innovation, efficiency, and flexibility in the manufacturing sector.

2. ADDITIVE MANUFACTURING PROCESSES FOR LARGE-SCALE PRINTING

Additive manufacturing processes for large-scale printing are revolutionizing the way in which objects are produced. These processes involve the layer-by-layer fabrication of three-dimensional objects using difficult techniques. In a large-scale printing, advanced techniques, like fused deposition modelling (FDM) and selective laser sintering (SLS), are commonly employed. FDM utilizes thermoplastic filaments that are melted and extruded through a nozzle, while SLS employs lasers to fuse powdered materials together. Large-scale printing requires industrial-grade printers capable of handling sizable objects. These additive manufacturing processes enable design flexibility, intricate geometries, reduced material waste, and customized production. They find applications across various industries, including aerospace, automotive, healthcare, and construction, revolutionizing manufacturing possibilities in the era of highly demanding Industry 4.0.

3. TECHNICAL-TECHNOLOGICAL SOLUTIONS OF LARGE-SCALE 3D PRINTERS

A gantry-based solution is essentially an upscale version of additive manufacturing for construction purposes. In simple terms, it can be described as a "giant 3D printer" equipped with an actuator that allows movement along the X, Y, and Z axes in Cartesian coordinates [1]. Notable examples of gantry-based developments include Contour Crafting and D-Shape.

3.1 Contour Crafting (CC)

Contour Crafting (CC) is a highly promising gantry-based 3D printing technical system developed specifically for the construction industry (Figure 1). It involves the extrusion of successive layers of material, typically cement-based paste, in an on-site process [2]. The CC system comprises a gantry system and a nozzle, similar to those used in precast concrete fabrication. However, unlike precast concrete production, contour crafting is fully automated, eliminating the need for on-site personnel to monitor the discharge system. Actuated and computer-controlled trowels to smooth are utilized and ensure the accuracy of the printed material's planar and free-form surfaces. Maintaining a consistent viscosity level is a key challenge in contour crafting, as it directly influences structural strength and surface finish quality [3].

Figure 1. D-Shape 3D Printing
Source: www.archdaily.com/949531

3.2 D-Shape

D-Shape utilizes a process similar to the inkjet powder bed method, where a binder is selectively sprayed onto the printing material. Upon contact with the powder material, the binder initiates the solidification process, adding a new layer. The solidification process typically takes 24 hours to

complete. D-Shape is a gantry-based powder-bed 3D printer designed for factory settings, capable of printing architectural structures with dimensions up to 6×6×6 m. Objects printed using D-Shape technology can exhibit a compressive strength of up to 235-242 MPa [2].
Excess powder not involved in the structure acts as temporary support during solidification. Once printing is finished, the object is removed from the loose powder bed, and the surplus powder can be reused for other structures (Figure 2). While D-Shape was initially designed for off-site production of complex structural elements, ongoing research explores its potential for on-site printing, using available construction materials, such as sand and binder substances [4].

Figure 2. D-Shape 3D Printing
Source: www.newatlas.com/d-shape-3d-printer/21594

Contour Crafting and D-Shape have made significant advancements in scaling up additive manufacturing for construction. However, both methods have notable limitations. D-Shape faces criticism for its unreliable hydration of cementitious powder and the subsequent need to remove and clean the excess powder, which adds time and effort to the process. On the other hand, Contour Crafting to vertical extrusion is limited, resulting in 2.5D typologies rather than true 3D structures. Contour Crafting uses 3D-to-2D slicing software similar to small-scale 3D printing techniques. Each layer consists of a contour line and a honeycomb-like filling pattern, with adjustable filling density based on requirements. However, this technique presents challenges when printing cantilevered structures, as weak interfacial zones between printed layers may occur [2].

4. INTEGRATION OF LARGE-SCALE 3D PRINTERS IN SMART FACTORIES

Integrating large 3D printers into smart factories is a transformative step towards redefining manufacturing processes. This chapter in the paper presents the multifaceted aspects of this integration, encompassing essential chapters on cyber-physical systems and digital twins, supply chain optimization and distributed manufacturing, human-machine collaboration and the implications for the workforce, as well as sustainability and environmental impact. By examining these key dimensions, we uncover the potential for enhanced efficiency, flexibility, and sustainability in smart factories.

4.1 Cyber-Physical Systems and Digital Twins

Cyber-Physical Systems (CPS) and digital twins are integral components in the integration of large 3D printers into smart factories. CPS refers to the integration of physical and digital systems, enabling real-time monitoring and control. Digital twins are virtual replicas of physical assets, providing insights, predictive analytics, and optimization. Together, CPS and digital twins facilitate efficient production planning, remote monitoring, and predictive maintenance, enhancing the overall productivity and performance of smart factories (Figure 3).

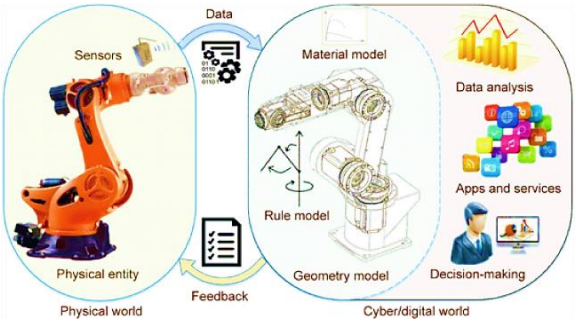

Figure 3. D-Shape 3D Printing
Source: www.engineering.org.cn/en/10.1016/j.eng.2019.01.014

4.2 Supply Chain Optimization and Distributed Manufacturing

Supply chain optimization and distributed manufacturing have a crucial role in the integration of large 3D printers into smart factories. Supply chain optimization aims to streamline production processes, reduce costs, and enhance flexibility by leveraging real-time data and analytics. Distributed manufacturing decentralizes production, enabling localized production and reducing transportation and inventory costs. Together, these approaches transform the supply chain, facilitating efficient and responsive manufacturing within smart factory ecosystems.

4.3 Human-Machine Collaboration and Workforce Implications

Human-machine collaboration and the associated workforce implications are key considerations in integrating large 3D printers into smart factories. Collaboration between humans and machines allows for improved efficiency, accuracy, and productivity in manufacturing processes. However, this integration also raises some questions about workforce skills, training, and job roles. Balancing automation with human expertise becomes crucial to ensure a smooth transition, redefining job responsibilities and fostering a collaborative environment that maximizes the potential of both humans and machines in smart factory settings.

4.4 Sustainability and Environmental Impact

Sustainability and environmental impact are critical aspects to consider when integrating large 3D printers into smart factories. These printers offer the potential for reduced material waste, energy consumption, and carbon emissions compared to traditional manufacturing methods. By utilizing eco-friendly materials and optimizing production processes, smart factories can minimize their environmental footprint. Additionally, the ability to produce on-demand and locally can reduce transportation-related emissions and promote sustainable practices, making a significant contribution to a greener and more sustainable manufacturing industry.

5. FUTURE PROSPECTS AND EMERGING TRENDS

There are diverse opinions regarding the future of 3D printing technology. While fully printed buildings are yet to exist [5], the progress in automation and robotics suggests the possibility of large-scale, fully automated 3D printing. Proficiency in software skills becomes crucial for future engineers, as they collaborate with automated and 3D printing technologies. Moreover, 3D printing holds promise for space exploration, with NASA's "3D Printed Habitat Challenge" aiming to develop innovative capabilities for building homes in space. Sustainability is another area where 3D printing can make a significant impact, allowing for environmentally evaluated building materials and sustainable designs tailored to the environments [6].
This chapter explores future prospects and new trends in the integration of large-scale 3D printers in smart factories. Two significant areas of focus are 3D printed metal and plastic bridges, as well as

Artificial Jntelligence (AI) and Machine Learning (ML) applications. The use of printing techniques from different additive materials enables the creation of complex and functional bridges with improved structural integrity and performances. Moreover, the integration of AI and ML enhances the capabilities of large-scale 3D printers, enabling real-time monitoring, predictive maintenance and intelligent decision-making. These advances promise exciting possibilities for the future of smart factories and the manufacturing industry as a whole.

5.1 3D printed projects connect communities and countries

As a highly significant project in the realm of Industry 4.0, 3D-printed bridges stand out prominently. These bridges not only showcase architectural masterpiece, but also represent noteworthy construction projects, that can be completed within a remarkably short timeframe. The first 3D-printed bridges emerged in 2016, and since then, numerous countries have embraced additive manufacturing for constructing these structural connections. Among the most impressive examples is the bridge in Amsterdam, showcased in this paper (Figure 4). A 3D-printed metal bridge was installed in Amsterdam's Red Light District, created by Dutch company MX3D using WAAM (Wire Arc Additive Manufacturing) technology. The bridge was fabricated through generative design, an iterative process that generates multiple design outputs to meet specific criteria, utilizing inputs from sounds, images, and CAD models. In addition to its unique aesthetics, the bridge with sensors is equipped, to record data on crowd behavior, deformations, loads, vibrations, and movements. These data enable the creation of a "digital twin" that provides real-time insights for project managers to understand the bridge's evolution [7].

Figure 4. MX3D Bridge in Amsterdam
Source: www.3dnatives.com/en/3d-printed-bridge-051120214

One of the highly interesting techniques and technologies in this field is 3D printing of plastic bridges. In 2018, Shanghai Mechanized Construction Group Co (SMCC) and Polymaker collaborated to develop a 3D printed pedestrian bridge. The bridge, made from plastic and measuring 15.25 m long and 3.8 m wide, weights 5,800 kg. An XXL printer with a print volume of 24 m long by 4 m wide was used. The applied material was ASA (acrylonitrile styrene acrylate) infused with fiberglass [7].

5.2 Artificial Intelligence and Machine Learning Applications

Artificial Intelligence (AI) and Machine Learning (ML) are playing a pivotal role in the integration of large-scale 3D printers within the realm of Industry 4.0. These advanced technologies are revolutionizing the manufacturing landscape by enhancing efficiency, customization, and productivity. When applied to 3D printing, AI and ML algorithms enable intelligent design optimization, real-time monitoring, and predictive maintenance. One notable AI application is generative design, which utilizes algorithms to explore countless design possibilities based on specific criteria. This approach helps to optimize the structural integrity, material usage, and performance of 3D-printed objects, leading to lighter and more efficient designs.
Another significant application is real-time process monitoring and quality assurance. AI algorithms can analyze sensor data from the 3D printing process to detect anomalies, identify defects, and

ensure consistent quality throughout production. That is helpful to eliminate errors, reduce waste, and enhance overall manufacturing efficiency. Furthermore, AI and ML in simulation software are employed, for virtual testing and optimization of 3D-printed models. These simulations allow manufacturers to predict and analyze the behaviour of printed structures under different conditions, enabling design improvements and risk mitigation before physical production. Software solutions, such as Autodesk's Netfabb, Materialise Magics, and Siemens NX integrate AI and ML capabilities to streamline the 3D printing workflow. These tools offer functionalities, such as automated support generation, design validation, and material optimization, enhancing the overall efficiency and accuracy of a large-scale 3D printing.

6. CONCLUSION

The emergence of Industry 4.0 has unveiled the significant potential of large-scale 3D printers in reshaping production processes across various industries. These printers offer substantial benefits, including enhanced production efficiency, reduced material waste, and expanded design flexibility. Nonetheless, the current challenges, such as technological limitations, cost implications, and the need for advances in additive manufacturing techniques, material properties, and software solutions, must be meticulously addressed. Future solutions should prioritize the development of multi-material printing, real-time process monitoring, and seamless integration with AI and ML technologies.

The integration of large-scale three-dimensional printers into Industry 4.0 represents a significant leap in manufacturing capabilities. These printers offer unmatched customization, efficiency, and sustainability advantages. While D-Shape excels in printing large architectural structures, it faces challenges related to material hydration and post-processing. Contour Crafting streamlines in-situ construction through automated, layer-by-layer extrusion but is limited to vertical extrusion. The adoption of Cyber-Physical Systems and Digital Twins optimizes monitoring and predictive maintenance, while supply chain optimization and distributed manufacturing drive cost reduction and environmental sustainability. Human-machine collaboration reshapes workforce roles, and sustainability initiatives gain traction with reduced waste and eco-friendly materials. The integration of artificial intelligence and machine learning augments printer capabilities, ushering in a transformative era within Industry 4.0. Embracing these solutions promises to unlock new levels of innovation, efficiency, and sustainability within the dynamic landscape of Industry 4.0.

LITERATURE

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ENVIRONMENT AND SUSTAINABLE DEVELOPMENT. MECHATRONICS.
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MECHANICAL ENGINEERING. ECOTOURISM AND RURAL DEVELOPMENT.

STRAIN BEHAVIOR ANALYSIS OF STEEL S235JRH RING SPECIMENS

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Abstract: *Different pipe manufacturing techniques, such as the manufacture of seamless pipes in the oil sector employing a conical shaft, necessitate data on the circumferential strain and stress condition of the pipe. The purpose of this study was to evaluating the displacement, strain, and stress behavior of a pipe ring tensile specimen (PRTS) in the hoop direction, as there was a lack of a standardized testing methodology. Five single S235JRH steel PRTS were tested for the study. The study describes how to test S235JRH steel PRTS with a Digital Image Correlation approach. The 3D Digital Image Correlation technique methodology was used to record the evolution of the strain. In the break zone and almost equivalent locations, all Single PRTS fractured. The experimental ultimate strength value's deviation value (also known as the real stress value) is greater than the theoretical ultimate strength value.*

1. INTRODUCTION

In an effort to establish a uniform distribution of strain and stress, many initiatives, such as those presented in [1moj rad] [2] and [3], have been made in recent years to improve the shape of testing specimens. Gaining useful experimental data that precisely depicts a well-defined distribution of stress/strain fields is the goal of testing methods such as shear, strain tests in plane, and tensile tests. With regard to metal sheets in particular, the information may be used to assess the material qualities of anisotropic materials. Due to the form of the tube, examining pipe materials is not as straightforward as examining metal sheets. Simple processes are still employed in [4] and [5] to cut specimens from flattened pipes and test them in tensile tests. Nonetheless, the flattening process adds residual stresses and pre-existing strains in the material, which impact the behaviour of the pipe material and, ultimately, the accuracy of material parameter identification, as indicated in the publications [6,7].
The study field of Digital Image Correlation (DIC) method has grown at a rapid rate during the last two decades. The use of the DIC method for evaluating Pipe Ring Tensile Specimens (PRTS) with various geometries is covered in the papers [7, 8-11]. Table 1 publications [7, 8] performed a numerical analysis and compared the numerical analysis findings to the DIC technique results.
The purpose of this research is to evaluate the strain behaviour of S235JRH steel PRTS in the hoop direction using the DIC technique.

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2. MATERIAL AND METHOD

2.1 Material

PRTS were fabricated of structural steel S235JRH for this study. PRTS specimens have pipe size of DN32 (42.4 x 2.8 mm). According to the published study [1] five Single PRTS were generated in total (Fig.1a).

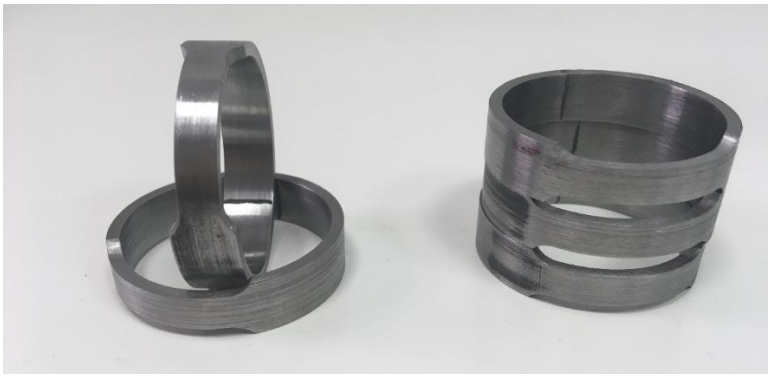

Figure 1. The PRTS of S235JRH material

Figure 2. Experimental setup

Fig.2 depicts the experimental setup. Shimadzu tensile testing equipment AGS-X (Shimadzu, Japan) was used for the tensile testing. The same PRTS tool that was used in the study [1] was utilised for testing using D blocks. The Aramis 2M system (Fig.2) employs the 3D DIC method [1]. Calibration was performed as part of the experimental setup. Several research [1,12, 14] go into considerable depth about the mode of operation, calibration, object preparation, and measuring procedure. The test procedure consisted of the following steps shown in [1].

Table 1. Aramis setup settings

Parameter	Value
Resolution of two CCD cameras	1600 × 1200 pixels
Camera lenses	50 mm
Measuring volume	105 mm×75 mm×55 mm
Facet (subset) size	25×20 pixels
Calibration deviation	0.027

3. RESULTS AND DISCUSSION

All of the PRTS that fractured did so on the side where the camera was pointed. The average value of these break forces for all PRTSs is shown on Fig.3. All PRTS readings indicated minimal variations in brake force.

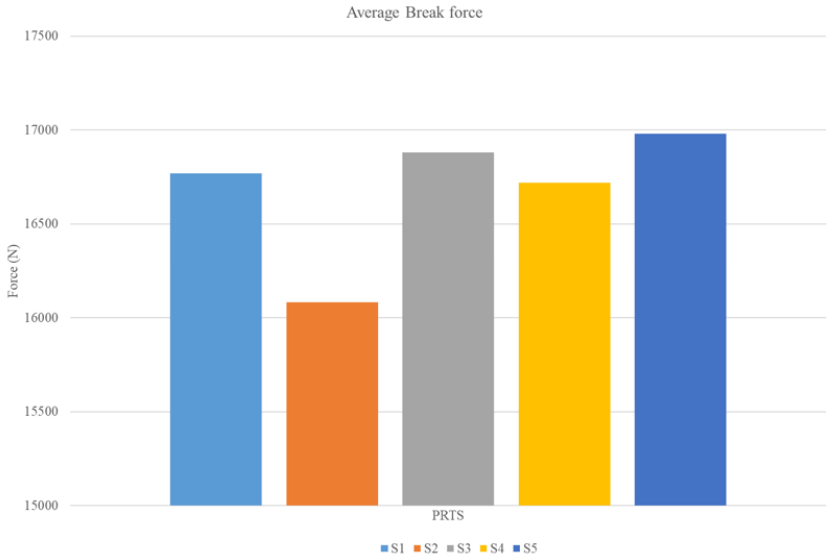

Figure 3. Average break force values

Figure 3 shows the results of a representative Single PRTS-S1 specimen. In this research, the DIC measurement findings for the Misses strain are provided. Four points (stage points 0-3) and two sections (Sections 0 and 1) were used to investigate the strain field in Figure 4 (Stage points 0-3). The intersection of the D blocks is where Section 0 is situated horizontally (black line). Vertically positioned on the Area of interest, Section 1 is orthogonal to Section 0 (yellow line). Stage points are positioned at the conclusion of each Section. Stages 0 and 1 were put on Section 0, while Stages 2 and 3 were put on Section 1. The experimental data shown in Fig. 4 demonstrates that the intersection of the D blocks is where the highest strain values are recorded. The highest von Mises values, which are 35%.

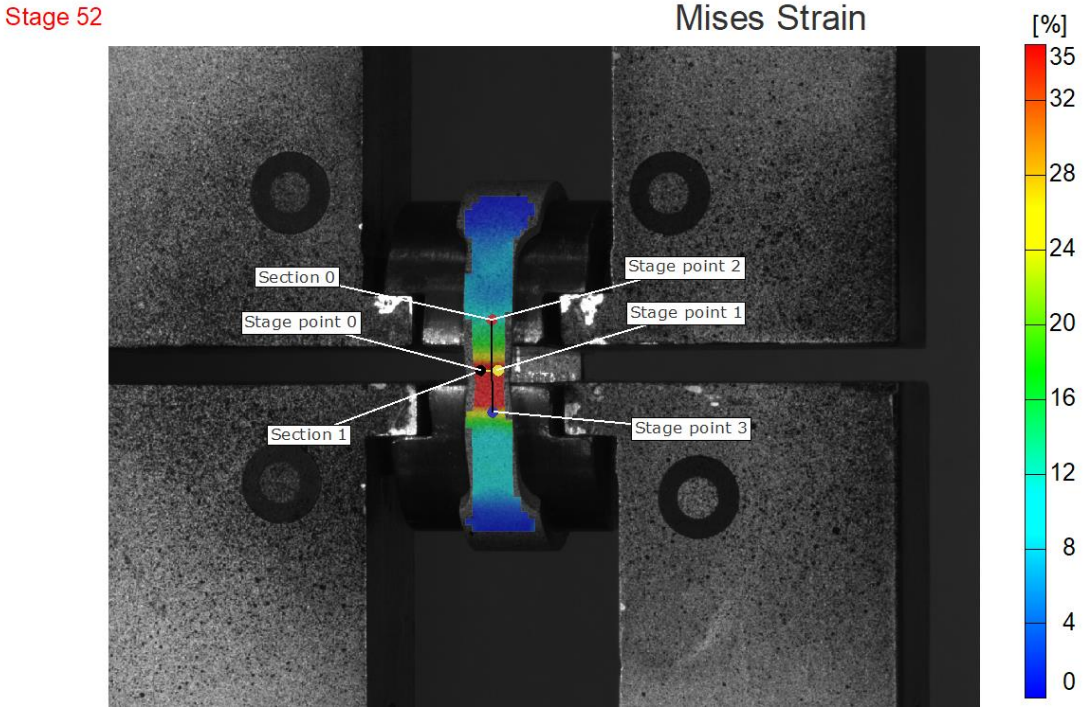

Figure 4. Von Misses strain field on PRTS S1

4. CONCLUSION

Based on prior work [1] with plastic PRTS, identical steel PRTS with a single configuration were created and evaluated using the same methods.
The above findings lead to the following conclusions:

- Fractures of all Single PRTS occurred in the break zone and almost identical places;
- All PRTS readings indicated minimal variations in brake force;
- The experimental data shown in Fig. 4 demonstrates that the intersection of the D blocks is where the highest strain values are recorded. The highest von Mises values, which are 35%.

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EFFECTS OF CHANGING DESIGN PARAMETERS

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Abstract: *The present study delves into the implications of altering various design parameters on the performance of structural systems. With a focus on the implications for dynamic behavior and overall system responsiveness, the research investigates the effects of modifications in key structural elements. Through a comprehensive analysis of specific design variables, such as cross-sectional dimensions, material properties, and geometric configurations, the study sheds light on how these changes influence structural characteristics and performance metrics.*
Keywords: Modification, variables, frequencies, dynamic characteristics

1. INTRODUCTION

In the field of structural engineering, the effects of altering design parameters have gained significant attention due to their potential impact on the performance and behavior of various structural systems. With a growing emphasis on optimizing structural designs for enhanced functionality and reliability, it becomes imperative to comprehend the implications of design modifications on the overall dynamic response and stability of these systems. Throughout the history of structural engineering, the focus of research initially revolved around static optimization methods, primarily centered on minimizing weight while adhering to displacement or stress constraints for various static loading conditions. The two main approaches, analytical and numerical methods, were commonly employed. Analytical techniques, including mathematical calculations and variational methods, were utilized for simpler geometric optimization problems. Although these methods provided theoretical insights into optimization concepts, their practical application was limited, particularly in complex structural systems comprising diverse structural elements. An optimization criterion was established as an example of an analytical approximation, where an iterative procedure was employed to fulfill the requisite optimization conditions. While analytical criteria were effective in some cases, they were occasionally intuitive and less robust. In contrast, numerical methods were developed to minimize specific functions directly with imposed constraints, leveraging the advancements in numerical

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mathematics and high-speed computing. These iterative procedures offered near-optimal solutions, often involving a finite number of design variables. Notably, reducing the number of structural variables played a pivotal role in mitigating the computational challenges associated with these methods. The integration of mathematical programming techniques with the finite element method emerged as a powerful strategy, enabling efficient and direct approximations. However, the applicability of this technique diminished in large-scale systems with increased degrees of freedom due to computational complexities and associated costs. As the field advanced, the focus gradually shifted toward dynamic modification, leading to a substantial body of literature exploring dynamic optimization methodologies. In the work "Sensitivity Analysis and Optimal Design of 3D Frame Structures for Stress and Frequency Constraints" by O. Sergeyev and Z. Mroz [1], the problem of determining the optimal position of nodes and cross-sectional elements of linear-elastic spatial frame structures with given stress and eigen frequency constraints is studied. It is assumed that the frames are loaded with active loads, including temperature and self-weight. Stress analysis includes tension, bending, shear, and torsion of the beam frames. A series of quadratic programming problems were used to obtain optimally designed construction. Sensitivity analysis was also provided in the case of different or repeated eigen frequencies with analytical differentiation by design parameters. The work also provides illustrative examples of optimal design of simple and complex frames, especially the case of bimodal optimal solutions. The work "Solution Existence of the Optimization Problem of Truss Structures with Frequency Constraints" by W. H. Tong, J.S. Jiang, and G.R.Liu [2] provides the basic theory for determining the existence of a solution to the optimization problem of truss structure with frequency constraints. This theory states that natural frequencies do not change if the truss is uniformly modified and that the constraint of eigen frequencies is usually the key constraint in determining the existence of a solution to the optimization problem of the truss's dynamic problem. Based on this theory, a practical problem is presented, in which the existence of a solution is discussed based on various optimization algorithms. An illustrative example is provided to demonstrate the application of this theory in finding the optimal design of truss structures. These academic works showcase the extensive research and development in the field of sensitivity analysis, experimental data refinement, and model updating in structural dynamics. They highlight the complexity and challenges in accurately modeling and predicting the dynamic behavior of mechanical structures and provide valuable methods and techniques to enhance the accuracy and efficiency of structural analysis and optimization.

2. ABOUT FREE OSCILLATIONS

2.1 Theoretical background

If an elastic structure is displaced from its equilibrium position at the initial moment $t_0 = 0$ (by imposing a suitably chosen initial displacement), the structure can undergo harmonic oscillations. This oscillatory motion is a characteristic of the structure and depends on the distribution of mass and the stiffness of the structure. In the presence of damping, the amplitudes of the oscillations will progressively decrease, and if the magnitude of damping exceeds a certain critical value, the oscillatory motion will cease entirely. On the other hand, if there is no damping, the oscillatory motion will continue, with amplitudes of oscillation depending on the imposed initial displacements, and frequencies of the free undamped oscillations of the structure (mechanical system) which do not depend on the initial conditions but on the mass and stiffness of the system. The study of free undamped oscillations is very important in determining the parameters of the dynamic response of the structure. Assuming, therefore, that there are no external forces (the external force vector is a zero vector), particular solutions to equation

$$[M]\cdot\left\{\ddot{\underset{\sim}{Q}}(t)\right\}+[K]\cdot\left\{\underset{\sim}{Q}(t)\right\}=\left\{\underset{\sim}{P}(t)\right\}. \tag{1}$$

can be sought in the form

$$\{Q\} = \underline{\{Q\}} \cdot e^{i\omega t} \quad . \qquad (2)$$

$$(e^{i\omega t} = \cos\omega t + i \sin\omega t)$$

After double differentiation of equation (2) and substitution into equation (1), it follows

$$[[K] - \omega^2 [M]] \cdot \underline{\{Q\}} = \{0\} \quad . \qquad (3)$$

The matrix equation (3) represents a system of homogeneous linear algebraic equations with unknown coefficients $\underline{\{Q\}}$. There is a trivial solution $\underline{\{Q\}} = 0$, which is not interesting because it implies no motion. Homogeneous algebraic equations (3) will have other solutions different from zero if the condition is fulfilled (1).

$$\left|[K] - \omega^2 [M]\right| = 0 \quad . \qquad (4)$$

Equation (4) is written in the form of a determinant and, in its expanded form, represents an nth-degree polynomial in ω^2, known as the characteristic equation or, as is known, the frequency equation. In general, it will have n roots: ω_1^2, $\omega_2^2, ..., \omega_n^2$. Since $[K]$ and $[M]$ are positive definite matrices, all the roots of the characteristic polynomial are real positive numbers, introducing the following notation: $\omega_1^2 < \omega_2^2 < ... < \omega_n^2$. To solve characteristic polynomials of higher degrees, it is necessary to apply numerical methods [3]. The quantities $\omega_1, \omega_2, ..., \omega_n$, represent the circular frequencies of the free undamped oscillations of the elastic structure, the squares of which are often also referred to as eigenvalues. Oscillations corresponding to these frequencies are called principal oscillations of the system. The lowest frequency is often called the fundamental circular frequency, and the first principal oscillation of the system, which has that frequency, is called the fundamental oscillation, as in the resulting motion of the system, oscillations at the lowest frequency are of primary importance. If any of the roots of the characteristic equation ω_j^2 were substituted into the system of equations (3), then, since it is a homogeneous system of algebraic equations, one of these equations would be consistent, i.e., dependent, so there would not be n independent equations but n-1. Then one equation is omitted from the system as redundant, and the remaining equations need to be divided by any unknown from the vector $\underline{\{Q_j\}}$, assuming it is different from zero. Therefore, it is not possible to determine the absolute values of amplitudes from the system (4), only their ratios. Finally, by introducing any eigenvalue ω_j^2 into equations (4), it is possible to determine the eigenvector $\underline{\{Q_j\}}$, so it is said that ω_j^2 and $\underline{\{Q_j\}}$ represent an eigenpair. The elements of the eigenvector $\underline{\{Q_j\}}$ physically represent the ratios of the displacements of individual masses in the case when all masses oscillate with the same circular frequency ω_j, or they indicate how many times the amplitude of the corresponding principal oscillation of one coordinate is greater or less than the amplitude of the other coordinate for the same principal oscillation, and are called coefficients of the jth principal mode of oscillation of the system with the eigenfrequency ω_j, and the vectors $\underline{\{Q_j\}}$ are also called modal vectors, where $j = 1,2,...,n$. The vectors $\underline{\{Q_j\}}$ can also represent amplitude vectors if it is assumed that one amplitude is equal to unity (usually the first, the one by which the algebraic equations (4) are divided). The coefficients of the principal modes of oscillation represent the physical constants of the system that depend only on the dynamic parameters of the system and do not depend on the initial conditions of the motion. Their total number is $n \cdot (n-1)$. Eigenvectors have the important property of orthogonality with respect to the mass matrix and the stiffness matrix, which can be expressed in matrix form as:

$$\underline{\{Q_i\}}^T \cdot [M] \cdot \underline{\{Q_j\}} = \delta_{ij} \quad , \qquad (5)$$

$$\underline{\{Q_i\}}^T \cdot [K] \cdot \underline{\{Q_j\}} = \omega_i^2 \delta_{ij} \quad . \qquad (6)$$

If the vectors $\left\{\underline{Q}_j\right\}$ are arranged to form the columns of a matrix, the resulting matrix represents the modal matrix, which represents the transformation from generalized to principal coordinates, in which system (1) can be represented as a system of n uncoupled differential equations, as is customary in the Theory of Oscillations [3-5] and [8].

2.2 Characteristics of changes. Modification coefficients

The characteristics of changes and modification coefficients in the context of structural engineering often refer to the parameters that are altered or adjusted within a structural model to account for various factors such as material properties, environmental conditions, or design requirements. These modifications are implemented to improve the performance, efficiency, or other specific attributes of the structure. The modification coefficients are numerical factors that represent the extent to which certain parameters or elements within the structural model are adjusted or altered. These coefficients are typically determined through various analytical or experimental techniques, and their application can have a significant impact on the overall behavior and response of the structure. In structural analysis and design, modification coefficients are used to account for uncertainties, variability, or dynamic changes in the structural properties or loading conditions. By adjusting these coefficients, engineers can achieve better accuracy, reliability, and safety in the design and performance of structures. Modification coefficients play a crucial role in sensitivity analysis, model updating, and optimization processes, allowing engineers to fine-tune the structural parameters to meet specific design objectives or constraints. They are often employed in the context of finite element analysis (FEA) or other computational modeling techniques to ensure that the structural design meets the required standards and performance criteria. Certainly, the relationship between eigenvalues and frequencies is a well-established concept in structural dynamics. The eigenvalue, representing the square of the frequency, holds a crucial position in the analysis of dynamic systems. By its nature, the eigenvalue can be considered a fundamental parameter, often regarded as a simpler variable compared to the frequency itself. When discussing modifications to the eigenvalue, it is essential to understand the implications for the overall system dynamics and structural behavior. Expressing the modified eigenvalue involves considering the adjustments made to the fundamental characteristics of the structure, which can influence its vibrational properties and dynamic responses. These modifications may stem from various factors, such as changes in material properties, geometric alterations, or adjustments in the boundary conditions. The expression of the modified eigenvalue encapsulates these changes and provides insights into the transformed dynamics of the structure. By analyzing the modified eigenvalue, engineers can gain a deeper understanding of the system's behavior under different operating conditions and make informed decisions regarding structural modifications and optimizations. The modified eigenvalue can be expressed as follows [8]:

$$\lambda + \Delta\lambda = \left(\omega + \Delta\omega\right)^2 = \omega^2 + 2\omega\Delta\omega + \left(\Delta\omega\right)^2 \tag{7}$$

that is,

$$\Delta\lambda = 2\omega\Delta\omega + \left(\Delta\omega\right)^2 \tag{8}$$

If relative modification relations are introduced as follows $\psi = \frac{\Delta\lambda}{\lambda}$, $\xi = \frac{\Delta\omega}{\omega}$, the previous equation can be written in the form

$$\psi \cdot \lambda = 2\omega^2 \cdot \xi + \omega^2 \cdot \xi^2 \quad \Rightarrow \quad \psi = 2 \cdot \xi + \xi^2 \tag{9}$$

and for small changes in frequencies, the approximate linearized form holds $\psi \approx 2 \cdot \xi$.

For example, if the frequency increase is 10%, the following calculation applies:

$$\left.\begin{array}{ll} \omega' = \omega + \Delta\omega = 1.1\omega & \xi = 0.1 \\ \lambda' = \lambda + \Delta\lambda = \left(\omega'\right)^2 = 1.21\lambda & \psi = 0.21 \end{array}\right\} \quad \psi_{priblizno} = 2\xi = 0.2 \tag{10}$$

However, if the frequency increase is 30%, the following holds:

$$\left.\begin{aligned} \omega' &= \omega + \Delta\omega = 1.3\omega & \xi &= 0.3 \\ \lambda' &= \lambda + \Delta\lambda = (\omega')^2 = 1.69\lambda & \psi &= 0.69 \end{aligned}\right\} \quad \psi_{priblizno} = 2\xi = 0.6 \tag{11}$$

The disparity between linearized and exact values can potentially lead to discrepancies, highlighting the necessity of retaining nonlinear forms for larger frequency changes.

In the case of a beam element with a rectangular cross-section, whose dimensions are $b \times h$, the axial moment of inertia for one of the principal axes is $I_z = \frac{b^3 h}{12}$. If structural modifications are made by altering the dimensions b and/or h, the relative modification ratios, $\psi = \frac{\Delta b}{b}$ and $\xi = \frac{\Delta h}{h}$, and the corresponding modification coefficients, α_e and β_e, in this case would be as follows:

$$\alpha_e = (1+\psi)^3 (1+\xi) - 1,\ \beta_e = (1+\psi)(1+\xi) - 1 \tag{12}$$

In tables 3.2-3.5, the relative modification ratios are indirectly represented through the relationships of axial moments of inertia and cross-sectional areas for some characteristic profiles, as illustrated by the corresponding diagrams.

Table 1. I profiles,
Source: [8]

I profiles						
h [cm]	A [cm^2]	A_i/A_1	I_y [cm^4]	I_{yi}/I_{y1}	I_x [cm^4]	I_{xi}/I_{x1}
8.0	7.58	1.00	6.3	1.00	77.8	1.00
10.0	10.6	1.40	12.2	1.94	171	2.20
12.0	14.2	1.87	21.5	3.41	328	4.22
16	22.8	3.01	54.7	8.68	935	12.02
18	27.9	3.68	81.3	12.90	1450	18.64
20	33.5	4.42	117	18.57	2140	27.51
22	39.6	5.22	162	25.71	3060	39.33
24	46.1	6.08	221	35.08	4250	54.63
26	53.4	7.04	288	45.71	5740	73.78
28	61.1	8.06	364	57.78	7590	97.56
30	69.1	9.12	451	71.59	9800	125.96

Table 2. U profiles,
Source: [8]

U profiles						
h [cm]	A [cm^2]	A_i/A_1	I_y [cm^4]	I_{xi}/I_{x1}	I_x [cm^4]	I_{xi}/I_{x1}
6.5	9.03	1.00	14.1	1.00	57.5	1.00
8.0	11	1.22	19.4	1.38	106	1.84
10.0	13.5	1.50	29.3	2.08	206	3.58
12.0	17	1.88	43.2	3.06	364	6.33
14	20.4	2.26	62.7	4.45	605	10.52
16	24	2.66	85.3	6.05	925	16.09
18	28	3.10	114	8.09	1350	23.48
20	32	3.54	148	10.50	1910	33.22
22	37.4	4.14	197	13.97	2690	46.78
24	42.3	4.68	248	17.59	3600	62.61
26	48.3	5.35	317	22.48	4820	83.83
28	53.3	5.90	399	28.30	6280	109.22
30	58.8	6.51	495	35.11	8030	139.65

Table 3. Box profiles,
Source: [8]

Box profiles, δ=2 mm						
a,b [cm]	A [cm^2]	A_i/A_1	I_y [cm^4]	I_{xi}/ I_{x1}	I_x [cm^4]	I_{xi}/ I_{x1}
18	1.177	1.0000	0.404	1.0000	0.404	1.0000
20	1.337	1.1359	0.603	1.4926	0.603	1.4926
22	1.497	1.2719	0.857	2.1213	0.857	2.1213
25	1.737	1.4758	1.357	3.3589	1.357	3.3589
30	2.137	1.8156	2.558	6.3317	2.558	6.3317
35	2.537	2.1555	4.306	10.6584	4.306	10.6584
40	2.937	2.4953	6.701	16.5866	6.701	16.5866
50	3.737	3.1750	13.833	34.2401	13.833	34.2401
60	4.537	3.8547	24.754	61.2723	24.754	61.2723

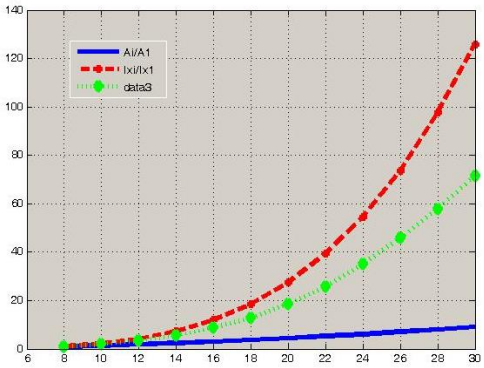

Figure 1. I profiles
Source: [8]

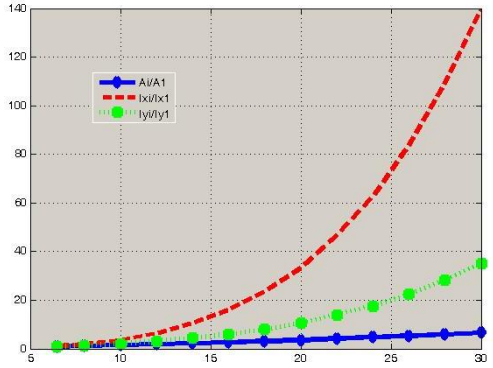

Figure 2. U profiles
Source: [8]

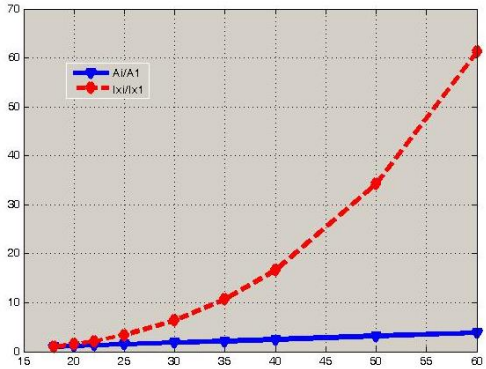

Figure 3. Box profiles, δ=2 mm
Source: [8]

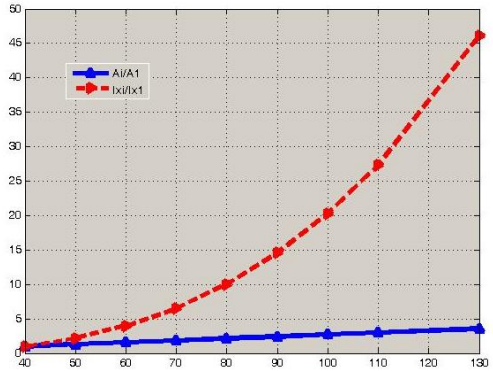

Figure 4. Box profiles, δ=3 mm
Source: [8]

From the above diagrams, the following conclusions can be drawn. The red line denotes the relative ratios of axial moments of inertia for one of the principal central axes of the corresponding cross-section, while the green line represents the other axis. As the beam's bending stiffness is proportional to the corresponding axial moment of inertia, a suitable choice of profile type can significantly increase the natural frequencies of the system during the original structure's construction phase. It is evident that the U-profile is more suitable for one direction, whereas the I-profile is better for the other direction. Box profiles are acceptable since they exhibit the same properties in both directions [6-8].

Table 4. Box profiles,
Source: [8]

Box profiles, δ=3 mm						
a,b [cm]	A [cm^2]	A_i/A_1	I_y [cm^4]	I_{xi}/ I_{x1}	I_x [cm^4]	I_{xi}/ I_{x1}
40	4.208	1.0000	8.618	1.0000	8.618	1.0000
50	5.408	1.2852	18.510	2.1478	18.510	2.1478
60	6.608	1.5703	33.925	3.9365	33.925	3.9365
70	7.808	1.8555	56.065	6.5056	56.065	6.5056
80	9.008	2.1407	86.129	9.9941	86.129	9.9941
90	10.208	2.4259	125.317	14.5413	125.317	14.5413
100	11.408	2.7110	174.829	20.2865	174.829	20.2865
110	12.608	2.9962	235.865	27.3689	235.865	27.3689
130	15.008	3.5665	397.310	46.1023	397.310	46.1023

3. CONCLUSION

In conclusion, the study of structural behavior, underscores the significance of precise calculations and modification elements. These elements, play a pivotal role in understanding and enhancing the operational performance of structures. The mathematical pursuit of modification involves the optimization of various parameters, considering constraints and non-linear functions. Sensitivity analysis serves as a cornerstone, providing essential insights into the behavior of the objective function. While conducting sensitivity analyses in real-world scenarios can be challenging, the alternative approach of parameter distribution analysis within specific elements serves as a practical substitute. Ultimately, achieving the desired natural frequency for a structural system often demands extensive computations and analyses of multiple structural variations. This approach is pivotal in ensuring the effective and reliable performance of structures in practical applications.

Acknowledgements
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MECHANICAL ENGINEERING. ECOTOURISM AND RURAL DEVELOPMENT.

SELECTED ACHIEVEMENTS IN THE RESEARCH OF THE DIAGNOSTICS OF THE LACK OF COMBUSTION IN THE ENGINE AND CHANGES IN THE INSTANTANEOUS ANGULAR VELOCITY OF THE CRANKSHAFT

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Milica Timotijević[2], College of Applied Studies Aviation Academy

Abstract: *The paper presents selected achievements in the research of diagnostics of lack of combustion in engine cylinders. The variation of the angular speed of the crankshaft of the engine is an extremely unfavorable phenomenon, however this "disadvantage" contains a large amount of information about the work processes that take place inside individual cylinders of the engine. Several diagnostic concepts are presented with the measurement techniques used.*
Keywords: Dijagnostic, Angular velocity, Crankshaft, Misfire, Engine, Measurement.

1. INTRODUCTION

Legal regulations regulate in-vehicle diagnostics, for which the term "On Board Diagnostics" or "OBD" for short is used in technical practice. The first such regulations (OBD I) were officially introduced in 1987 in the United States of America*, i.e.* the federal state of California, and were valid for all passenger vehicles sold on its territory, including imported vehicles.
OBD II regulations came into force in 1996, and compared to OBD I, they are significantly more complex because they provide for the control of a larger number of devices and specify strictly permitted limits for changing the characteristics of individual engine subsystems. Today's OBD II protocol, from the aspect of fault diagnosis, in its specification requires an assessment not only of the final parameters of the state of one of these subsystems (regular or irregular), but as a preventive measure, it also requires the reporting of suspicious behavior in the operation of an engine subsystem. The main control functions of OBD II in the diagnostic process are: constant checking of exhaust gas emissions, early signaling of errors and the use of diagnostic functions that greatly simplify fault finding and their resolution by professional personnel.

2. DIAGNOSTICS OF THE LACK OF COMBUSTION IN THE ENGINE AND CHANGES IN THE CURRENT ANGULAR VELOCITY OF THE CRANKSHAFT

There are several methods for detecting an occasional misfire in one of the engine's cylinders. The method of controlling angular speed variations of the crankshaft proved to be the most suitable. In this paper, only one detail of the complex tests will be presented, conducted by experts from the companies "Audi" and "Robert Bosch" on a large number of vehicles with engines of 4, 6, 8 and 12 cylinders, with manual and automatic gearboxes [1]. The point is that the possibility of correct misfire detection is directly related to the number of engine cylinders. Research has shown that for engines with more than six cylinders, the requirement to detect "misfire" in all operating modes and for positive torque values cannot be fully met. Figure 1 precisely illustrates the limits of the possibility of correctly detecting the occurrence of "misfire" for engines with 4, 6, 8 and 12 cylinders [1]. The

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position of these limits depends on the vehicle construction, engine type, suspension system, applied transmission, etc.. It is obvious that with engines having a larger number of cylinders (8 and 12) there are areas where it is impossible to correctly detect the occurrence of "misfire". However, it can be said that these limitations are not to be critical, because vehicles during exploitation usually work very little in conditions of speed and load where the detection of "misfire" is difficult. The problem of uneven rotation of the crankshaft of a reciprocating internal combustion engine appeared simultaneously with the first version of this engine. The variable torque acting of the motor during one working cycle is a consequence of the periodically changing total tangential force of the motor mechanism, to which this torque is directly proportional.

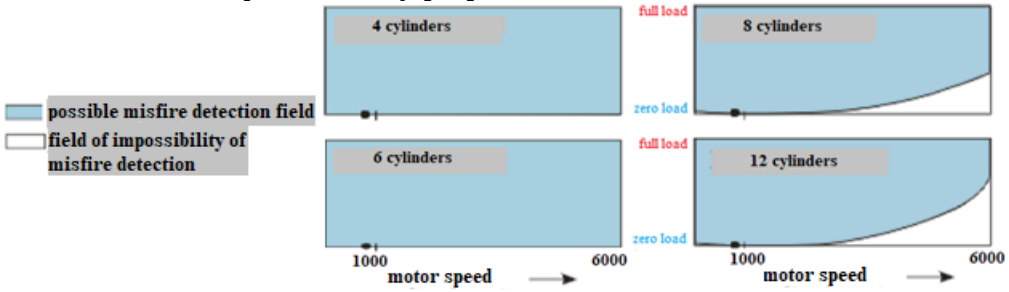

Figure 1. Limitations on the ability to detect misfires in the engine cylinders
Source: Klenk, M., Moser, W., (Robert Bosch GmbH); Meuler, W., Wimmer, W., (Audi AG), paper 930399: Misfire Detection by Evaluating Crankshaft Speed – a Means to Comply with ODB II

Due to this character of the torque change, even with constant resistance that the motor would overcome, in some phases there is an excess, and in others a torque deficit. Excess torque is communicated to the movement system of the engine (and connected machines), increasing the speed or kinetic energy of their rotative parts. On the contrary, the lack of work of the tangential force, when combustion ends in the observed cylinder and in the next one the working cycle has not yet started, will be accompanied by a slowdown, and thus a reduction in the kinetic energy of these parts. These changes depend on the number of engine cylinders and the operating mode and in principle are repeated periodically.

Since reciprocating internal combustion engines (ICE) are used exclusively as power units, variations in the angular velocity of the crankshaft represent an extremely unfavorable phenomenon, which is considered one of the serious drawbacks of their existing concept. However, this "disadvantage" contains a large amount of information about the work processes that take place inside individual engine cylinders.

Among the measuring techniques of the last decades, the existing toothed rings on the rim of the engine flywheel [2] or specially made and mounted toothed discs [3] in combination with magnetic inductive converters have been most often used. This concept is generally accepted since, in addition to the low price, it ensures stable operation of the encoder independent of the engine speed with minimal risk of negative environmental effects.

In parallel, research was conducted with the aim of correctly identifying and using the information contained in the angular velocity of the engine crankshaft, using suitable mathematical apparatus and different evaluation criteria, for diagnostic purposes [4, 5]. Thus, by controlling variations in the angular speed of the crankshaft in modern passenger vehicles, one of the key requirements of the "OBD II" regulations is fulfilled, namely the diagnosis of the phenomenon of lack of combustion in individual engine cylinders (in Western literature, the term "misfire" is used for this phenomenon)[1]. Engine torque and cylinder pressures are parameters of fundamental importance, which were previously considered very difficult to obtain during conventional vehicle use. According to [4], when trying to determine the fluctuations of the engine torque of a four-cylinder engine, the fact that the engine is connected to its load via elastic elements and that the entire system is one elastic assembly, which can be replaced by an equivalent torsional system (Figure 2), was taken into account.

For this cause, a mathematical model with four degrees of freedom was developed, which includes four inertial masses, such as: the engine (including the crankshaft with connecting rods), the flywheel, the torsional oscillation damper and, most importantly, the inertia of the vehicle itself, i.e., the brakes.

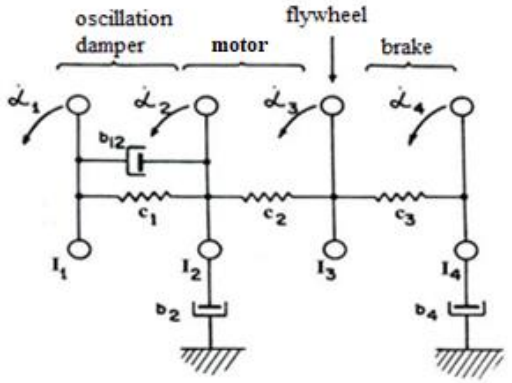

Figure 2. Propulsion system model
Source: Citron, S. J., O′Higgins, J. E., Chen, L. Y., Cylinder by cilinder engine pressure and pressure torque waveform determination utilizing speed fluctuation (SAE Paper 890486)

Taking into account the total variable motor torque and the "constant" load torque, after identifying the corresponding stiffness coefficients (c_1, c_2 c_3) and damping (b_{12}, b_2 и b_4), the fluctuations of the motor torque waveforms were reconstructed via FFT – Fast Fourier harmonical analysis transforms using the angular fluctuation data of flywheel speeds *(a)*.
A similar, but far more complicated mathematical model was applied to the large twenty-cylinder V50 diesel engine of the company "Warstila" with a nominal power of 20 MW and a total cylinder volume of 200 dm^3, intended for electrical power production [5]. With that engine, each cylinder was equipped with an "independent" fuel supply system, and the engine itself was an extremely "torsion-elastic" system with 13 degrees of freedom.

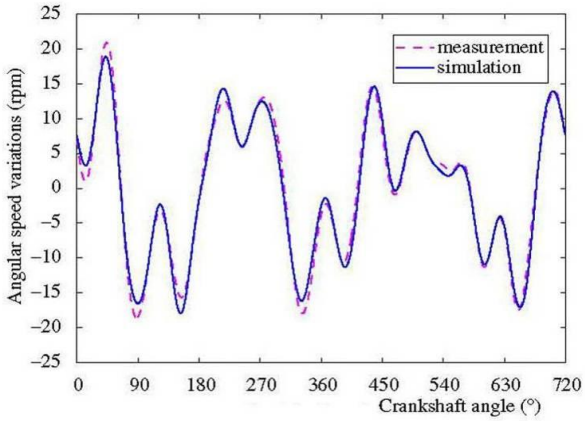

Figure 3. Measured and calculated fluctuations of the free end of the crankshaft of the 20-cylinder diesel engine "Warstila"
Source: Desbazeille, M., Randall, R.B., Guillet, F., Badaoui, M.El., Hoisnard, C., Model-Based Diagnosis of Large Diesel Engines Based on Angular Speed Variations of the Crankshaft, Mechanical Systems and Signal Processing 24 (2010), pp. 1529–1541

By using neural networks and many other sophisticated solutions, the authors were able to explain and reconstruct the fluctuations of the angular velocity of the free end of the crankshaft (Figure 3), for different states of correctness of the working processes in the engine cylinders. With this, they laid the foundations for the use of a technique known as "pattern recognition" for the purpose of detecting malfunctioning working processes in one of the engine's cylinders.
In addition, worthy of attention is the research presented in [6], where the authors set the theoretical foundations and then demonstrated practical results in order to detect both lack of combustion and

poor compression on one or more cylinders in a four-cylinder diesel engine with a volume of 1,6 dm^3. Through a complex "energy model" that included the variable flow of angular velocity of the crankshaft, two "energy indices" were defined that were calculated for each of the engine cylinders: compression index and expansion index. The validation of the method was carried out by monitoring the changes in these indices during a series of tests on the test bench, where the input parameters of the model were varied: the number of revolutions per minute, the coefficient of excess air whose real values are ranked in the range from 0 (no combustion) to 1 (regular combustion), the engine filling coefficient, which for the naturally aspirated variant of the engine was ranked in the range of 0 to 1, and for the supercharged variant of the engine could be greater than 1, the cross-sectional area of the gap between the cylinder and the piston sealing rings.

Finally, a brief review will be given of the tests of angular velocity fluctuations of the crankshaft of the turbocharged variant of the engine from the V46 family, which bears the V46-TKA mark, described in [7]. During the development of various variants from the family of twelve-cylinder diesel engines of the V46 series (635 kW, 735 kW, 882 kW), and especially in forced turbocharged variants, unusually high temperatures of the exhaust gases of some cylinders were observed, which exceeded the permitted 700 ºC. This phenomenon represented a signal of shortcomings in the performance of work processes in individual engine cylinders. Through a series of measurements of the angular velocity of the crankshaft of the engine and the camshaft of the high-pressure pump, the cause of the mentioned phenomenon was found in the strongly expressed amplitudes of fluctuation of these angular velocities [8]. By measuring the angular speeds of the crankshaft at its free end and at the end of the power output, it was concluded that the V46-TKA engine represents an extremely "torsion-elastic" system, as evidenced by the diagram of the relative angular displacement of those ends at full load and at 2000 min^{-1}, shown in Figure 4.

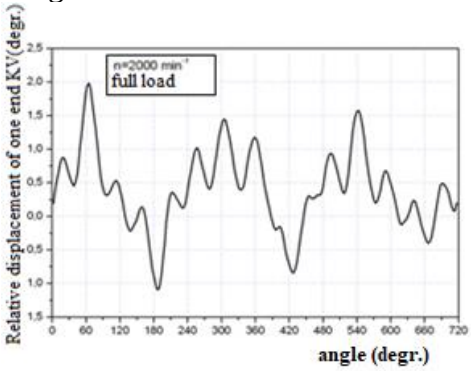

Figure 4. Relative displacement angle of one end of the crankshaft in relation to the other end in the V46-TKA engine for the regime n = 2000 min^{-1}, full load

Source: Bulatović, Ž. Possibilities of diagnosing the working process of the engine based on the change in the angular velocity of the crankshaft, Master thesis, Belgrade, 2008.

From the diagram in Figure 4, it can be seen that the maximum value of the relative displacement angle of one end of the crankshaft in relation to the other end is +1.982º, and the minimum is -1.091º. This means that the value of the maximum deformation amplitude for the given conditions is about 3.073º of the crankshaft. This diagram explains the cause of the totally different, even phase-shifted "flows" of angular velocities of the crankshaft at its free end and at the end of the power output.

The angular velocity measurement itself was performed by using an optoelectronic position sensor at the free end of the crankshaft, and at the end of the power output, towards the brake, a toothed disk coupled with an inductive sensor. By using the internal "clock" with a resolution of 2 MHz, which was utilized the acquisition module ADS2000 and special adaptive software, the creator of which was the late prof. Dr. Rade Jankov, the time intervals $\Delta\tau_i$ between adjacent increments of the optoelectronic sensor were measured and recorded in digital form. After the complex processing procedure explained in [7], diagrams of angular velocity fluctuations of the crankshaft at its ends were obtained. The regime of n = 2000 min^{-1} and full load are shown in Figure 5. These differences can be clearly seen on the comparative diagrams of the measured crankshaft angular velocity for 2000

min^{-1} at full load, which is also shown in Figure 5 (end 1 on the diagram is its free end, and end 2 is the end through which the power is taken). The marks 6L, 1D, 2L, 5D etc. on the tops of the given diagrams represent the mark of the cylinder in which the working process was taking place at "that moment", and it is quite clear that no clear correlation can be drawn between the development of these working processes and the fluctuations of the angular velocity crankshaft.

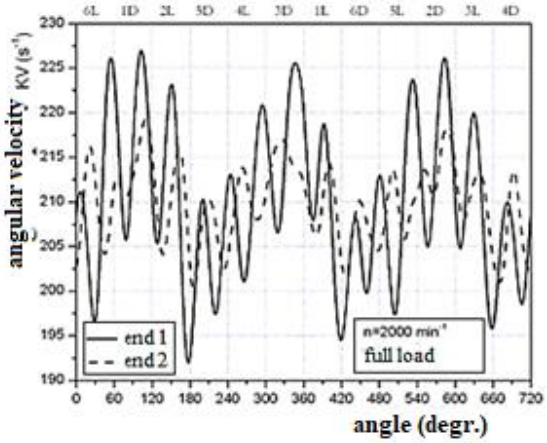

Figure 5. Comparison diagram of the measured angular velocities of the crankshaft at its different ends for the regime n = 2000 min^{-1}, full load

Source: Bulatović, Ž. Possibilities of diagnosing the working process of the engine based on the change in the angular velocity of the crankshaft, Master thesis, Belgrade, 2008.

The results of these tests are very reminiscent of the results given in [5], a fragment of which is also shown in Figure 3. It can be said that such, at first glance, chaotic and illogical diagrams of crankshaft angular velocity fluctuations can often be found in professional literature when in question engines of higher power and dimensions. Understanding this phenomenon and explaining its physicality is possible only if such test objects are viewed as "torsionally elastic" systems. A mathematical model that would manage to reconstruct and explain the angular velocity fluctuations of the crankshaft of the V46-TKA engine would be similar to the models presented in [4,5] and would have seven degrees of freedom. This arises from the fact that the equivalent torsional system would be composed of six identical concentrated masses representing the six crankshaft segments and a seventh mass representing the laboratory brake. Each of these masses, under the influence of a variable coercive torque (equivalent to engine torque), as well as internal stiffness and damping, would rotate with a characteristic angular velocity, and the diagrams of the angular velocities of the first and sixth masses would correspond to the diagrams of the measured angular velocities at the free end and at the at the end of the power output of the crankshaft, analogous to the diagrams shown in Figure 5.

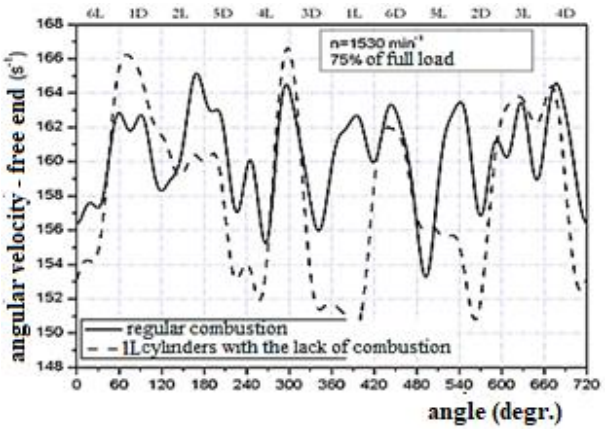

Figure 6. Angular velocities of the free end of the crankshaft at the regime of n = 1500 min^{-1} and 75% of full load

Source: Bulatović, Ž. Possibilities of diagnosing the working process of the engine based on the change in the angular velocity of the crankshaft, Master thesis, Belgrade, 2008.

It is shown that the diagrams presented in Figure 5 are not the product of any stochasticity, on the contrary are the result of the real response of the system for certain operating modes, which are absolutely repeatable every time the system is under identical conditions in terms of variable coercive moment, internal stiffnesses and internal dampings, which was also proven experimentally [7,9]. In the relation to that, it follows that the angular speed of the crankshaft of the V46-TKA engine can be used to detect the correctness of the working processes in its cylinders. This is supported by the diagrams shown in Figure 6, which represents the fluctuations of the angular velocity of the free end of the crankshaft at mode n = 1500 min^{-1} and 75% of full load, where the difference between the measured curves for two different conditions is clearly visible: regular combustion in all cylinders and the lack of combustion in the first left cylinder of the engine.
The experience gained during many years of work on the development of turbocharged variants of the V46 series engine made it possible to connect the cause of the appearance of unacceptably high exhaust gas temperatures with the dynamics of the high pressure pump (HPP) drive. The elements of the HPP drive, together with the crankshaft and the HPP itself, form a complex oscillatory system. The measurements showed the change in the angular speed of the HPP camshaft during one revolution, with clearly defined six periods and an extremely large amplitude of the angular speed (dashed line in Figure 7).

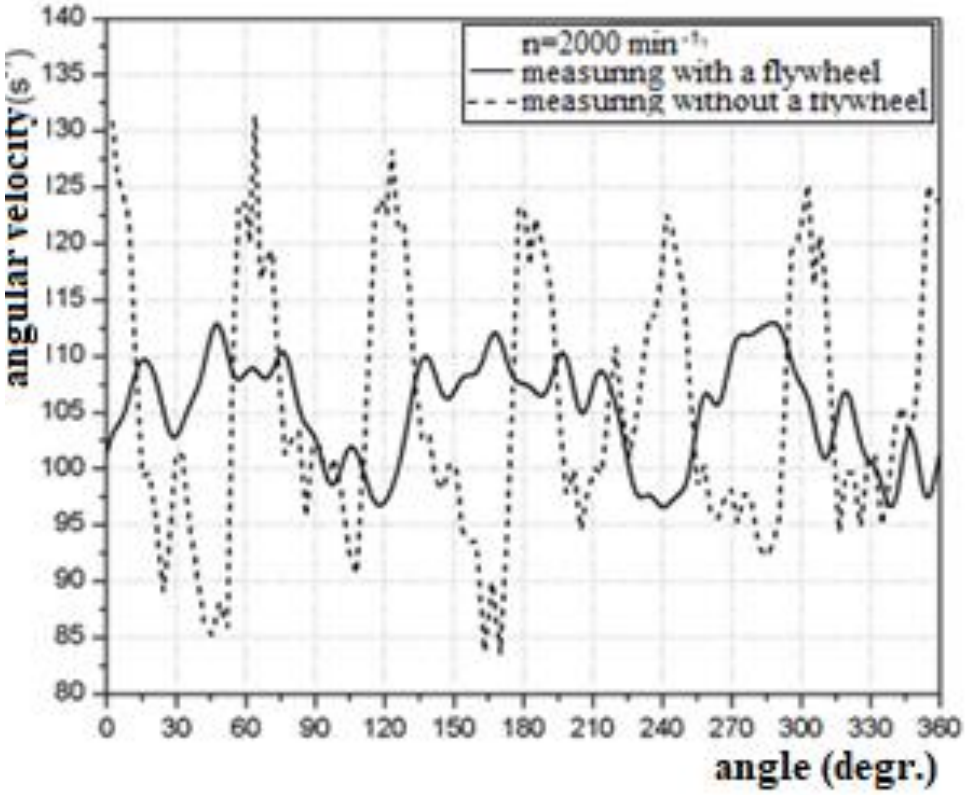

Figure 7. Camshaft angular velocity HPP measured with and without flywheel
Source: Bulatović, Ž. Possibilities of diagnosing the working process of the engine based on the change in the angular velocity of the crankshaft, Master thesis, Belgrade, 2008.

3. CONCLUSION

From what was written in the paper, it can be concluded that today technical diagnostics represents a serious and unavoidable discipline in the field of exploitation of internal combustion engines. The application of digital microprocessors and microcontrollers, as well as ultra-fast analog-to-digital and digital-to-analog converters, gave the engine a new quality because they enabled complex management of the engine's working process. On the other hand, possibilities of adaptive control of the work of almost all vital subsystems of the engine, as well as the quality of the working process itself, have expanded, in order to immediately identify and eliminate possible malfunctions.

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PANEL SHEAR PROPERTIES OF CARBON FIBER REINFORCED LVL BOAPANEL SHEAR PROPERTIES OF CARBON FIBER REINFORCED LVL BOARD

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Abstract: *Problem of rational use and lack of quality wood raw material for producing veneer boards, can be solved using poor quality wood raw materials for design composite veneer board. Poplar LVL panels do not have structural use because of its mechanical properties. Fiber reinforced composites can improve mechanical properties of wood-based panels, and thus enable the structural use of poplar panels. Synthetic fibers can reinforce panels, minimize the negative properties of wood raw material and improved dimensional stability of the board. This paper presents the results of experimental testing of the panel shear tests of unreinforced and reinforced seven-layer LVL (laminated veneer lumber) poplar veneer panels. The aim of the research is to determine the influence of woven carbon fibers on the improvement of the panel shear test of LVL, in order to test the potential of using this composite material as a structural element. The orientation of fibers has a strong influence on the reinforcement. The main research task is investigation the effects of orientation of the carbon fibers and their position in the panel construction on the shear properties of the panel. This research present possibility of applying poplar veneer to design structural elements in LVL using epoxy adhesive.*
Keywords: mechanical properties; LVL; CFRP; epoxy.

1. INTRODUCTION

Wood as a natural material used throughout history as one of the most commonly materials in construction. As natural material wood have great potentials for use in construction, due to its availability, easy processing and good physical and mechanical properties. The disadvantage of wood raw material is that not every type of wood is suitable for structural use, especially fast-growing soft species. Domestic wood species like poplar wood are very common in south Europe. The two leading countries that encourage the use of poplar in the construction industry and its structural application are Italy and Spain. With its 32,000 ha, Serbia is the 5th country in Europe in terms of the area of poplar plantations [1]. Lower load capacity and weaker mechanical characteristics compared to other species used for structural timber, make poplar is a less represented species in the construction industry. In order to make the best possible use of wood raw materials, wood-based products were made. Products based on veneer layers, plywood and laminated veneer lumber (LVL) are of special importance, and they stand out additionally due to their mechanical and aesthetic performance. Advantage of composite products like LVL and plywood is on distributing the errors through the panel and eliminating them in production. This reduce the variability in material properties, and equalize the mechanical properties of the product in the longitudinal and transverse direction. In order to improve mechanical properties of wood raw material and wood-based products, various

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strengthening techniques have been investigated throughout history. Strengthening timber construction with synthetic materials has been the subject of research studies since the 1960s [2].
The pioneers of using polymer composites - glass fiber reinforced polymers (GFRP) for strengthening of wood were Wangaard and Biblis [3]. During early 2000s, these authors continued to improve this idea, and examined the bending properties of three- and five-layer plywood reinforced with glass fiber fabric using phenol-based adhesives [4]. More intensive research in this area was made in the last ten years, and they mostly focused on bending properties of composite product created from wood veneer and fiber reinforced polymers. The research of mechanical propeties of reinforced veneer based panels or LVL, can be defined into two types of reinforcement - carbon or glass fibers. The flexural strength and modulus of elasticity were tested on three- and five-layer boards made of pine veneer, reinforced on the outside with two-way woven glass mesh in two layers, impregnated with polyester resin [4]. Examining the influence of the amount of fibers on the buckling of GFRP-reinforced veneer panels when exposed to compressive stresses and their behavior when exposed to different temperature conditions was investigated by Choi (S.W) and others [5, 6]. Investigation of the influence to mechanical and physical properties of panel using glass fabrics reinforcement with fibers oriented in two directions and their position in the veneer panel construction show significant improvements, especially to modul of elasticity and modul of rupture [7, 8]. An examination of the influence of the amount of carbon fibers in the strengthening of plywood with CFRP products on its mechanical properties and, above all, on its bending properties was presented in research by Brezović et al. [9]. Strengthening of veneer-based panels with carbon fibers oriented in two directions and analysis of their position in construction on the mechanical properties of the plywood [10] shows an increase in flatwise bending strength, tensile strength, and Young's modulus of elasticity. Just a few researches analyse the examination of the panel shear properties of composite LVL or plywood panel. For the structural application of these panels, it is very important to examine that mechanical properties.
Depending on the design and position in the construction, panels can be exposed to different types of loads, differ is primarily in their direction and position, which means that the elements are exposed to different type of stress. Panels used as diaphragm due to their small static height cannot accept bending perpendicular to the plane of the plate, and the diaphragms are designed as complex cross-sections of veneer plates and substructures. In these constructions, veneer based panels have the role of accepting shear forces perpendicular to the plane of the plate when the structure is exposed to a horizontal load, or shearing in the plane of the plate that occurs as a result of bending under the effect of gravity load. Potential of new reinforced material is to use panels as structural element, to unconventional way. This implies to use panel for folds, polygonal shells and structures formed in a constructive system of reciprocal constructions. To use panel as desribed, it needs to have exceptional resistance to in-plane compression and tension, as well as perpendicular to planar and panel shear.
This research investigates the possibility of producing composite panels based on veneer reinforced with CFRP. The aim of the research is to determine the influence of woven carbon fibers on the improvement of the panel shear test of LVL, in order to test the potential of using this composite material as a structural element. The main research task is investigation the effects of orientation of the carbon fibers and their position in the panel construction on the shear properties of the panel.
The focus is on the investigation of the possibility of applying this material as structural elements in architectural buildings, especially those exposed to forces in the plane of the plate, like beams, polygonal shells and folded structures.

2. MATERIALS AND METHODS

2.1 Veneer

In this study, constructive poplar veneers, produced by peeling (rotary-peeled veneers) at a thickness of 4 mm and humidity of 7 ± 1%, were selected for the formation of LVL panels. All veneers are cut to dimensions of approx. 550 × 550 × 4 mm. Reinforced and control LVL panels were formed from

all veneers. Four set of sheets were formed using epoxy adhesive (EK panels). Three types of reinforced sheets and one type of non-reinforced sheet were formed. LVL panels were produced in the laboratory at the Faculty of Forestry.

2.2 Adhesives

Epoxy adhesive Mapei "MapeWrap 31" was applied in all layers, between the veneers as well as between the veneers and the fiber reinforced polymer (FRP). The adhesive was formed in a mass ratio of A:B = 4:1 (according to Technical sheet [11]). The same amount of adhesive was applied to each glueline and each layer of CFRP wood on both sides of the carbon fabric. Epoxy adhesive properties show in Table 1.

Table 1. Epoxy adhesive properties
Source: [11]

Technical properties	Epoxy	
	Resin – A	**Hardener - B**
Density ρ (20°C) (g/cm^3)	1.05	1.12
Brookfield viscosity (mPa·s (25°C))	17000	110

2.3 Woven carbon fiber

The unidirectional "plain-weave" type of knitting carbon fiber, MapeWrap C UNI-AX 300/40", weighing around 300 g/m^2, was used for reinforcement. The physical and mechanical properties of the CFRP fabric are shown in Table 2.

Table 2. Physical and mechanical properties of MapeWrap C UNI-AX 300.
Source: [12]

Technical properties	**MapeWrap C UNI-AX 300**
Mass (g/m²):	300
Density (kg/m³):	1800
Equivalent thickness of dry fabric (mm):	0.164
Load resistant area per unit of width (mm²/m):	164.3
Tensile strength (MPa)	≥ 4900

2.4 Manufacturing LVL

All panels are produced as seven-layer panels with six veneer sheets oriented in the longitudinal direction, and the central, fourth veneer sheet oriented perpendicular to the grain of the outer veneer sheets. Reinforcements are placed between the veneer layers, according to the following scheme, shown in Figure 1:

- Combination 1 (K1) – reinforcement placed in the first and sixth glueline (S1‖6‖), unidirectionally oriented, carbon fibers placed longitudinally, parallel to the grain of outer veneer;
- Combination 2 (K2) – reinforcement placed in the first and sixth glueline, parallel-oriented as outer veneer, and the third and fourth glueline - perpendicular to the direction of orientation of the outer veneer sheets (S1‖3⊥4⊥6‖);
- Combination 3 (K3) – reinforcement placed in two layers perpendicular to each other, forming a mesh in two directions. The fabrics are placed in the first and sixth glueline (S1‖⊥6⊥‖), taking into account the symmetry of the cross-section;
- Combination 4 (K4) – unreinforced panels, i.e. control reference samples.

For each combination, 3 panels measuring 50×50 cm were formed. All plates were pressed in a laboratory press for 15 minutes from the moment of reaching a temperature of 100°C in the central layer at a pressure of 1.5 MPa. After that, they were stored for a week for additional curing. After that, 30-mm edges were trimmed off of the panels, and samples were cut from the panels. Samples

dimensions 150x50 mm, were conditioned in standard climate (20±2)°C and (65±5)% relative humidity during 30 days.

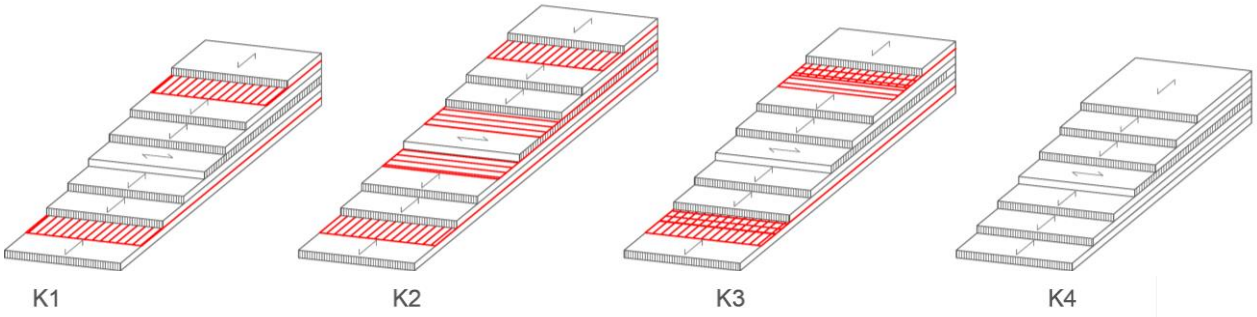

Figure 1. Strengthening configuration of reinforced and unreinforced LVL panels
Source: original copyright

Determination of shear strength perpendicular to the plane of the panel or panel shear test was performed according to the standard [13] SRPS CEN/TS 14966:2010 Wood-based panels - Small-scale indicative methods for testing certain mechanical properties using a small-scale indicator (Figure 2).

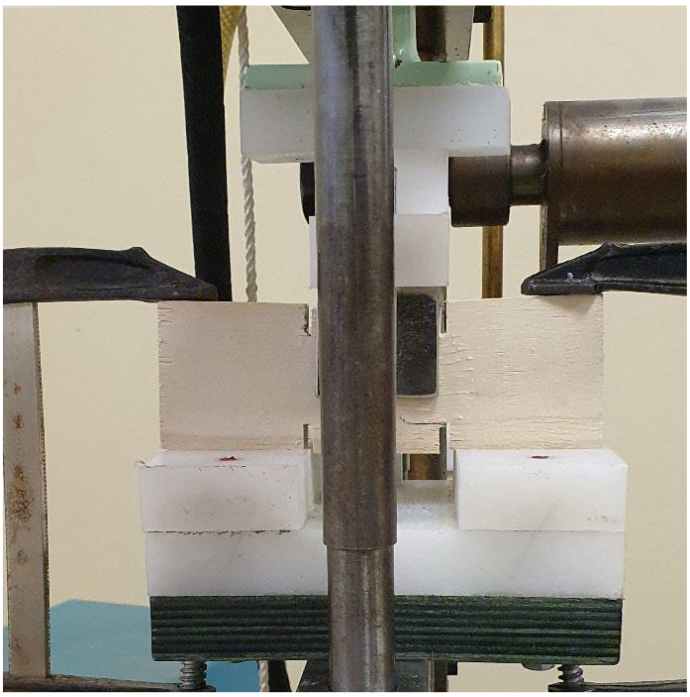

Figure 2. Fracture of the test sample due to shear stress.
Source: original copyright

3. RESULTS AND DISCUSSION

The test results for the test samples are shown in Table 3. For reinforce with two longitudinal, two longitudinal sheets and two perpendicular sheets, and sheets in disposition like a mash, the critical panel shear strength has increased by about 20.42%, 22.04%, 44.75%, respectively, compared to the untreated plate. These results show that higher panel shear load can be achieved using fiber reinforcement in two directions.

The best results are for combination K3, where carbon is oriented like mesh, in bi-directional orientation. In all tested samples, fracture occurred due to exceeding the shear stress. The fracture starts in the central sheet of veneer, whose wood fibers are transversely oriented in relation to the outer sheets of veneer, in the direction of the pressure force. In all other layers, shear occurs, which is manifested by the compression of fibers. Complete crush and cutting of the wood fibers does not occur, the fabric helps the test sample remains coherent (Fig.3).

Table 3. Shear properties of RLVL and LVL in edgewise directions, epoxy adhesive.
Source: original copyright

Combination	$f_{v,0,edge}$ (N/mm^2)	x (%)
EK1	15.16	20.42%
EK2	15.36	22.04%
EK3	18.22	44.75%
EK4	12.59	

Note: $f_{v,0,edge}$ – average shear stress, x – increase of average shears stress relative to EK4

Figure 3. Panel shear test - characteristic fracture for EK1
Source: original copyright

For combination 2 the mechanical damage of the test samples is less expressed compared to EK1. All test samples have the same forms of damage. In this combination the possibility of splitting along the longitudinal fibers of the wood was reduced.

On all the test samples of Combination 3 the fracture occurred by shear stress, but the deformations on the samples are very small, and on some of them are noticeable. Plastic deformation occurred on the test samples due to compression and crumpling of the fibers at the point of weakening of the material.

In all test samples from the control, unreinforced plates of Combination 4, failure occurred as a result of shear stresses. In relation to reinforced samples, the fracture of the test samples is quite expressed. The fracture tends to complete fracture of the test sample EK4.

4. CONCLUSION

In this study, laminated veneer lumber and reinforced laminated veneer lumber were produced with poplar veneer bonded with epoxy adhesive (EK). Reinforced laminated veneer lumber was produced by inserting woven carbon fiber between veneers, and some of their mechanical properties were tested. Reinforcement of EK3 panels, where the carbon fabric is placed in the first and sixth glueline in two layers, like mesh, oriented perpendicularly to each other, shows a much higher degree of increase panel shear capacity. The force at which the fracture occurred increased by 57.05%, while the percentage of improvement in shear stress is 44.75% compared to the control sample (EK4). In the test samples from these plates, it was observed that the degree of damage is the lowest compared to all tested test samples. The conducted research confirmed the possibility of applying the newly obtained poplar veneer composite material for the design of structural elements in LVL using epoxy adhesive. In this way, the use of technically weaker wood in the construction industry is encouraged and the use of wood raw materials is rationalized.

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ENVIRONMENT AND SUSTAINABLE DEVELOPMENT. MECHATRONICS. OCCUPATIONAL SAFETY AND HEALTH AND FIRE SAFETY. SMART MANAGEMENT SYSTEMS. GRAPHIC ENGINEERING. DESIGN. TRAFFIC ENGINEERING. BIOTECHNOLOGY AND HEALTHCARE. MECHANICAL ENGINEERING. ECOTOURISM AND RURAL DEVELOPMENT.

THE INFLUENCE OF REFRIGERATED DRYERS ON THE COMPRESSED AIR QUALITY

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Abstract: *Robotic systems that use pneumatic actuators in the form of grippers are in very frequent use in automated production systems. In order to ensure their reliable operation over a long period of time, the compressed air they use should meet the prescribed standards, that is, it must be of appropriate quality. In pneumatic systems, each of the elements can affect the quality of compressed air in different ways, but the key components for realizing its desired quality are dryers and filters. The paper presents a case study through which, using an example from the food industry, the influence of refrigerator dryers on the quality of compressed air was pointed out.*
Keywords: Compressed Air Quality, Refrigerated Dryers

1. INTRODUCTION

Automated systems are an extremely important part of any modern production. For the purposes of realizing automatic movements, pneumatic actuators are most often used. Consequently, control processes are realized as pneumatic, electropneumatic or systems driven by programmable logic controllers. Within the framework of automated systems, robotized systems are particularly important, which most often use electric motors for their drives, and various types of pneumatic grippers are used for gripping. Common to all these systems is that for their correct, reliable and long-lasting operation, compressed air of appropriate quality [1,2] must be provided.
The question of the quality of compressed air is directly related to the composition of ambient air, the condition and type of system for the production, preparation and distribution of compressed air and the types of applications that use compressed air. This issue was standardized in 1991. with the adoption of the ISO 8573-1 standard [3], which defined three types of pollutants: solid particles, water and oil. However, this standard does not define what quality of compressed air is needed for which application, but that is left to pneumatic equipment manufacturers and users in production systems who can use certain recommendations [4]. If the required quality for a certain application is known, a special problem is how it is technically possible to achieve that quality [4]. The main components for realizing the desired quality are dryers [5] and filters [6,7], where dryers reduce the moisture content in the air and filters remove particles and oil.
However, even if the required quality is well defined and the compressed air preparation system is well chosen, there may be problems with the quality of the compressed air and all the consequences that this may have if any of the elements in the preparation system break down or do not function in accordance with expected results. In that sense, this paper provides a brief overview of the quality standards of compressed air, the methods of measuring components of compressed air quality and,

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through a case study, the influence of the functioning of refrigerator dryers on the quality of compressed air in terms of water content.

2. COMPRESSED AIR QUALITY

As mentioned, the quality of compressed air for general use is defined by the ISO 8573-1 standard. In the first part, pollutants are defined and compressed air quality classes are given. For the permitted level of pollution, a number is defined that identifies the quality class as shown in table 1, in relation to three types of pollutants:

1) solid particles, where the maximum allowed number of particles per cubic meter of compressed air is defined for three different groups of particles according to their size,
2) water, which implies the maximum allowed amount of humidity and liquid water in compressed air, and
3) oil, which means the maximum allowed amount of liquid oil and oil aerosols in compressed air.

The designation of cleanliness classes according to the ISO 8573-1 standard consists of specifying the name of the standard and the revision year, followed by the numbers indicating the cleanliness class in parentheses.

Table 1. Compressed air quality standard ISO 8573.1:2010 [3]

Class	Solid particulate				Water		Oil
	Maximum number of particulates per m^3			Mass concentration [mg/m^3]	Vapour pressure dewpoint [℃]	Liquid [g/m^3]	Total oil (aerosol liquid and vapour) [mg/m^3]
	0,1-0,5 [μm]	0,5-1 [μm]	1,0-5 [μm]				
0	As specified by the equipment user or supplier and more stringent than Class 1						
1	≤ 20.000	≤ 400	≤ 10		≤ -70		≤ 0,01
2	≤ 400.000	≤ 6.000	≤ 100		≤ -40		≤ 0,1
3	-	≤ 90.000	≤ 1.000		≤ -20		≤ 1
4	-	-	≤ 10.000		≤ +3		≤ 5
5	-	-	≤ 100.000		≤ +7		-
6	-	-	-	$0 < c_p \leq 5$	≤ +10		-
7	-	-	-	$5 < c_p \leq 10$	-	$C_w \leq 0,5$	-
8	-	-	-	-	-	$0,5 < C_w \leq 5$	-
9	-	-	-	-	-	$5 < C_w \leq 10$	-
X	-	-	-	$c_p > 10$	-	$C_w > 10$	> 5

c_p - mass concentration of solid particles [mg/m^3]
C_w - maximum water concentration [g/m^3]

Particle filters of different gradations are used to achieve the desired quality in terms of solid particles, and coalescent filters are used to achieve the desired quality in terms of oil content. Achieving the desired quality in terms of liquid water and water vapor content is, for the most part, achieved by using appropriate dryers. In modern conditions, three types of dryers are generally used for this: refrigerated, adsorption and membrane dryers.

Refrigerated dryers, or subcooling dryers, condense moisture from compressed air by lowering the temperature of the air that is cooled in heat exchangers with some of the cooling agents. These dryers achieve saturation points less than or equal to 3°C at system operating pressure, which corresponds to the fourth class of compressed air quality. Adsorption dryers are used to achieve better quality (classes 1, 2 and 3), while the third and fourth quality classes can be achieved with the use of a membrane dryer in terms of liquid water and water vapor content.

3. MEASUREMENT OF COMPRESSED AIR QUALITY COMPONENTS

Compressed air quality is measured individually for each of the contaminants defined by the standard ISO 8573-1. Special devices called solid particle counters are used to measure the number of particles.

They are the most expensive of all devices used to measure compressed air quality and very few factories, except pharmaceutical companies, own them. Pharmaceutical factories that work under the Good Manufacturing Practice (GMP) system have the obligation to validate, i.e. prove the parameters at the entrance and exit of the production facilities, and thus they must also validate the quality of compressed air. The operation of solid particle counters can be based on several different principles. However, in the field of measuring solid particles in compressed air, systems based on the principle of machine vision are most often used, because their application makes the measurement very fast and accurate. Hygrometers are used to measure the humidity of compressed air. Their work is based on different phenomena, some of which are:

- hygroscopic properties of some substances, for example hair strands, which lengthen in wetter air and shorten in drier air (hygrometer with hair),
- on the absorption of water vapor from a known amount of gas where the humidity is determined by measuring the absorbed vapor (absolute humidity determination or absolute humidity),
- on condensation, i.e. determining the dew point where the air cools until it condenses and
- on a change in the electrical conductivity of an electrolyte, for example lithium chloride (electrolyte hygrometer), etc.

Special test tubes are used to measure the oil, which must be suitable for the type of oil used in the system. Below are some of the devices used to test the quality of compressed air. In this case, the following equipment was used to determine the required parameters of compressed air quality:

- Festo AirBox [8], a device that can be used to determine the amount of moisture and oil in compressed air and
- Dräger indicator tubes, which are used together with the AirBox device, to determine the amount of moisture and oil in the compressed air.

3.1 AirBox, type GHDA-FQ-M-FDMJ-A

AirBox (Fig. 1) is a mobile device designed for two types of measurements, depending on how the compressed air is delivered to the device itself:

- measurement of compressed air flow, and
- measuring the amount of water and oil in compressed air.

3.1.1 Flow measurement

The measurement of compressed air flow is based on the flow of air past a surface that is continuously heated. The air current absorbs heat energy from the hot surface and the sensor measures the flow rate necessary to maintain a given temperature on the surface. The measured flow represents the amount of air that flows through the device in a unit of time. Flow values are recorded in the device's internal memory. In addition, pressure and air temperature are measured by pressure during each flow measurement.

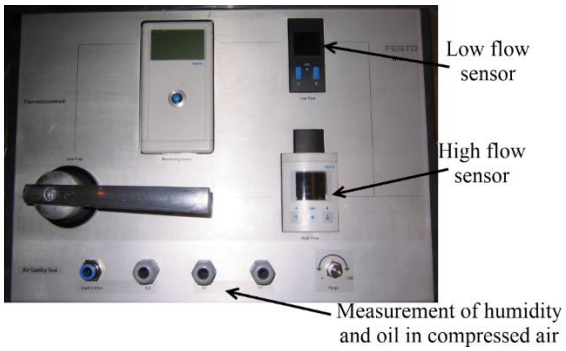

Figure 1. AirBox, type GHDA-FQ-M-FDMJ-A

3.1.2 Measurement of water and oil content

When measuring the dewpoint and the amount of oil in compressed air, a chemical reaction method is used. This method involves the use of tubes with chemical reagents. Reading of dewpoint and amount of oil in the air is done directly, based on the color change, which occurs as a result of the reaction of water/oil from the compressed air and the chemical substance in the tube.
Three types of Dräger indicator tubes (Fig. 2) were used during the experimental research:

1. Dräger indicator tube 5/a-P (Fig. 2a),
2. Dräger indicator tube 10/a-P (Fig. 2b), and
3. Dräger indicator tube 1/a (Fig. 2c).

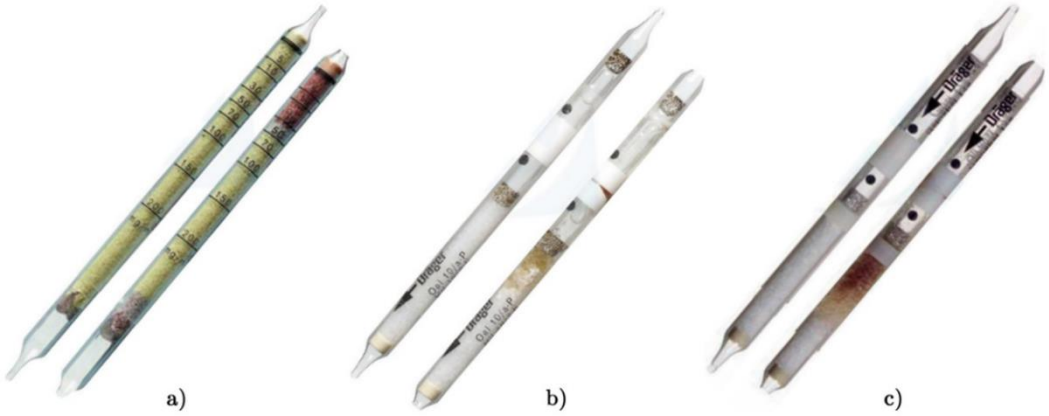

Figure 2. Dräger indicator tubes: a) 5/a-P, b) 10/a-P, i c) 1/a

A chemical reaction causes a change in the color of the crystal in the indicator tube, and based on the degree of color change, the amount of moisture and oil in the compressed air is determined.

4. CASE STUDY

A food industry factory [9] has automated the line for packaging of products into boxes by installing a large number of modern tripod robots at the end of the line, where the products that are already individually packed arrive. The robots are equipped with sophisticated machine vision systems that dynamically recognize the products on the conveyor belt and deliver the desired coordinates to the robot in real time. The robot grabs the products with a pneumatic gripper, transfers them to the boxes that also move in a parallel sequence with the product line, and places the products in the boxes.
After a long successful operation, problems appeared in the functioning of the pneumatic grippers on this line. After visual observation, it was concluded that the only possible reason is a change in the quality of the compressed air.
In order to confirm the assumption, as well as to find the cause of the problem, it was requested to measure the quality of the compressed air in terms of the content of liquid water and humidity as well as liquid oil and oil aerosol and vapor in a certain number of places.
In order to confirm that the quality is inadequate, two measurements were made at the points of air consumption, immediately before the robot, after additional air preparation in the preparatory group. For the adequate operation of these consumers, the fourth class of air quality in terms of water content is necessary.
In order to establish the cause of inadequate air quality, measurements were carried out after each of four compressors. As for Atlas Copco compressors of the GA FF series, which have built-in refrigerator dryers, it is expected that these dryers provide air in the fourth quality class, that is, that the dewpoint is less than or equal to 3°C.
In order to determine the time of compressed air flow through the indicator tubes, when determining the quality of compressed air at the observed measuring point, it is desirable to know the type of

compressor oil used in the factory. That is why, before the measurements were made, the client received information that the same oil was used for compressors, and that is Atlas Copco Roto Injectfluid.
An overview of the results of all measurements is given in Table 2.

Table 2. Overview of all measurements and quality class identification

No	Measuring point	Dewpoint [℃]	Quality class	Oil quantity [mg/m^3]	Quality class
1.	„K4“ (compressor 4)	-5	4	1	3
2.	„K5“ (compressor 5)	-12,5	4	1	3
3.	„K1“ (compressor 1)	>10	>7	1	3
4.	„K3“ (compressor 3)	>10	>7	0	1
5.	„ROBOT 2“	7,5	6	1	3
6.	„ROBOT 9“	7,5	6	0	1

Two of the 4 measuring points showed extremely poor results in terms of water content (compressors K1 i K3).
As for compressors that have built-in refrigerator dryers, it is obvious that these dryers do not work or not work properly. The problem is that all compressors are connected to the same tank, which is otherwise technically correct, but in the event of a malfunction, the following problem arises. In the tank, there is a mixing of quality class 4 air (correctly prepared air) and moist air with a significantly higher amount of moisture given by two faulty dryers. From there, the poorly prepared air in terms of water content is distributed into the main line. It should be noted that the first two compressors give the expected, fourth class and that this should be the case throughout the main line. However, the quality of compressed air is unfortunately spoiled by two compressors that do not work as they should.
When it comes to the presence of oil, it was determined that the analyzed system is in a relatively good situation, as class 1 or 3 is achieved. The compressed air after compressor 3 is somewhat better prepared in terms of oil content (class 1), while all other measurements of compressed air after the compressor give class 3.
Two measurements were made at the places of compressed air consumption. Measurements were made in the robot line and it can be seen that obtained dewpoint is slightly lower (7,5°C) as a result of the mixing of relatively dry air after the refrigerator dryers with dewpoints of -5°C i -12,5°C and incoming air without drying. Although these measurements were made after the preparation group, it was not able to significantly affect the dewpoint reduction.
This compressed air is still insufficiently prepared because quality class 6 was achieved, while the quality in terms of oil content remained at the same level (class 1 or 3).

5. CONCLUSION

Refrigerator dryers are responsible for achieving the fourth class in terms of water and moisture content in the compressed air preparation system. However, if their failure or insufficient performance occurs, there is a change in air quality, which can cause serious consequences for the functioning of the system and the lifetime of all pneumatic components.
In this particular case, based on the results of air quality measurements in terms of water and moisture content at two out of four measuring points in the compressor station, it is concluded that this is an extremely bad result. As for compressors that have built-in refrigerator dryers, it is obvious that these dryers are not working or are working improperly.
Based on these results, the factory requested the immediate intervention of a service technician and, after the repair, repeated measurements were made on the critical compressors. This time, the expected result was obtained, i.e., the required fourth quality class in terms of water and moisture content was achieved.

Measurements on the points of consumption, on the robot line, were made after the preparatory groups and it can be seen that in terms of moisture, quality class 5 or 6 was achieved, while the quality in terms of oil content remained at the same level (class 1 or 3).
If something like this happens in practice, after eliminating the cause, it is necessary to inspect the pipeline and clean it because the main pipeline is exposed to extremely humid air for a long period of time. Also, it is necessary to change all the filter cartridges on all the preparation groups because they were exposed to a significant amount of water and moisture in the compressed air. For the prevention of such events, it would be good to introduce regular quality checks of compressed air before the most important and sensitive consumers.
In this paper it is pointed out the problems in the functioning of pneumatic systems in production lines, which occur very often in practice and can have significant negative consequences for the production process. The reasons for the occurrence of these problems can be different. One of the most significant is insufficient expertise of the person whose responsibility it is to supervise and maintain an automated systems that use compressed air.

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TYPES OF BEE DRINKERS

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Abstract: *A continuous and sufficient supply of top-quality water is imperative for the proper development and survival of bees. Beekeepers often rely on a variety of water containers, each afflicted with numerous shortcomings such as limited capacity, irregular water availability, and subpar sanitation. This analysis aims to investigate the different categories of bee drinkers essential for meeting the water needs of bees. Additionally, we will conduct an in-depth examination of the pros and cons associated with each type of waterer to gain insights into their effectiveness and their impact on bee colonies. Ultimately, we will determine the most suitable waterer for the unique conditions and demands of beekeeping operations.*
Keywords: water, bee drinkers, bees

1. INTRODUCTION

Water is an indispensable element in the lives of all living beings, and this is especially true for bees. Maintaining a continuous supply of water to bees is a key aspect of successful beekeeping and the preservation of bee colonies. Water is essential for bees in multiple aspects of their existence [1,2].

The first and basic function of water in bee society is to cool the hives [1]. Bees actively use water to regulate the temperature inside the hive, especially during hot summer days. Bees collect water and use it to cool the interior of the hive and preserve optimal conditions for the development and survival of the colony.

Another important role of water in the bee world is the dilution of honey [1]. Honey is a key source of energy for bees, but sometimes it can become too thick. The bees then use the water to separate the honey so they can consume or store it. This is essential for their nutrition and survival.

Furthermore, water plays a key role in the development of young bees. The bees use the water to prepare the beebread to feed the larvae. This is a vital step in the process of reproduction and renewal of the bee colony.

For bees to perform these vital functions, it is necessary to ensure the availability of clean water in their environment. Lack of water can have serious consequences for the health and productivity of the bee colony. Dehydration of bees can lead to a decrease in honey production, poor brood quality, and a decrease in the number of bees in the hive. The amount of water required by the colony depends most on the amount of bee brood and the external temperature. Water fluxes of honeybees can be very high at the colony level. For example, average annual requirements of 120 kg of nectar,

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20 kg of pollen, and 25 litres of water for a single wild colony are estimated [3]. This applies to honeybees in cold temperate conditions [4].
The way bees access and use water can vary depending on the environment and weather conditions. Bees will usually look for water sources near their hives, such as streams, lakes, fountains, or even dew drops on plants [5]. However, it is important to pay attention to the quality of water consumed by bees. Unfortunately, in some cases, the water that bees find may contain harmful substances.
This problem often appears in areas of intensive agricultural activity. The use of various chemicals for crop protection and weed control can lead to pollution of surrounding waters. When collecting water, bees can unknowingly introduce these harmful substances into the hive, which can have serious consequences for their health [6].
In addition, during longer periods of drought, water sources often dry up, making it even more difficult to supply water to bees [5]. Bee diseases (for example: American foulbrood - *Paenibacillus larvae*) can be spread by endospores, the form that allows survival in extreme conditions (in water and soil) and to have active form as soon as it reaches the brood [7]. While cleaning the beehive bees take out waste from possibly infected brood and their parts are scattered around the beehive, as well as the excrement, that can end up in a water bowl.
Therefore, for the preservation of bees and bee colonies, it is important to carefully monitor and ensure access to clean water to ensure their successful operation in the ecosystem.
In this analysis, it is shown the different types of drinkers that are essential for the proper supply of water to bees. In addition, were discussed in detail at the pros and cons of each of these waterers, in order to better understand their effectiveness and impact on bee colonies. Finally, it presents which type of drinker fits best in the different conditions and needs of beekeeping operations.

2. TYPES OF DRINKING BOWLS FOR BEES

The paper presents the design and implementation of drinking bowls for bees, emphasizing simplicity and accessibility. These bowls can be easily installed in gardens, parks, and urban areas, providing bees with a reliable source of clean water. A bee drinker is one of the important elements in beekeeping equipment that allows bees access to water, which is crucial for their nutrition. Drinking bowls for bees can be of different types and sizes, depending on the needs of the bee colony and the environment in which it is located [5]. A key aspect of the drinkers is to ensure that the bees can get to the water easily, but at the same time prevent the water from becoming contaminated or evaporating too quickly. Waterers are placed near the hive so the bees can get to water quickly without wasting too much energy.
There are different types of hygienic bee drinkers, each with its own characteristics and advantages. Some of them are presented in the paper [5]. In practice, various devices are often used to feed bees. Figure 1. is just a part of the various drinker cans that can provide water for their bees. Caring for bees and their needs, including providing water, is crucial for any responsible beekeeper. With this type of watering can, there is a big problem with hygiene, because the containers are constantly open, and contamination of the water can occur.

Figure 1. Bee drinkers as an open container [5].

Another example of a drinker can for bees described in the paper [5] is a traditional drinker can for bees. This drinker can is in the form of a wooden board on which water drips from a barrel placed on top (see Fig. 2). Slanted slats are placed on the board, which allow the water to stay on it as long as possible. The advantage of this drinker is that a large number of bees can take water, and a constant flow of water is present in these drinkers. Since this drinker hole is also open like the previous one, the tendency to create parasitic diseases is much higher, and therefore this watering hole is not suitable for use.

Figure 2. Wooden drinker for bees [8].

In recent times, inverted glass containers closed with a perforated cover or a piece of cloth are being used more and more often as hygienic drinkers for bees [5]. These containers meet hygienic requirements, and their price is low. The advantage of these watering cans is that the bees do not drown in the water, so there is no danger of droppings coming into contact with the water due to the position of the bees when drinking water. The lack of these drinkers necessitates the constant presence of a beekeeper who must regularly refill the containers because these watering cans are suitable for feeding bees up to 10 hives. Another disadvantage of these drinkers is that the wet cloths used to close the waterers are prone to bacterial growth. Also, these drinkers are ineffective due to the lack of water under the direct influence of the sun, which leads to an increase in the temperature of the water.

The automatic drinker is another option for bees seeking refreshment (see Fig. 3). In these drinker cans, the water level is regulated by a float, like in a water tank. The advantage of this watering can is the large amount of water that can be used to water a large number of bees at the same time. Regrettably, the drawback of this method lies in the barrel's potential lack of cleanliness due to the large landing surface from which bees take water and which is easily contaminated.

Figure 3. Automatic drinker for bees [9].

One of the patents that was made concerns a honeybee breeding apparatus, which is strategically placed within beehives to dispense feeding liquid for bee breeding [10]. More specifically, it focuses on an automated honeybee breeding apparatus, which ensures precise feeding liquid delivery, minimizing the chances of supply paths becoming obstructed by bees' secretions. The primary aim is to streamline the feeding process and maintenance, particularly cleaning [10].
Another one of the patents is the smart hygienic bee water drinker, a closed system that completely and simply solves the problem of watering [1]. This drinker can provide a sufficient amount of hygienically correct water and safe drinker of the bees. The device enables the application of high standards in accordance with the food safety policy, which was not possible until now. The bee trough is a central gathering place for water-carrying bees from all hives in the apiary, allowing water from one container to be available to all [1].

3. CONCLUSION

This paper provides an overview of existing bee-drinking fountains with all their advantages and disadvantages. While they can play a vital role in supporting bee health, it is essential to weigh the benefits against the potential drawbacks of these drinkers. Careful management and environmental considerations are crucial when deciding to introduce drinking bowls for bees, ensuring that they are a net positive for these vital pollinators.
In some further research, it is possible to choose the most optimal materials for making drinkers, as well as various methods of producing them. Some of the possible solutions are 3D printed drinkers with carefully selected materials and printing processes.

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EFFECT OF TANNIN ON INCREASING UF ADHESIVE PERFORMANCE

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Abstract: *The aim of this study was to evaluate the potential use of tannin in urea formaldehyde (UF) wood adhesives formulations. Tannins have been largely studied as wood additives and wood adhesives. In a perspective of a desirably increased utilization of natural raw material in the wood timber industries, this study provides specific information on the use of tannin to improve the performance of UF resins. Tannin-based UF resins were prepared and adhesive properties were tested. The results of tensile strength determination obtained showed that the tannin addition in UF adhesive formulation gives a better performance compared to pure UF adhesive. Therefore, it can be concluded that tannin-based UF adhesive can be good candidate for the application as wood adhesive due to better improvement in term of adhesive and mechanical properties to produce an environmentally-friendly wood adhesive.*
Keywords: wood adhesive, tannin, bio-adhesives**,** UF resin, tensile shear strength

1. INTRODUCTION

Phenolic resins are the first synthetic polymer that has been industrially produced since 1911 [1]. Modern times dictate a high demand for wood panels and other wood products, which causes the use of large amounts of wood adhesives. Formaldehyde-based adhesives account for approximately 90-95% of the total amount of wood adhesives used in the wood industry. Urea formaldehyde (UF) is the dominant type of adhesive in the production of wood-based panels, with a consumption of about 11 million tons of solid resin per year [2]. The global dominance of UF resins is due to favourable characteristics such as good binding properties and high reactivity, but these resins also have certain disadvantages related, first of all, to poor water resistance and formaldehyde emission (FE) [3]. A wide field of adhesive technology today can be "covered" using renewable materials, which can show equal or even better performance than their commercial variants based on oil and its derivatives. Lignin, tannin and proteins are raw materials that in numerous experiments have proven to be a good alternative for existing thermos reactive amino based adhesives. Tannins are, after lignin, a major source of polyphenol components all over the world, but their extraction potential is much higher than in the case of lignin [4]. As tannin is unique in its composition and abundantly available, the development of value-added products offers a sustainable alternative. It is emerging as a green substitute for the wood adhesives, produced from petroleum-based resources, specifically phenol and resorcinol [5, 6]. Copolymerization of tannins with synthetic adhesives decreases FE from synthetic resins in wood composites and acts as formaldehyde scavengers in phenol formaldehyde (PF), melamine formaldehyde (MF) and UF resin [7].

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Tannin-formaldehyde resins have been commercially available for several years and are characterized by very low FE and fast pressing times. However, formaldehyde is still an essential component. Therefore, low or no aldehyde tannin bio-adhesives have been developed.
Tannin bio-adhesives provide very good adhesion, high moisture tolerance, no need for combination with petroleum-based adhesives and offer many suitable cross linkers [8]. Generally, tannin is considered as an additional component that can be mixed with typical UF resins in different ratios [9]. Recently, a novel tannin-modified UF resin was reported by substituting a part of the urea with tannin for preparing the tannin–urea–formaldehyde resin (TUF) [10]. Presence of tannin caused lower formaldehyde emission (even though, it should be clear that too much tannin addition can cause gelation), but also effectively improved the bonding properties of conventional UF resin, especially in terms of water resistance, which is considered a green renewable approach for the synthesis of TUF resins. The joining of tannin introduced some aromatic rings and enhanced the structural rigidity of TUF resins, while improving the stability against hydrolytic degradation. The curing temperature of TUF resins fluctuated around that of UF resin, although TUF resins exhibited higher thermal stability with respect to UF resin.
In this work, new adhesives based on commercial UF resins and tannin were prepared and tested for the application as wood adhesives. The effect tannin on UF adhesive characteristics - the tensile shear strength was investigated.

2. EXPERIMENTAL SECTION

2.1 Materials

Two different commercial UF resins (UF1 and UF2) were provided by domestic company (Serbia). Tannin sodium salt was purchased from CHIMAR HELLAS SA (Greece). Ammonium chloride was purchased from Centohem (Serbia). Beech (*Fagus sylvatica*) logs were selected from a known locality and growth conditions (beech from mountain Goč). Afterward, primary boards with the desired orientation of growth rings were cut.

2.2. Tensile shear strength determination

2.2.1. Preparation of wood samples

The sawn timber was dried in a semi-industrial conventional kiln (Nigos MC 3000, capacity 0.8 m^3). The most homogeneous groups of testing samples were selected for further experiments.

2.2.2. Preparation of UF-tannin adhesive

Firstly, the adhesive solid content of UF resin was determined to be used for further adhesive formulations and analyses. Every formulation was prepared in concentration calculated using solid weight relative to UF resin solid content. Ammonium chloride salt solution (concentration of 20%) was used as hardener for all samples in the concentration of 1% w/w. Tannin was added to UF adhesive in 3% by weight.

2.2.3. Characterization of UF adhesive

Adhesives obtained in this research was performed according to the following standards: determination of pH (SRPS EN 1245:2012); determination of density (SRPS EN 542:2009); determination of conventional solids content and constant mass solids content (SRPS EN 827:2009); determination of tensile shear strength of lap joints for wood adhesives (SRPS EN 205:2017); and adhesives were classified according to standard for classification of thermosetting wood adhesives (SRPS EN 12765:2017).

The FTIR-ATR spectra were obtained with an FTIR spectrometer (iS20, Thermo Nicolet) with a resolution of 4 cm^{-1} in the wavelength region 4000–525cm^{-1}, using a diamond single reflection attenuated total reflectance (ATR). All spectra were obtained with 32 scans, and the background measurement was made using air.

2.2.4. Determination and optimization of glue-line quality

The adhesive mixes were applied by a rubber roller onto one surface of the two wood specimens to be bonded (200 g/m^2). Assembling was always performed in parallel grain directions. The ply without direct application of the adhesive mix was always in the bottom position to improve the penetration into its structure. Again, a special effort was made to have the taper as low as possible, guaranteeing equal penetration conditions for all samples. Five joint samples were pressed in a hydraulic press at 120°C and 1.5 MPa for 15 minutes. Before testing, the single lap shear test specimens (150 mm × 20 mm × 5 mm) were conditioned at 20 ± 2°C and 65 ± 5% relative humidity for one week. The lap shear test will be conducted according to SRPS EN 205 standard test on a hydraulic test machine (Wood tester WT4) with a measuring scale of 50 kN at a testing speed of 6 mm/min loading rate in tensile mode with the load direction always parallel to the grain in all tested specimens. The failure zone (shear area 20 mm × 10 mm) was examined using a light microscope to determine the proportion of wood failure and the thickness of the wood layer in the wood failure. Ten replications were performed for each set of parameters. An analysis of variance (ANOVA) was applied to obtain centralized values and standard errors.

3. RESULTS AND DISCUSSION

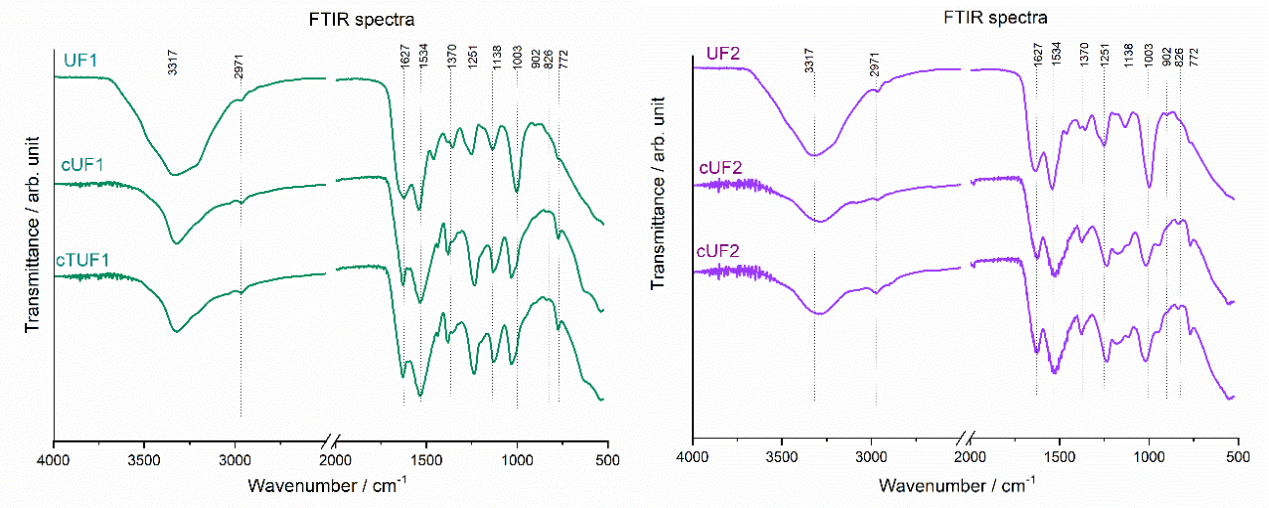
For any type of bio-based wood adhesives, it is important to effectively evaluate their prospects for wood composite application and understand the adhesive/wood interaction to gain scientific insights to guide the adhesive development in terms of the mechanical strength, water resistance, thermal and rheological properties of the adhesives, as well as the adhesive penetration. To interpret the measured bonding strength of wood adhesives, it is also essential to take into consideration the type of the failure or separation occurred in the mechanical tests. There are four main types of failure modes for the adhesive bonded wood composites: (a) cohesive failure of the adhesive; (b) adhesive failure (c) mixed failure - a combination of (a) and (b) - and (d) wood cohesive failure or wood failure. Since the UF resin, as the most important type of adhesive for the preparation of wood-based panels, due to good performance and low price, display poor water resistance and high formaldehyde emission, some modification of the UF resin is essential.

Figure 1. Cross-linked (cured) pure UF resin (cUF1, cUF2) and with tannin (cTUF, cTUF2)
Source: Authors

Herein, we prepared new adhesives based on commercial UF resins (UF1 and UF2), cured alone (cUF1 and cUF2) or with tannin (cTUF1 and cTUF2) characterized them and evaluated their adhesive properties by determination of the tensile shear strength (Figure 1).

3.1. FTIR analysis

Fourier transform infrared (FTIR) spectroscopy was used to characterize the chemical structures of the resins. Cross-linking of UF resin with tannic acid was confirmed via FTIR spectroscopy. The obtained FTIR spectra of commercial UF adhesive emulsions examined in this work are given in the Figure 2a) for UF1 adhesive and in the Figure 2b) for UF2 adhesive. Spectra of cured resins alone or with tannin were also presented on Figure 2. Spectra of cured adhesive mixed with tannin (cTUF) have not shown significant differences in regard to the spectrum of cured UF adhesive alone (cUF).



a) **b)**

Figure 2. FTIR-ATR analyses of pure UF adhesive emulsion, and pure UF and TUF after curing (cUF and cTUF)
Source: Authors

The wide bands at 3317 cm^{-1} represent stretching vibration of O–H and N–H and originate from the presence of byproducts such as water and excess formaldehyde that can hydrogen bond to the CH_2OH, NH_2, and NH functional groups present in the observed resins but their intensities decreased in cured samples. A sharp but small peak occurring at 2971 cm^{-1} belongs to the stretching C-H vibrations which may be the result of the contribution of dimethylene ether bonds (CH_2-O-CH_2), hydroxymethyl (CH_2OH) and methylene bonds (N-CH_2). The characteristic bands that appear at 1627, 1534, and 1251 cm^{-1} represent amide I (C=O stretching vibration in -CONH), amide II (stretching vibration of C-N and deformation of vibration of N-H in NH-CO), and amide III and all amide bands increase during curing. The methylene ether bridge (–CH_2–O–CH_2–) characteristic absorption peak at 1138 cm^{-1} belongs to the C–O stretching vibration of hydroxymethyl and becomes stronger after curing compared with UF resin, indicating reaction of UF resin and tannin and formation of new ether linkages. Weak band at 1370 cm^{-1} in UF emulsion, becomes sharp and strong after curing. This area of UF polymer spectra is usually assigned to C-H vibrations in CH_2 and CH_3 structures. Peak at 1035 cm^{-1}, assigned to hydroxymethyl group (–CH_2OH) in cUF and cTUF resin decreased when compared with UF resin, indicating the possible reaction between UF resin and tannin from hydroxymethyl groups. The peaks about of 1003 cm^{-1} were assigned to ν(C-O-C) of ether linkage and decreases with crosslinking due to breakage of ether bonds. A small peak at 772 cm^{-1} which appears in cured samples is the characteristic absorption peak of iron structure that is formed.

3.2. Tensile shear strength determination

The tensile shear strengths of examined adhesives are shown in Figure 3. The tensile test results of the samples demonstrated that the resin mixed with tannin had better performance than

corresponding pure cUF resin. Compared to UF resin, shear strength increased after the addition of tannin. Theoretically, in previous studies, the higher molar ratio of aldehyde to urea is used to enhance the cross-linking of the cured resin [11]. However, in that case, emission of formaldehyde has become one of the major causes of indoor air quality deterioration, which can negatively affect human health. Some authors showed that addition of tannin to UF resins in particleboards appears to decrease formaldehyde emission over a period of time proportional to the amount of tannin added but the improvement of the strength performance caused by the denser cross-linking was offset by the decrease of the amount of UF resin [11]. In that case, the formaldehyde emission of tannin-UF resin decreased but the bonding strength was also decreased compared with pure UF resin. Additionally, Zanetti et al. [12] used condensed tannins to improve the heat resistance of UF resins and the result showed that high percentage of tannin in UF-tannin blend improves the overall UF thermal resistance in a great extent. However, in this study, tannin was used to substitute some of UF resin, to reduce formaldehyde emission and to produce an environmentally-friendly wood adhesive along with enhanced adhesive properties. The higher shear strength of cTUF compared to cUF might be result of the better water resistance of the product arising from the reaction between tannin and UF resin.

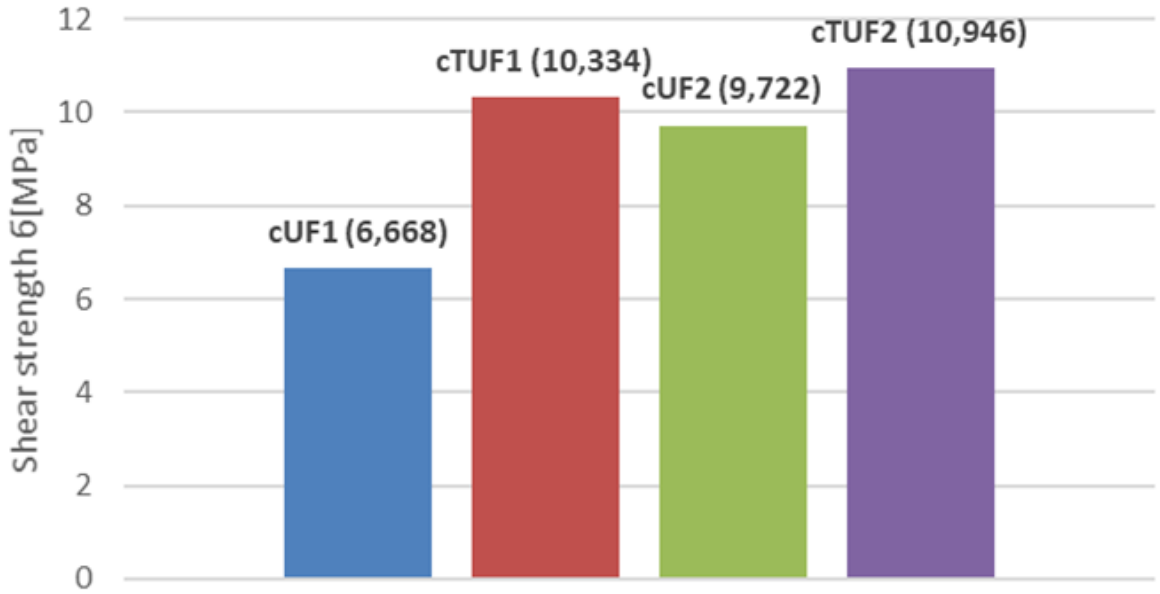


Figure 3. Shear strength of beech wood specimens bonded with pure, commercial UF resin and with the one with added tannin (TUF)
Source: Authors

Figure 4. The failure zone of tested samples
Source: Authors

The diverse types of failure after completion of the adhesion tests, i.e., cohesive, adhesive, and substrate failure, were considered by analysing the surface of both specimens through high-resolution imaging. Cohesive failure was considered when both samples presented adhesive on the overlapping surfaces; adhesive failure means that only one of the overlapping surfaces had adhesive, whereas substrate failure indicates breakage of the substrate itself so that the bonding surface was not altered. Examination of the failure showed that all samples had a 100% fracture trough wood (Figure 4).

4. CONCLUSION

Wood adhesives based on UF resin and tannin were prepared, characterized and their adhesive and mechanical properties were investigated to determine their potential as wood adhesives in order to reduce formaldehyde emission. Based on characterization processes, it was found that UF-tannin adhesives showed higher tensile shear strengths than corresponding pure UF adhesive. It was shown that 3% of tannin addition in UF adhesive formulation gives a better performance compared to pure UF adhesive. Therefore, it can be concluded that tannin-based UF adhesives can be good candidates for the application as wood adhesives due to better improvement in term of adhesive and mechanical properties to produce an environmentally-friendly wood adhesive.

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ECOTOURISM AND RURAL DEVELOPMENT

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ENVIRONMENT AND SUSTAINABLE DEVELOPMENT. MECHATRONICS. OCCUPATIONAL SAFETY AND HEALTH AND FIRE SAFETY. SMART MANAGEMENT SYSTEMS. GRAPHIC ENGINEERING. DESIGN. TRAFFIC ENGINEERING. BIOTECHNOLOGY AND HEALTHCARE. MECHANICAL ENGINEERING. ECOTOURISM AND RURAL DEVELOPMENT.

EDUCATION AS A PILLAR OF SUSTAINABLE AGRITOURISM IN SERBIA

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Abstract: *Education occupies an important place in a wide range of activities that support one business activity, in the specific case agritourism. This especially applies to individuals and families who are just starting their entrepreneurial venture in agritourism in Serbia. Education is combined with other numerous incentive measures, but the order in which these measures are implemented is important. First, education is carried out, and only then comes financial support (non-refundable loans, subsidies, loans under more favorable conditions). This is because only sufficiently educated agritourism service providers can provide sufficiently high-quality services, be competitive in the tourist market and make their business sustainable in the long term. It is especially important that the offer holders in agritourism accept the Lifelong learning (LLL) concept. This means that they are ready to constantly improve their existing knowledge, as well as acquire completely new skills. In addition to the readiness of the offer holders in agritourism to constantly learn, the quality of the educators, i.e. the persons who will create and implement the educations, is also important.*
Keywords: Agritourism, education, sustainable business, Serbia, incentive measures

1. INTRODUCTION

There are several serious reasons why agritourism in Serbia must be supported by education, as the first and basic measure in the system of institutional support. The first reason is that the largest number of offer holders in Serbian agritourism do not have formal education in the field of tourism. In other words, beginners and entrepreneurs in agritourism generally do not have theoretical knowledge about agritourism because they did not graduate from one of the high schools, colleges or faculties that train personnel for tourism, more precisely catering.

Another reason is that beginners in agritourism generally do not have previous practical experience in tourism. This means that the vast majority of them did not work in an agritourism facility (eg ethno restaurant, apartments, rural houses for rent to tourists), or if they did, they did not manage a business in agritourism. The third reason is modern tourists. They have high expectations from providers in agritourism and often prefer quality service to a lower price. Today, guests in agritourism are not satisfied with a "beautiful view", friendly hosts and "clean air".

They are looking for much more than that - additional content, local products, authentic atmosphere, intangible content (Storytelling, Living history/heritage), activities in nature, excellent hygiene, respect for ecological standards, quality accommodation, a certain level of business communication with guests, etc. [1]. Changes in (agri)tourism (both on the supply side and on the demand side) are a constant and dynamic phenomenon. The only way for agritourism offer holders to understand these changes, to respond to market changes in a timely manner, as well as to adequately respond to the needs and expectations of modern tourists, is to be educated.

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2. ELEMENTS OF EDUCATION IN AGRITOURISM

2.1 Principles in the creation and implementation of education in agritourism

In the last two decades, a large number of educations in the field of tourism, especially agritourism, have been held in Serbia. Those educations differ from each other in many indicators (content of lectures, quality of educators, duration of lectures, method of financing). Nevertheless, educations have fundamentally improved the offer of agritourism in Serbia. Also, it was education that encouraged a large number of individuals, families and companies to start their entrepreneurial venture in agritourism. When creating education in agrotourism, certain principles must be respected. In the first place, that the offer in agritourism is based on the needs and expectations of modern tourists, then that business in agrotourism is based on valid regulations in the field of (agri)tourism, as well as that the basic principles of the tourism profession are respected. A particularly important principle is the one that talks about the sequence of implementation of incentive measures. According to this principle, education is the first step and a prerequisite for the implementation of all other incentive measures ("first knowledge, then money") [2]. In order to respect the mentioned principles, it is important that the person commissioning the training, the creator and the implementer of the training have clear answers to the questions listed in table 1 beforehand.

Table 1. Elements of education in agrotourism
Source: [3].

Who are the educations intended for?	Target groups
What do we want toachieve by educations?	Goals of education
What knowledge and information do we want to transfer to the beginners?	Content of education
Who should initiate and realize educations?	Holders of education
How will the education be implemented?	Way and quality implementation of education

2.2 Target groups for education in agritourism

The trainings are primarily intended for residents of rural areas who are already engaged in agritourism or have a serious intention to start an entrepreneurial venture in that activity. These are mostly families from rural areas who see agritourism as a chance for additional income or as a basic activity. In recent years, completely new categories of education participants have appeared. It refers to heirs, that is, people who live in cities but have inherited houses and country estates. They do not want to sell what they inherited, but want to start a business in the field of agritourism. We should also mention the returnees to the countryside (people who lived in urban areas for a certain period of time and decided to return to their properties in rural areas), returnees from abroad, as well as private companies that recognized the benefits of investing in agritourism. Common to all mentioned categories of new offer holders in agritourism is that they also need education because they are mostly beginners in the agritourism business. Business owners in agritourism are not the only target group for education. Employees in local administration should also be involved in training. This refers to: employees and officials in municipal administrations (in the sectors of economy, tourism, entrepreneurship), in offices for local economic development, in municipal Commissions for the categorization of accommodation and rural tourist households; employees in local tourism organizations (LTO); members of farmers' associations, women's associations, entrepreneurs' associations; NGO representatives, journalists in print and electronic media… [4].

2.3 Objectives of conducting education in Serbian agrotourism

The objectives of the training are determined depending on the category of participants. For those participants who are just planning to engage in agritourism, the education aims to encourage them, to point out the specific benefits of engaging in agritourism, to familiarize them with the regulations

(Act on Tourism, Act on Hospitality, regulations and other by-laws); to familiarize them with the characteristics of future guests and the process of categorizing accommodation facilities.
The goals are somewhat different for those who are already engaged in agrotourism. They should improve their existing knowledge and be provided with specialized training (foreign languages, marketing with a special emphasis on the Internet and social networks, fair appearances, food services, etc.). The members of the municipal/city Committee for Categorization should be trained for the proper implementation of the categorization procedure (they get to know the regulations and procedures in detail). In addition to the specified specific goals, there are also general goals.
The participants of the training should be encouraged:

- to mutual business association (from local to international level)
- to accept the position that they are not mutual competitors but collaborators and "allies",
- to provide quality service continuously.

2.4 Defining the content of education in agritourism

Only when you know who the participants are and what the goals are, you can start creating the content of the training. The objectives of the training are determined depending on the category of participants. The theoretical and practical part of the training usually includes the following topics: familiarization with the current regulations, characteristics of modern tourists, application of the Central Information System (CIS) of E-tourists, categorization procedure; furnishing rooms, apartments and houses for tourist accommodation; residence tax, food and beverage services; additional services, attitude towards guests, dealing with conflict situations; pricing, promotional activities, sales channels; relation to the environment (to local authorities and inspections; cooperation with travel agencies, tourist guides and the media). Special training content is created for municipal administration employees and members of the Commission for Categorization. The same applies to employees of local tourism organizations (LTO).
Specialized educations are focused on certain aspects of business and require a higher level of prior knowledge of the participants. In practice, there is a lack of such training, especially those related to communication with guests, application of digital technologies, creation of websites and profiles on social media.

2.5 The process of initiation and organization of education

The initiators, organizers and financiers of agritourism education in Serbia are competent institutions at the local, regional and national level, often in cooperation with foreign and international organizations. These are municipalities, cities and their tourist organizations[2]; Regional Development Agencies (RDA), Regional Tourist Organizations (RTO), network of Regional Chambers of Commerce; Ministries responsible for tourism, agriculture; professional associations, educational institutions[3] ... Among the foreign institutions, the German GIZ should be mentioned[4], American USAID, SDC from Switzerland, United Nations Development Program (UNDP), EU. Education in

[2] The local level, although the lowest in the hierarchy of government, is particularly important. Municipalities and cities will to have the greatest benefit from educated offer holders in Serbian agritourism (through a greater number of tourists, greater spending by tourists, higher tax revenues).

[3] A large number of higher vocational schools and faculties from Serbia, Republika Srpska, FBiH, Slovakia, Greece, Romania and Slovenia formed a consortium, in order to participate in the project related to agritourism under entitled "Next Destination Serbia: Agritourism Landscapes Development (LANDS). They are active in the project representatives of the non-academic community also participated (four regional development agencies- RDA from Užice, Sarajevo, Niš and Mostar). The project lasted from 2017 to 2021. It was also created in that period realized a large number of educations [5].

[4] A well-known German organization called „Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ)“ is currently implementing the project "Support to youth in rural areas in Serbia". The project lasts four years (2020-2024) and is implemented throughout Serbia. Within the aforementioned project, a large number of educations were held in relation to agrotourism (for beginners as well as for those who already have experiences in agritourism). The domestic partner is the Ministry of Tourism and Youth [6].

agritourism in Serbia is often carried out as part of larger and broader projects. This means that education is not the only one, but it is the first and basic activity where participants (beginners in business, entrepreneurs...) acquire basic knowledge that they later build on through other business support instruments. It should be emphasized that education in agritourism is carried out through the partnership of a large number of participants, mainly from the public and state sectors. This is especially important for municipalities in Serbia that do not have enough money or professional staff to independently finance, organize and implement education. In practice, this means the following: one institution (e.g. the Ministry) finances the project, another institution (e.g. the Regional Development Agency or the Serbian Chamber of Commerce) implements it, while the third partner (e.g. the municipality) is the immediate implementer. Education in agritourism is often realized within the framework of "cross-border cooperation" projects (Serbia Hungary, Serbia-Romania, Serbia-Bulgaria).

2.6 Method of implementation and quality of education in agrotourism

The success of an education in agritourism will depend on numerous factors. The key factor is the educator - the person who will create and then implement education. That person must have practical experience and not just theoretical knowledge about agritourism. In addition, the educator must establish an interactive relationship with the participants (two-way communication between the educator and the course participants)[5].

Education must be adapted to the participants (their level of knowledge, their free time[6], that the venue is accessible to attendees). The focus must be on acquiring practical knowledge (without unnecessary theory) which the participants will be able to apply directly in practice - in communication with guests, when creating an offer, when equipping accommodation facilities, etc. All this in order to enable the participants to independently run their own personal or family business in agritourism[7].

Many participants will meet for the first time not only with professional terms from agritourism, but also with numerous aspects of business in this type of tourism. This means that every education must first have a theoretical and then a practical part (workshop). The workshop involves the acquisition of knowledge such as: application of the E-tourist portal, preparation of mandatory documents (contracts with travel agencies, creation of menus, price lists, house rules and inventory lists); simulations of different situations in the host-guest relationship and resolution of conflict situations. During the entire duration of the lecture, the educator must cite examples from practice (both positive and negative) and explain them, so that the participants do not make mistakes, especially those typical for beginners in business.

Fieldwork can significantly improve the quality of any agritourism education. This means that the educator visits several agritourism providers and provides them with expert advice on the spot, i.e. points out the good and bad aspects of their business. The education organizer must try to avoid the most common mistakes in agritourism education. It happens, not so rarely, that the educator does not have practical knowledge of agritourism, that he maintains an "academic level" so the participants cannot follow him (they do not understand what he is telling them), that he gives them incorrect or outdated information because he does not follow trends in agritourism, i.e. does not know enough about this issue.

[5] A special form of education is mentoring with selected participants. This form of education is increasingly being applied in agritourism in Serbia.

[6] Education usually lasts one day, two or three combined days, but series of lectures are also organized (eg once a week for a month). Verbal and visual methods are used.

[7] The most common form of business in agritourism in Serbia is the rural tourist household. It has to be categorized. In addition to accommodation and food services, it can provide numerous additional facilities, including the possession of a mini camp.

3. CONCLUSION

The quality of the offer in agritourism in Serbia has improved significantly in the last fifteen years. This was undoubtedly contributed by a large number of educations that were conducted in all parts of the country. This is clear evidence that education is one of the pillars of business in agritourism, that is, one of the prerequisites for long-term sustainable business. Education should be seen as the first step in the system of business support in agritourism. However, it is not enough for agritourism business owners to attend training only once. Sustainable business means that entrepreneurs in agritourism must constantly improve their knowledge and business skills by taking part in appropriate education throughout their career. On the other hand, the content and form of education must also be changed and improved in accordance with the changes in the tourist market.

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ENVIRONMENT AND SUSTAINABLE DEVELOPMENT. MECHATRONICS. OCCUPATIONAL SAFETY AND HEALTH AND FIRE SAFETY. SMART MANAGEMENT SYSTEMS. GRAPHIC ENGINEERING. DESIGN. TRAFFIC ENGINEERING. BIOTECHNOLOGY AND HEALTHCARE. MECHANICAL ENGINEERING. ECOTOURISM AND RURAL DEVELOPMENT.

CULTURAL HERITAGE AS A GENERATOR OF SUSTAINABLE DEVELOPMENT OF TOURISM IN LOCAL COMMUNITIES IN THE COUNTRIES OF THE WESTERN BALKANS

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Abstract: *Intangible cultural values and heritage represent a significant factor in promoting certain tourist destinations. The countries of the Western Balkans have a rich intangible cultural values and heritage age that can be a important generator of not only tourism development, but also the overall sustainable development of local communities in the whole region. Within the project Perspectives of interregional cooperation of local communities in the countries of the Western Balkans - in the fields of science, education, culture, economy, tourism and sustainable development various researches were carried out in order to determine the real potential of intangible cultural values.*
Keywords: Intangible cultural values, cultural heritage, tourism, motives, Western Balkans

1. INTRODUCTION

Tourism is a social phenomenon and an activity immanent to human nature that has existed in various forms since the beginning of human society. From the ancient times, the slave and feudal social system in which we find the first outlines and beginnings of the movement and today's tourist trips, through the period of the so-called "oligo tourism" from the middle of the 19th century to the Second World War, the period up to 1950, then through the so-called "poly tourism" which includes the period from 1950 to 2000, up to the modern and postmodern tourism of today - tourism gradually developed to become one of the most significant indicators and models of economic and general social development today.
The connection of modern tourist products with numerous economic and non-economic activities has the effect that the socio-economic effects of tourism are multiple. The development of tourism creates the necessary prerequisites for the initiation of a number of other economic and non-economic activities and activities, which means that tourism represents a significant factor for the initiation of overall economic and economic development. (Premović & Arsić, 2018).

2. THE BASIC MOTIVES AND NEEDS FOR TOURIST TRAVEL

Travels, as a form of manifestation of various human needs and motives, have appeared since the beginning of human society, from mythical ancient times and nomadic conquests of new spaces until today and the mass tourist trips we are witnessing. At the same time, throughout the long history of human existence, the motives and needs for travel have changed under the influence of different cultures and eras and parallel to the development of human society and man as an individual.
The main reason why each individual decides to go on a tourist trip is his inner needs and different ways of satisfying them, since the majority of these needs cannot be satisfied in the place of residence, i.e. "at home". The opinions of numerous scientists on the subject of human needs are different and consequently there are numerous theories of motivation. Incentive or motive represents an internal force or force that moves, stimulates and inspires each individual towards the fulfillment of needs or

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the achievement of certain goals, while motivation is a complex psychological process of encouraging and directing an individual to act in a certain way in the direction of realizing his needs and achieving goals and a desired state.

One of the most widely used and cited theories of motivation is the theory defined by Maslow. Maslow structured all the different human needs into a well-known hierarchical structure of needs that includes five basic categories or levels of human needs. Hierarchical structure of needs means that the individual tries to satisfy the most important needs first, and when he fulfills them, he tries to fulfill all other needs according to the degree of importance, i.e. according to their hierarchy. These are: physiological needs, the need for security, love, belonging and attachment, the need for appreciation and the need for personal development and new experience (self-affirmation, self-actualization or self-realization).

The need for rest, sports and recreation can be satisfied through tourist trips and it belongs to tourist needs - self-affirmation needs. The needs of self-actualization or self-affirmation can be satisfied within the framework of visiting various cultural contents and cultural manifestations. Only when all primary (existential) needs are satisfied, it is possible to realize touristic needs as needs of a higher order, i.e., secondary needs.

"Tourist motives arise under the influence of needs and other internal incentives that act from the inside and spatial stimuli, as goals that determine from the outside." They encourage a person to be active in a certain direction, that is, the individual tends to get closer to the object of his desires, the tourist object" (Čomić, Đ., 1990). There are authors who believe exactly the opposite, stressing spontaneity, unplannedness, unexpectedness and the factor of surprise as the key elements of every quality trip. This group of opinions also includes the opinion of John Steinbeck, according to which "people do not go on a journey. Travels go to them." Therefore, they should not be specially planned and analyzed, but rather indulged and enjoyed (Premović, Arsić, 2020).

Regardless of different approaches in the interpretation of key tourist needs and motives, there is an almost unique attitude that the factors that influence their creation can be of objective and subjective nature. Objective factors include socio-economic and cultural (cultural) factors such as: social structure of the population, degree and level of education, vocational training or occupation, quality of the environment and the like. Subjective factors are internal psychological processes: specific needs, interests, desires and emotions, which can move an individual to travel. Various motives and needs therefore encourage individuals to travel as tourists to a destination outside their place of permanent residence, i.e. residence. The most common reasons for traveling by most tourists are as follows: the need for rest and relaxation, "getting away from everyday life", the need for health, wellness, fitness, sports and adventure, religious reasons and religious needs, the need for art, sightseeing and sightseeing, the need to get to know each other new, attending seminars, conferences and exhibitions, business reasons, visiting friends and relatives, shopping and others.

3. INTANGIBLE CULTURAL VALUES AND HERITAGE AS A GENERATOR OF TOURISM DEVELOPMENT

Natural, anthropogenic, human and cultural factors are the most important factors that influence the creation of tourist offers and the performance of tourist activities in a destination. In recent decades, the importance and role of cultural factors in the further sustainable development of tourism has been highlighted more and more. The trend of increased tourist interest in new experiences, events, knowledge and experiences is becoming more and more evident. The so-called the cultural dimension as an intangible component of tourism is important both from the position of supply and from the position of tourist demand. Culture has a significant influence on the behavior of individuals and their contribution to the process of economic and social development, as well as on their economic choices and business decision-making. When talking about culture and national cultural heritage in the function of creating a tourist offer, it should be borne in mind that cultural heritage does not include only material objects, but that cultural heritage also consists of "the social and cultural relationship that a human community has towards these objects, importance that gives them a place in its value

system, i.e. in the experience of oneself as a community. Oral literature, customs or culturally shaped awareness of oneself, as a member of the community, are also part of it". (Žikić, 2010). In this sense, as Žikić concludes, cultural identity is a part of the intangible cultural heritage of the community in which it is constructed. Accordingly, national culture is based on a clear idea of one's own identity, but also on the possibilities of expanding and opening its development perspectives and its verification at the international, multicultural and transcultural level (Premović, Pejanović, 2018).

In countries and tourist destinations that have a developed tourism economy, significant multiplier effects of the influence of tourism activities can be observed. Tourism can and should play a particularly important role in the overall socio-economic development of underdeveloped countries and regions, including the Western Balkan region. As a separate economic activity, tourism is developed and developed differently in the countries of the Western Balkans. In addition to Montenegro, which is recognized as a tourist destination and where tourism is the leading economic activity, in other countries of the region tourism as a revitalizing factor of economic and social development was recognized only at the beginning of this century, which is why it is in the initial phase of development. However, it is noticeable that Albania has been investing in the promotion of coastal tourism in recent years, while Serbia is trying to position itself on the map of Southeast Europe and the region as a tourist destination for spa, mountain and increasingly event tourism. The current situation created under the influence of the global pandemic caused by the Kovid 19 virus certainly presents new challenges and opportunities for finding new and sustainable solutions for the further development of tourism before the countries of the Western Balkans (Premović, J, 2022).

Tourism provides an opportunity to travel and get to know other places, continents, nations, and religions. He encourages interest in researching the traditions and customs of other peoples and countries, different forms of culture, in learning foreign languages, information and communication technologies, and the like. The development of tourism increases the general level of education and culture of the local population that participates in tourism activities. By creating and constantly developing awareness of the essential richness of diversity and respect for different cultures, religions, nations and lifestyles, tourism enables the establishment of stronger ties and relations between peoples. The change of the individual and collective-social value system under the intense influence of tourism through the change of the quality and style of life, represents significant socio-cultural effects of the influence of tourism (Premović, J, 2021).

Making a decision about traveling and choosing a certain destination is influenced by various motives that, viewed from the perspective of the time horizon, have changed as a result of the dominant influences of different social epochs and cultural identities. Contemporary trends in the motives and expectations of tourists show a growing interest in learning about different forms of intangible cultural heritage. The number of visits to important museums, galleries, protected cultural and historical monuments, archaeological sites, as well as numerous celebrations and manifestations of different contents is increasing. Observed tendencies of increased interest of tourists in various cultural contents influenced the development of cultural and event tourism (Vukadinović et al., 2018).

The intangible cultural component has a significant potential for further improvement and development, not only of tourist activities, but also of overall socio-economic development in the countries of the Western Balkans. Local communities in the countries of the Western Balkans have significant potential for the development of tourism activities through the improvement of the offer of cultural and event tourism and the promotion of their authentic intangible cultural values.

Tourism and the exercise of tourism through various tourist trips represents a special way of life. Tourism provides an opportunity to travel and get to know other places, continents, nations, and religions. He encourages interest in researching the traditions and customs of other peoples and countries, different forms of culture, in learning foreign languages, information and communication technologies, and the like. The development of tourism increases the general level of education and culture of the local population that participates in tourism activities. By creating and constantly developing awareness of the essential wealth of diversity and respect for different cultures, religions, nations and lifestyles, tourism enables the establishment of stronger ties and relations between peoples.

Tourism as a mass social phenomenon can significantly influence the reduction of numerous prejudices, above all linguistic, cultural, religious and national ones. Tourism broadens the horizons and cognitive-value horizons of all participants in tourism... Getting to know new cultures and getting to know other people, with their customs, traditions, religion, habits, represents a significant positive social impact of tourism. This group of positive influences certainly includes the acquisition of new knowledge and the expansion of knowledge about precisely those new spaces, religions, customs and cultures.In this way, tourism can have a positive effect on increasing the degree of tolerance, understanding and acceptance of diversity of all kinds among the population of the Western Balkans. (Premović, J, 2021).

Cultural habits and practices that can become specific tourist products and services, especially if they are contextualized and organized around events, such as various festivals, are inexhaustible resources for the (re)interpretation of the physical environment of the city (authentic natural environment, architecture, historical-archaeological sites and buildings and the like). Events, from family gatherings and celebrations to public festivals, as the "soft fabric" of cities and local communities, always give a different meaning to the same or changed physical space, and perhaps above all else, they provide the best "certificates" of city and local identity (Premović, Pejanović, 2018). That is why it is important that the local and national tourism policy, if it wants to attract demanding and spiritual tourists, focuses on active cooperation with the organizations of the city society, local artists and cultural creators.

Within the project Perspectives of interregional cooperation of local communities in the countries of the Western Balkans - in the fields of science, education, culture, economy, tourism and sustainable development various researches were carried out, of which a particularly important segment was precisely on the topic of the local population's knowledge of their own cultural heritage and the influence and role of various forms of culture on tourist trips to other communities in the Western Balkans. One of the studies that was conducted in the area of the Autonomous Province of Vojvodina - in the South Bačka District, which is the most developed in the area of the province, showed that the level of knowledge and awareness of cultural heritage and heritage among respondents of a younger age (pre-university age - students up to the age of 18) is very low. Namely, research has shown that the local population is not sufficiently familiar with the intangible cultural heritage of the local community in which they live. However, as a positive trend we can point to the level of openness and willingness to learn about the specific cultural identities of the younger population with the cultural heritage of other local communities in the Western Balkans region.

4. CONCLUSION

Getting to know new cultures and getting to know other people, with their customs, traditions, religion, habits, represents a significant positive social impact of tourism. This group of positive influences certainly includes the acquisition of new knowledge and the expansion of knowledge about precisely those new spaces, religions, customs and cultures. In this way, tourism can have a positive effect on increasing the degree of tolerance, understanding and acceptance of diversity of all kinds among the population of the Western Balkans. With the expansion of cognitive and value horizons, tourism also develops awareness of the importance of preserving nature and the environment by preserving the authenticity of natural, cultural and anthropogenic heritage at the local and regional level. The results of research carried out within the framework of the actuarial project show that these possibilities have not yet been adequately used, but the fact that awareness of the possibilities of improvement is growing, especially among the younger population, is encouraging.

The paper is part of the research within the International scientific and professional project: Perspectives of interregional cooperation of local communities in the countries of the Western Balkans - in the fields of science, education, culture, economy, tourism and sustainable development.

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ANALYSIS OF THE REAL NUMBER OF TOURIST OVERNIGHTS BASED ON THE ESTIMATION OF WATER CONSUMPTION IN ZLATIBOR

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Abstract: *Zlatibor tourist resort* face *the problem of a large number of unregistered accommodation and not up-to-date management of tourist traffic. This makes it difficult to monitor the real number of tourist arrivals and overnight stays, which affects the creating development policies and further activities aimed at the development of the destination. It also prevents a realistic assessment of the impact of tourism on the environment and the local community and timely response. For Zlatibor, as one of the most developed tourist destinations in Serbia, it is important to find a way to summarize the real size of tourist traffic, which can be achieved by comparing and using data on water consumption at the destination. In this paper, with the help of a methodology that has already been applied in the major tourist centers of Europe, the calculation of the actual number of overnight stays of tourists at the destination is presented and compared with official statistical data.*
Keywords: Zlatibor, tourist overnights, tourist traffic, water consumption

1. INTRODUCTION

Zlatibor is a mountain tourist center located in southwestern Serbia and is one of the most visited tourist destinations in Serbia and the region. The tradition of developing tourism on Zlatibor is 130 years long, and the year 1893 is taken as the beginning of organized tourism on this mountain, when the king of Serbia, Aleksandar Obrenovic, visited Zlatibor [1]. Throughout the long history of development, this tourist center has gone through various phases and forms of development, changing the structure of tourist destination itself and the tourist offer, as well as accommodation capacities. Tourism is the most developed and important economic sector of the municipality of Cajetina, to which the territory of the Zlatibor mountain administratively belongs. Tourism is an activity that is influenced by global trends and is very sensitive to environmental changes. These changes are mainly related to the needs and wishes of tourists, but also the continuous development of the offer in order to meet the requirements of specific tourist demand [2] . For this reason, regular monitoring of tourist traffic is very important in creating a development policy and planning the further development of the destination. A better and more extensive knowledge of trends in the development of tourism ultimately leads to a greater chance of defining appropriate strategies to achieve a competitive advantage [3].
In recent years, the destination Zlatibor has faced the problem of a large number of unregistered accommodation, which makes it difficult to assess the real tourist traffic on an annual basis, but also in the peak tourist season. The real situation in destination is that there are a much larger offer of accommodation than registred beds capacities, and tourists who stay in unregistered accommodation are not part of the official tourist traffic statistics. The destination

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faces another problem, which is that a large number of registered accommodations do not keep up-to-date records of tourist arrivals and overnight stays. This problem is particularly pronounced in the accommodation capacities owend by private individuals, while hotels and other accommodation facilities that operate as legal entities keep up-to-date records of tourist arrivals and overnight stays. Many studies have shown that other destinations around the world face similar problems, where data from official statistics underestimate the real volume of tourists staying at the destination, who are accommodated in unregistered facilities. That is why it is difficult to monitor the real scope of the tourism sector in the destination, which creates problems when planning the development of the destination, but also makes it difficult to analyze the market for the needs of the public and private sectors [4]. In their research, Martín and Salinas [5] point out that it is necessary to know the actual tourist traffic and data on the seasonal concentration of tourists and due to the amount of pressure exerted on the destination due to tourist activity and the carrying capacity of the destination.

One of the ways in which it is possible to estimate the real tourist traffic at the destination is the water consumption model, which is an innovative proposed methodology for estimating the real size of the tourist traffic [4]. The aim of this paper is to show, based on the methodology presented in the professional literature, the approximate volume of actual tourist traffic in relation to the tourist traffic registered by official statistics, through the pattern of water consumption in the city of Zlatibor.

2. METHODOLOGY

The methodology applied in this paper to calculate the real tourist traffic realized on the theritory of Zlatibor city through a secondary indicator such as water consumption, relies on research that was carried out in 2022. and published in July 2023. for the Balearic Islands area, by Gonzalez-Perez , D.M.; Martín Martín, J.M.; Guaita Martínez, J.M.; Morales Pachon. The work methodology is adapted to the local region and available information provided by the Public Utility Company for water supply "Vodovod Zlatibor". The territorial unit that this paper deals with is the Zlatibor city, as the tourist center of the mountain that generates the highest percentage of tourist traffic. The years 2021. and 2022. were taken as reference years for this research, and according to the same model, the calculation of the real volume of tourist traffic can be performed for other years or individual months.

The data made available for inspection by the Municipal Public Company for water supply "Vodovod Zlatibor" includes the invoiced amount of water separated by categories and time frames from the monthly to the annual level. Of the separate categories of water consumption, the data on the invoiced amount of water in the "residential-holiday" category are relevant for this paper. Meters for water consumption connected to the public water supply network under this category include buildings such as houses, villas, individual apartments and all other buildings that are not registered as residential buildings intended for permanent living.

To calculate the total number of overnight stays, according to the water consumption indicator, according to the recommended model, it is necessary, in addition to the total water consumption in the corresponding category, to establish the average water consumption per tourist per day. In this work, the value accepted in the professional literature was used, which is proposed by Gossling [6]. that one tourist consumes an average of 350 liters of water per day for accommodation needs and 20 liters per day within the activities related to their stay, which makes average consumption of 370 liters per tourist per day. One inhabitant of the town of Čajetina consumes an average of 140 liters of water per day (data from "Vodovod Zlatibor"). Data grom professional literature is that the water consumption of one tourist per day is two to three times higher than the water consumption of a local population [7]. When we consider

these two data the suggested amount of water consumption of 370 liters per tourist per day can be taken as relevant in this case as well.
The number of overnight stays obtained by this methodology excludes the traffic generated in hotels, resorts, guesthouses, inns, lodgings and campsites because the category of users of the public water network "residential-holiday" whose consumption is observed in this case excludes the consumption of water in facilities connected to the public water network as legal entities. Company "Vodovod Zlatibor" monitors the consumption of water by legal entities in the territory of the settlement of Zlatibor under the special category "business facilities". From the category "business facilities" it is not possible to single out only water consumption realized in facilities intended for tourist accommodation. For this reason, the number of overnight stays achieved in tourist accommodation facilities that are registered as legal entities was added to the final number of overnight stays obtained by the methodology of calculating water consumption for holiday facilities. This is information that is relevant for use because all tourist accommodation facilities that are legal entities at the destination are categorized according to current regulations and the number of overnight stays that is officially maintained in the Central Information System maintains real traffic in this category. In this way, data on the actual number of overnight stays at the destination were obtained and compared with official statistical data.

3. RESEARCH RESULTS AND DISCUSSIONS

Tables 1. and 2. show the data needed to calculate the real number of overnight stays according to the methodology used in the work. Data on the number of overnight stays and the number of tourists were obtained from official publications of the Statistical Office Republic of Serbia. Data on the number of overnight stays in accommodation facilities that are registered as legal entities were obtained from the Central Information System in the field of tourism and hospitality, while data on water consumption are official data of Municipality pblic company "Vodovod-Zlatibor". The data refer to the years 2021. and 2022. and refer to the town of Zlatibor.

OS = C*w* / 370 l + OS*h*	C*w* – water consuption in cathegory „holiday facilities“
OS – overnight stays	OS*h* – overnight stays in hotels and other legal entities

Table 1. Data on tourist traffic and water consumption by selected categories for 2022.
Source: Statistical Office Republic of Serbia, Municipality Company “Vodovod Zlatibor” and CIS e-tourist

	Overnight stays (SORS)	**Tourist arrivals (SORS)**	**Water consumption/„holiday facilities“ in m³**	**Water consumption / „residental“ in m³**	**Overnight stays/ accommodation facilities - legal entities**
January	71.964	19.036	24.461	9.504	55.092
February	53.592	15.778	42.976	17.172	44.895
March	30.666	10.370	48.224	18.787	24.722
April	35.619	14.955	55.182	13.898	33.831
May	37.532	13.252	52.269	21.613	35.864
June	42.613	14.265	33.352	16.144	36.751
July	67.269	20.535	55.973	17.868	63.396
August	99.665	27.573	82.983	24.400	77.977
September	66.400	20.569	67.067	22.555	38.621
October	68.401	23.514	40.562	16.019	49.149
November	53.744	18.653	45.015	15.263	33.559
December	46.387	18.287	30.673	11.511	29.174
Total	**673.852**	**216.787**	**578.743**	**204.740**	**523.021**

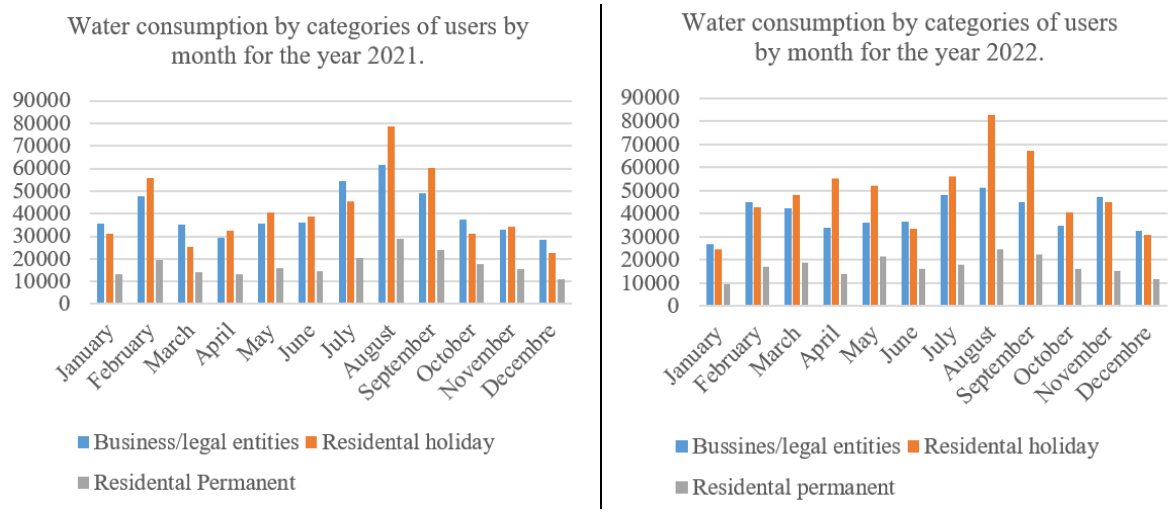
Based on the given methodology and the previously presented formula, it was found that more than 200 percent overnight stays are achieved in Zlatibor on an annual basis than registered by official statistics, and the obtained data are shown in table 3. Based on this methodology, it is possible to calculate the number of overnight stays accomplished at the destination by month. For the seasonal nature of business, which is characteristic of tourism, it is interesting to know how much tourist traffic was actually realized in the months of the highest and lowest tourist traffic on Zlatibor. Such a drastic difference in the turnover that is officially recorded and the turnover obtained by this methodology is due to a large number of unregistered accommodation. The problem in monitoring real tourist traffic also arises due to the non-up-to-date management of traffic in the domestic crafts sector, i.e. irregular registration of tourists in the Central Information System. Official statistical data can be used and are used to monitor the trend of growth or decline in tourist traffic at the destination, but they do not represent the real picture of tourist traffic in any way.
The data on the number of overnight stays obtained by the water consumption estimation methodology include overnight stays in unregistered facilities for tourist accommodation, but also include persons staying at the destination in their own weekend facilities, as well as seasonal workers and all persons staying for any other reason. and who do not have a registered permanent place of business or residence in the territory of the settlement of Zlatibor.

Table 2. Number of calculated overnight stays (OS) and official registred overnights stays

Period	Official statistics data	Data obtained by the water consumption method	%
2022	673.852	2.087.191	209,74 %
2021	600.405	1.881.381	213,35 %
August 2022	99.665	302.255	203,25 %
March 2022	30.666	155.057	405,63 %
August 2021	100.488	297.080	195,64 %
March 2021	23.661	88.440	273,78 %

Graphs 1. and 2. show water consumption by user category for the town of Zlatibor, by month. The graph clearly shows that oscillations in water consumption vary by month, which, along with data on tourist traffic, is a clear indicator of pronounced peaks with the highest tourist traffic. During the seasonal months, water consumption increases by about 240 percent compared to the months of reduced tourist traffic. Oscillations in water consumption in the "business" and "residential holiday" categories are followed by oscillations in the "residential facilities" category, so water consumption in this category also increases during the peak tourist season. This is one of the indicators that in households that are connected to the public water network as residential facilities, there are special accommodation units intended for accommodation of tourists. Although these oscillations are noticeable, they are not expressed in such a large percentage as the oscillations in the other two categories of users.

Chart 1. and 2. Water consumption by user categories by month for 2021. and 2022. in m³



4. CONCLUSION

Zlatibor, like numerous other destinations, faces the problem of a large number of unregistered arrivals and overnight stays of tourists that do not provide a relevant overview of tourist traffic. Methodology applied in this paper led to data that the tourist traffic recorded by official statistics is even three times lower compared to the estimated volume of tourist traffic. Such large differences in the exposed data indicate that there is a serious problem in the recording of traffic. Given data show that statistic in hotels and other accommodation facilities that operate as legal entities is managed up-to-date, and the problem is in sector where private individuals are oweners of accommodation. These data indicate that a large number of accommodation facilities are not officially registered and categorized according to the current law. This should be an important signal to undertake extensive activities to increase the number of categorized accommodation. In the first place, an important role must be played by the education of accommodation capacity owners, increased inspection supervision with advisory visits. Authorities at the local and state level can approach this problem by adopting various incentive measures for registered accommodation facilities and thus try to influence the reduction of this problem. A realistic volume of tourist traffic will enable the destinations to plan further development, manage capacities, but also to attract new investments and improve the offer. Monitoring tourist traffic plays a key role in the sustainable development of tourism. It enables the identification of potential problems such as over-consumption of resources, negative impacts on the environment, which then enables measures to be taken to conserve resources and preserve the authenticity of the destination.

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SAFETY AND SECURITY STANDARDS AND PROCEDURES OF MODERN HOTELS

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Abstract: *There are several reasons why the security aspect is becoming an increasingly important element in the business of modern hotels. The first reason is that tourists attach more and more importance personal security (life, health, property, personal data) during their time trips, including staying in an accommodation facility. Another reason is the stricter regulations which directly and indirectly protect the interests of consumers, in the specific case tourists or guests in accommodation facilities. The third reason is the aspiration of hoteliers to minimize the risks of endangering the safety of their guests, their staff and property because every unwanted event has a negative impact on their image as well as on the business result. Also, threats to security in tourism are not in the favor of the destinations, either for the same reasons as hoteliers. All of the above applies especially to hotels because they represent the highest quality and most complex type of accommodation offer, especially those of the highest categories (with four and five stars).*
Keywords: *Security, Hotels, Standards, Procedures, Tourism*

1. INTRODUCTION

The problem of security in hotel facilities implies knowledge from several different areas, because the forms of endangering the safety of guests, employees, equipment, buildings, installations, personal data... are also different. That is why the issue of achieving and maintaining a certain level of security in hotels must be implemented according to pre-established procedures, standards and regulations. The two sources of regulation should be clearly distinguished.

The first level is the hoteliers who adopt and implement their own internal procedures, whether it is an independent hotelier or a hotel chain of which it is part [1]. The second level is the competent state bodies that enact laws and by-laws, as well as the inspection bodies that control the implementation of those regulations in practice. It is especially important that all employees (including managers of all levels) are familiar with the regulations, possible risks, and procedures in case of a specific form of security threat. This is only possible through constant education of all employees, but also following regulations and modern technologies in the field of security in tourism and hotel industry.

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2. THE MOST COMMON FORMS OF SECURITY THREATS IN HOTELS

2.1 Sources (causes) of security threats in modern hotels

The management of each hotel must identify potential sources (causes) of security threats, taking into account the specific conditions of their business (category of hotels, type of guests who visit them, additional facilities, local environment). However, common to all hotels is that there are four potential sources of threats to hotel security. These are guests, employees, third parties, as well as the owners (that is, the top management) of the hotel. All the mentioned potential sources can threaten the security of the hotel intentionally or unintentionally, that is, by their actions or inactions [2].

How can *guests* endanger other people's and their own safety in the hotel? In the first place, by their inappropriate behavior by entering into unnecessary conflicts with other guests and employees (causing verbal and physical conflicts, insulting employees; aggressive attitude towards guests, maids, waitresses, receptionists). The "target" of irresponsible guests can be the hotel's property and reputation. These are the theft of inventory (e.g. bathrobes, small inventory), attempts to escape from the hotel in order not to pay for the services they used, false accusations that their money or jewelry disappeared from the room or safe in order to hide the fact that they spent it in an inappropriate way (gambling, prostitution). It happens that guests completely unintentionally (carelessness) endanger their health (they slip in the bathroom or pool, they consume alcohol excessively) and their property (they leave their luggage unattended in the hotel lobby, they leave their car unlocked in the hotel parking lot). There are also known cases (in Serbia and abroad) of mentally unstable persons choosing a hotel as the place where they will commit suicide (jumping out of a hotel room window, "overdosing" on drugs or narcotics).

Employees in hotels (almost in all positions) can also threaten the safety of guests, other employees (their colleagues), tangible and intangible property of the hotel, but also their own personal safety. This refers to conflicts between employee-guest, employee-employee, but also criminal activities (theft of things and money from the guest room by an employee, for example, a maid...). It is specific to employees that they can abuse the guest database that every hotel has; to endanger the safety of food in the kitchen (accidentally or intentionally) as well as equipment (elevators, electrical installations, etc.). In addition, employees who do not know enough about security procedures or do not implement them can seriously threaten the hotel's business.

If *third parties* (persons who are neither hotel guests nor employees) threaten the security of the hotel, they usually did it on purpose. It is about criminal groups and individuals who rent a room (fake guests) or use additional facilities in the hotel (restaurant, sports and recreational facilities - swimming pool, wellness and spa center; night club; garage) in order to facilitate criminal activities inside the hotel (they ransacked rooms, stole guests' cars, robbed or cheated wealthier guests, especially in the most expensive hotels; carried out kidnappings and murders) and even carried out terrorist activities. "Third parties" certainly include cybercriminals. They can "attack" a hotel in order to obtain certain data about guests and hotel operations with the aim of abusing the collected data for criminal purposes.

It is also possible to *combine the mentioned sources, i.e. a connection (complicity)* between e.g. criminal groups (as third parties) and hotel employees, between hotel guests and employees as well as between third parties and hotel guests. For example, the hotel guest can participate in illicit (illegal) trade with local criminal groups; that an employee (eg a maid) "tips" wealthy guests to local criminals; that an employee (eg receptionist) sells confidential information about a hotel guest to an unauthorized person or criminal; that the terrorist has a guest or employee

as a helper (insider), etc. Although the intentional endangering of the safety of property and persons in hotels is not a very common occurrence, hoteliers should not rule out such a possibility.
And the *hotel owner (including top managers)* can be held responsible for compromising security in their hotel. In that case, it is about his lack of knowledge of regulations and non-compliance with procedures, which entails corresponding legal consequences.

2.2 The most common forms of security threats in hotels

Criminal activities are the most common forms of endangering security in hotels. The so-called is particularly endangered guest rooms (breaking the entrance door, entering through the window on the lower floors); then common areas (reception hall, restaurants...) through pickpocketing, scamming gullible guests, theft of luggage; then the hotel parking lot (break-in and theft of guests vehicles)[3]. Criminal activities certainly include endangering *the hotel's intangible assets* (guest databases and other confidential information) through cyber attacks and unauthorized provision of data to criminal groups by hotel employees. In this sense, criminals are particularly interested in employees in the IT sector of hotels, receptions and middle and higher level managers, i.e. all those who have access to sensitive data.
In addition to guests, *the hotel's employees can be at risk*, especially those in the laundry room (due to the fumes of detergents and other chemicals, due to vibrations and noise), then the security service (due to potential conflicts with guests and third parties), maids and valets (due to lifting loads by floors and rooms) as well as technical service (maintenance service).
Food safety, safe operation of elevators, electrical installations, swimming pools, wellness and spa centers are also important issues for every hotel. The safety of the above is primarily threatened due to non-compliance with standards and procedures, both by guests and employees.
However, certainly the most serious forms of endangering security are *terrorist activities and fires* because they endanger a large number of people, often with fatal consequences. By attacking guests in hotels, terrorists achieve a great propaganda effect, especially if the guests are from large and influential countries and if the hotel attacked is part of one of the international hotel chains. In addition, the hotel and the destination will have a serious drop in tourist turnover in a short period of time (immediately after the terrorist attack), a shaken image of a safe place for tourists, as well as economic damage [3].

2.3 External and internal procedures and standards relevant to hotel security

The hotel owner's responsibility for the state of security can be complete, partial or excluded. Every hotel owner has a legal obligation but also a moral responsibility to ensure the maximum possible level of security in his hotel. Risk is present in all activities, including tourism and the hotel industry. The only way to minimize the risk of security in the hotel is

- prevention and
- appropriate action when an unwanted situation occurs.

This means that all stakeholders must know and adhere to the appropriate standards, regulations and procedures. By "all interested parties" we mean hotel owners as *the most responsible for the safety of people* (guests and employees) and their property, ie their hotel business; employees (managers of all levels and workers) *who encounter security risks on a daily basis* and who will operationally implement appropriate procedures; *hotel guests (tourists) who must*

[3] To this must be added the threat to guests' privacy through unauthorized monitoring of guests' movements and recording of their activities (audio and video recordings).

also bear their share of responsibility by complying with regulations, instructions of employees in case of emergency situations and avoiding risky behaviors and all other activities that endanger their safety and that of others during their stay in the hotel; *inspection authorities whose task is to control compliance with regulations in the area of safety in hotels* and, if necessary (in case of non-compliance with regulations), impose appropriate sanctions in accordance with the law; other competent authorities (scientific institutes, ministries, educational institutions...) *that should work on constant improvement and innovation of safety standards and procedures.*

For modern hotels, the application of certain international standards is particularly important, of which the ISO standards (and substandards) are certainly the best known. They were developed by the International Organization for Standardization (ISO) and each of them refers to a specific aspect of business.

The ISO 9001 standard refers to the quality management system (QMS) in one business entity, including hotels. The main goal of this standard is for the hotel that applies it to meet the needs of its users (guests) while respecting legal norms [4]. The offer of each hotel is primarily based on the provision of services, which means that its quality must be in line with the needs and expectations of modern tourists. The standards of this series consist of: ISO 9000 (presents the concept of the management system and the terminology used), ISO 9001 (refers to the criteria that must be met in order to operate in accordance with the standard and to obtain a certificate), ISO 9004 (includes performance improvement guidelines as well as eight principles of quality management as a basis for guiding business policy while respecting the needs of all stakeholders, not just clients). ISO 9001:2015 represents a significantly improved version of this standard compared to revisions from 2000 and 2008.

Health protection and safety at work is regulated by the ISO 45001 standard. The goals of this standard are to support health protection and safety at work, to enable the prevention of incidents, to contribute to the reduction of injuries at work, to minimize damage to the safety and health of employees so as to simultaneously improve working conditions and protect the employer [5]. It should also be mentioned the "Law on Safety and Health at Work" which regulates "the improvement and implementation of safety and health measures at work for persons participating in work processes, as well as persons who find themselves in the working environment, in order to prevent injuries at work, occupational diseases and work-related diseases, general principles of prevention, rights of special groups of employees, employer's obligations...".

The document entitled "Act on risk assessment" (Article 16 of the law), which is adopted by the employer for all workplaces, is especially important, as well as to determine the method, measures and deadlines for eliminating or reducing the risk to the smallest possible extent [6]. Based on the criteria, the degree of risk is assessed for each workplace - unacceptable risk, high risk, moderate risk, low risk and negligible risk.

Food safety is especially important for every hotel. ISO standard 22000:2018 deals with this issue and refers to the entire chain of food production and distribution. The advantage of the mentioned standard is that it can be applied independently but is also compatible with ISO 9001:2000 and ISO 14001:2004. The application of the mentioned standard as well as HACCR[4] and HALAL standards has great marketing importance because it provides guests with psychological security that the food they consume in hotels is completely safe [7].

The ISO 14000 standard refers to environmental protection and aims to reduce the negative impact of a business entity (hotel) on the environment. Modern hotels are not only large consumers of electrical energy, water and chemicals, but also polluters of the environment. However, one part of the hotel has positioned itself on the market as an "ecological hotel" or

[4] „HACCR“ is acronym of Hazard Analysis Critical Control Point.

"eco hotel" because it operates responsibly towards the environment and uses renewable energy sources.
Hotels apply other standards that are no less important than those explained so far. The security of information assets is the focus of the ISO 27001:2015 standard, while ISO 31000 standard [8] is intended for risk management. Particularly interesting for hotels is the ISO 22320 standard for emergency management, as well as ISO 50001 standard, which deals with energy efficiency.
Apart from the mentioned ISO standards, hotels also use their own internal written procedures and standards, especially international hotel chains. Also, hotels have a video surveillance system, a physical security service, and fire protection systems that work around the clock. Safety procedures and standards in hotels have come to the fore especially during COVID-19[5]. In that period, the emphasis was on high hygiene and health standards regarding the use of personal protective equipment, serving meals, maintaining rooms and common areas. For the few hotel guests, the safety of their health was a key element when deciding which hotel to stay in. In addition, the representative Serbian Business Association of Hotel and Restaurant Industry (HORES) then launched the "Clean & Safe" campaign. Every hotel in Serbia that passed the strict certification at that time had the right to place the official mark of the campaign, in order to promote itself and gain a competitive advantage in the hotel market.

3. CONCLUSION

The existence of standards and clear procedures are the first pillar of safety in any hotel. This means that every hotelier must, as a first step, adopt appropriate standards and procedures in case of various risky situations in a timely manner. Another pillar of safety in the hotel is regular training of all employees through courses and simulations of risky situations. It is understood that the hotelier is obliged to familiarize the employees in detail with all standards and procedures. Both mentioned pillars can be seen as preventive activities. However, the most important thing will depend on the quality of the aforementioned preventive activities: how employees will act in real situations of jeopardizing security in the hotel. Also, hotel owners should cooperate with their colleagues in the country and abroad (exchange of information and experiences), all in order to improve the safety of guests, employees and property in hotels.

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ENVIRONMENT AND SUSTAINABLE DEVELOPMENT. MECHATRONICS.
OCCUPATIONAL SAFETY AND HEALTH AND FIRE SAFETY.
SMART MANAGEMENT SYSTEMS. GRAPHIC ENGINEERING. DESIGN.
TRAFFIC ENGINEERING. BIOTECHNOLOGY AND HEALTHCARE.
MECHANICAL ENGINEERING. ECOTOURISM AND RURAL DEVELOPMENT.

GUIDED TOUR AS A TYPE OF ANIMATION IN CULTURAL TOURISM

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Abstract: *A guided tour or a walk accompanied by a tourist guide is based on the services of specialized staff in tourism - tourist guides, and represents an important segment of a travel in creating a tourist experience and the 'final' product of a tourism destination. The quality of the work of these staff is the last and key link in the assessment of the destination value chain. In creating the tourist experience and the 'final' product of the tourism destination, tourism animation plays an important role. Tourist animation aims to revive the tourist offer with new contents and contribute to its enrichment. By applying the concept of storytelling, tourist guides present and interpret attractions in the destination in an interesting way and thereby contribute to the quality of the service provided and used, but also to the creation of a tourist experience. The concept of storytelling is usually based on the principles of life seeing and life participating, which gives the guided tour elements of animation, and the tour guides assume the role of animators on the tour.*
Keywords: guided tour, animation in tourism, quality of service, free time, cultural heritage

1. INTRODUCTION

In accordance with contemporary trends in tourism, activities that play a supporting role in the destination value chain and that influence the degree of tourist satisfaction and their evaluation of the 'final' product of a tourism destination are of great importance [1]. It primarily refers to activities aimed at organizing tourists' free time in the destination. One of such activities is a guided tour, which is the scope of work of specialized staff in tourism - tourist guides. The quality of the work of tourist guides represents the last and key link in the evaluation of the destination value chain, and 'affects the complete satisfaction that the tourist takes with him from his travel' [2, 1].
A guided tour or a walk accompanied by a tourist guide is for many consumers a way to get to know an unknown destination in a comfortable, reliable, safe and interesting way. Well-designed programs and contents of the guided tour affect the quality of the organized free time of the consumer (tourist). Depending on the quality of guided tours as well as the degree of participation of tourists in their realization, the degree of tourist satisfaction or dissatisfaction with the purchased and used service is directly affected [3].
Tourist guides, with the quality of the service provided on a guided tour, have a direct influence on the formation of the tourism destination experience and on consumer satisfaction with the service provided and used. They are 'ambassadors of the destination' where they work and represent guided tour mediators who have the task of presenting and interpreting attractions in the destination to tourists in an interesting way, using the concept of storytelling. Thus, they assume the role of animators, and the guided tour becomes a type of animation through which tourists want to experience and learn something new.
Tourist animation represents an important component and an integral part of the contemporary tourism offer. As the main motive of contemporary travel, it aims to revive the tourism offer with new contents and to encourage guests to actively participate in them [4].

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2. TERM AND MEANING OF GUIDED TOUR AND ANIMATION IN TOURISM

The term ‘guided tour’ comes from the word ‘tour’, which means a multi-day round trip, i.e. ‘a guided tour’, ‘a tour carried out by a group accompanied by a guide’ or ‘when one person gives orientation to a group of people and explains the surrounding landscape’ [5]. The definition indicates that a guided tour is based on the service of a tourist guide, and as such represents an important segment of a travel and the ‘final’ product of a tourism destination.

The first organized travel, based on the principle of ‘guided tours’, were created in the period of Grand tour. The English travel agency, ‘Thomas Cook and Son’, was the first to organize travel of this type in 1841. The travel was mostly based on discourse, i.e. verbal exchange of words. Unlike these journeys, modern journeys are based on visualization, i.e. are organized according to the principle of sightseeing. Sightseeing, observation and explanation of the observed scene by a professional licensed person represent a key aspect of contemporary travel and tourist experience [1].

In creating the tourist experience and the ‘final’ product of the tourism destination, tourism animation plays an important role. As a segment of the contemporary tourism offer, which encourages a more meaningful stay of tourists and affects their satisfaction during the travel, tourist animation represents ‘a set of services that satisfy the needs and wishes of tourists to experience the expected and desired tourism program, with which the organizer of the program increases tourist consumption’ [6], which indicates that animation appears as the main motive of travel in contemporary movements in tourism.

The term animation originates from the Latin word ‘anima’, which in translation means soul, revival, motivation, inner mood, etc. [6]. As an additional content that completes the free time of consumers in a tourism destination, the expansion of development is experienced with the appearance of mass tourism in the 50s of the XX century. The main goal of animation is to revive the tourism offer with new contents and to encourage guests to actively participate in them [7].

3. QUALITY OF THE GUIDED TOUR

The dynamic and intensive development of the tourism industry at the beginning of the 21st century influenced the focus on the tourism product, that is, on the quality of its intangible elements, but also on consumer satisfaction as a key element of loyalty. Today, quality represents the business policy of contemporary economic tourism entities, which is achieved by respecting the general principles, principles and standards of quality, as well as the system of total quality management (TQM) [8].

In contemporary tourism business, quality has become a decisive factor for success and competitiveness. Activities that play a key role in the destination value chain in attracting tourists, influence the satisfaction of their needs and have a positive effect on consumer satisfaction with the service provided and used are precisely based on the ‘quality concept’. On the other hand, the degree of tourist satisfaction with the provided and used service as an important qualitative indicator in the evaluation of the ‘final’ product of the tourism destination, stems from the ‘needs, demands and wishes of consumers’ [9] and directly affects the level of the tourist experience.

Service quality is defined by two aspects: the service provider and the service user. From the aspect of the service provider, i.e. stakeholders, the quality of the service indicates how well the delivered service pleased the expectations of the consumer, while from the perspective of the user of the service, quality implies the assessment of all links in the value chain of the tourism product of the destination, i.e. assessment of the quality of the services provided and used by all service providers.

As an important segment of the destination value chain, the quality of the guided tour affects consumer satisfaction and the level of tourist experience. The assessment of a guided tour, as an important link in the value chain, can be viewed from the aspect of outgoing and receptive tourism, that is, depending on the methodology of tour guiding and the methodology of the tourist guide's work.

The methodology of tour guiding refers to the realization of the task set before the tour guide[3], in order to satisfy consumers and all interest groups in the destination, through the implementation of all elements of the travel program, through the possession of knowledge and skills and preparation of the tour guide. The methodology of the work of a tourist guide includes actions from the preparation of the guide for the tour, the execution of all elements in the tour itinerary, i.e. to the travel program, to tasks upon completion of the tour.

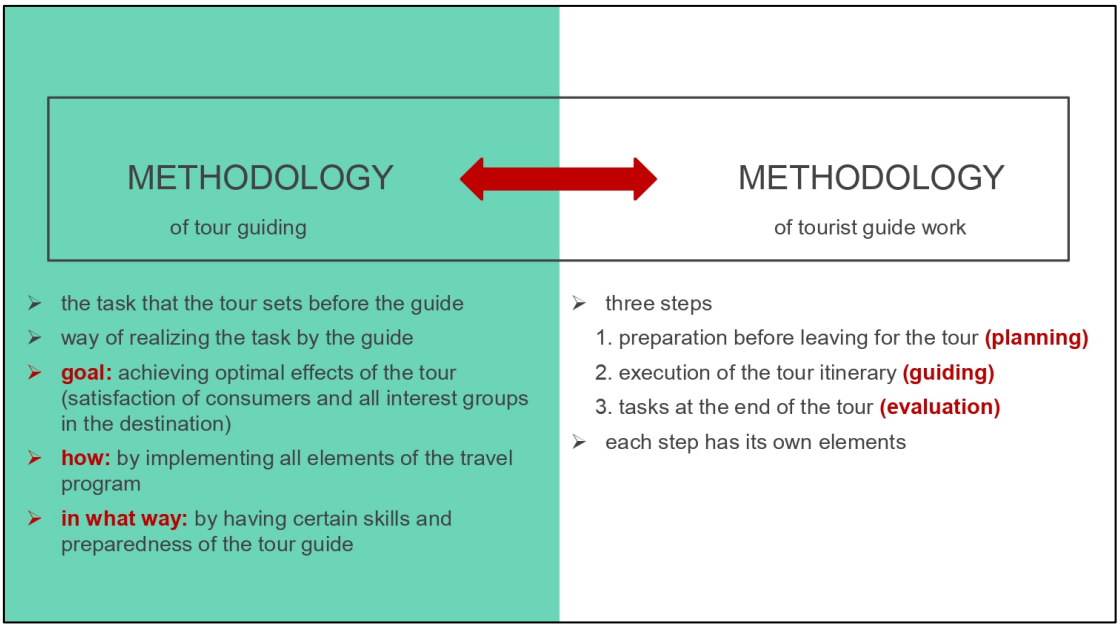

Figure 1. Methodology of tour guiding and Methodology of tourist guide work
Source: Screenshoot of Teaching material for the course Tourist guiding, prepared according to the [5, 11] author's textbooks

The sphere of outgoing tourism is related to the activity of tourist guides of a general nature. It is about staff hired by travel agencies (TA) tour operators for the realization of action travel arrangements, i.e. round-trip arrangements.[4] The service contact, as part of a trip organized in this way, begins at the moment of the guide's arrival at the meeting place and the departure of the group on a travel. From that moment, the process of evaluating the quality of the travel organizer service and the tourist product itself begins, and lasts as long as the escorted package tour travel program.
The sphere of receptive tourism is related to the activity of local tourist guides, i.e. guides who know the destination well where they work. We are talking about personnel who are 'tourism ambassadors' and 'destination experts'. The hiring of these staff is the responsibility of receptive travel agencies, whose offer is adapted to the needs and demands in the destination and is mainly based on one-day optional excursions, within which one or more attractions are visited.[5] The service contact within the guided tour begins with the departure of the group on an organized tour, when the process of

[3] Each task of a tourist guide consists of three components: navigation, presentation and logistics.
[4] Round-tours are multi-day tourist arrangements, on bus or combined transport. As part of these arrangements, more destinations are visited, and thus more attractions. A guided tour within which this type of arrangement is realized is known as an escorted package tour. Given that the program contents of the round-tours are mostly implemented in several foreign-receptive tourism destinations, for their realization it is necessary to engage local tourist guides, i.e. guide of destination experts. Thus, such activities acquire the character of a micro-tour, which means that several guided tours can be integral elements of one escorted package tour.
[5] Arrangements of the type of optional excursions, excursions and thematic one-day tours (e.g. wine tour, monastery tour, etc.) include visiting one or more attractions in the form of a half-day or full-day excursion, which can be organized on foot, by bus or other means of transport, outdoors and closed space. A tour within such arrangements is known as a guided tour. Such tours are organized exclusively within one tourism destination. They represent additional facilities in the destination and are intended mainly for guests on stationary or residential arrangements. Guided tour, as a segment of escorted package tour, also serve guests who come to the destination as part of an organized tourist package arrangement of the round-tour.

evaluating the tourist product of the receptive travel agency begins, then the evaluation of the guided tour as additional content in the destination, but also the evaluation of the entire integrated tourism product of the destination.
Based on the above, it can be concluded that tourist guides are the 'extended arm' of travel agencies, that is, they represent the last link in the chain of evaluation of the TA tourism product and the integrated product of the destination. Service contact with guests has a crucial role in achieving service quality, and it is achieved through the personal characteristics and behaviour of tour guides, which influence the guest's perception of service quality [8].
That the personal characteristics of the service provider have the greatest influence on its quality is indicated by surveys of consumer satisfaction, as participants in guided tours, on the quality of tourist guide services [11]. The interaction and time that the guides spend with consumers are key to the manifestation of their personal qualities, which consumers perceive as an integral part of the quality of the service. Enthusiasm, openness and warmth, self-confidence, creativity, determination, sensitivity, flexibility, intelligence, knowledge, awareness, organizational skills, energy, honesty and charisma are just some of the personal qualities that, according to consumers, guides engaged in guided tours should possess.

4. CONTEMPORARY TRENDS IN THE PROMOTION OF CULTURAL HERITAGE

Tourism, as a service sector, bases the quality of its services on the transmission of information, as an important factor for success and survival on the tourism market. It is generally known that the carriers of the tourist offer form their competitive advantage thanks to information [12]. Tourism today is dominated by digital channels, and the growth of SoMo networks (social networks and mobile devices) has contributed to the modernization of the sector [13].
The new trend in information development, Big Data (BD), BD analytics, analytics of massive data sets and business analytics, enables and supports business decision-making, as well as the design of efficient business models. Tourism destinations, companies and tourists are increasingly creating and implementing large data sets. It is predicted that research in tourism in the future will increasingly rely on BD, BD analytics and business analytics applying and including other types of digital technologies such as artificial intelligence and the Internet of things in different ways [12].
What is crucial is that the digitization of tourism has enabled the managers of tourism destinations to creatively promote the elements of the value chain of the tourism destination. DICRMS (Destination Integrated Computerized Information Reservation Management Systems), digitizes the entire tourism industry and integrates all aspects of the value chain. It works in a WAN network and is accessible via the Internet and mobile devices [14].
In the XXI century, in the era of the 'fourth industrial revolution', the application of the digital principle of business is of great importance, because it affects the increase in the competitiveness of the destination on the tourism market. Promotional activities were carried out by key stakeholders of tourism destinations through E-tourism (Web tourism) and Virtual tourism, which improve the functions and performance of the destination management system and become an important element in the evaluation of the value chain.
Virtual tourism began to develop intensively with the onset of the COVID-19 pandemic. It represents an innovative hybrid concept that creates a different dimension of travel. In the promotion of tourism destinations, it is used to improve the tourist offer by creating tourist products in an innovative way. Through this type of tourism, the service contents of all stakeholders in the destination can be presented and visited from a distance, primarily cultural service providers (theatres, galleries, exhibition centres, operas, museums, etc.) [12].
Cultural contents in contemporary tourism represent important motivators of tourist movements, whose digitization and presentation through virtual tourism contributes to the improvement of their visualization and accessibility to the general public, which additionally affects the development of the audience in culture and the creation of virtual tourists. This way of presenting cultural content is

easily accessible to sensitive social groups, especially people with disabilities, who represent a significant segment in contemporary cultural and tourist flows [12].
Today, virtual travel is mostly crucial in choosing a destination that a potential tourist wants to visit. Tourist destinations that have created and use virtual tours in their promotion have an advantage in the tourism industry. Virtual tours help potential tourists to experience destinations that they will probably not have the opportunity to visit by applying the concept of storytelling in the virtual world. The development of this type of tourism certainly represents and will represent a supplement to tourism traditional forms. Tourism stakeholders, who recognize and use the advantages of this technology, will not only create innovative additional content in the destination, but will also creatively promote the destination in a modern way. Examples of good practice in the promotion of cultural heritage in our country, through virtual tourism, are Manasija and Studenica Monastery, Golubac Fortress and Užice Old Town[6], as well as museums in Belgrade (National Museum, Museum of Contemporary Art, History Museum of Serbia, Nikola Tesla Museum, Aviation Museum, Museum of the City of Belgrade, etc.), etc.
In addition to virtual tourism, which appears as additional animation content in the organization of tourists' free time in the destination, in the realization of guided tours, especially guided walking tours, *life seeing*[7] and *life participating*[8] concepts are often applied. Their application is linked to certain localities in the destination when tourist guides through the concept of *storytelling*[9] present and interpret the attractions in the destination in an interesting way and thereby contribute to the creation of a tourist experience. Visits to sacral heritage, cultural values of rural and urban areas, getting to know traditions and customs based on the principles of *life seeing* and *life participating*, are the most visited animation activities organized by receptive TAs [15].

5. CONCLUSION

As an activity and the field of tourist guides work, a guided tour is a well-designed animation activity that presents and interprets attractions in the destination to tourists. The importance of tourist animation is based not only on the creation of a quality tourist offer for destination stakeholders, but also on the satisfaction of tourists with the service provided and used.
Tourist guides as the 'extended arm' of tour operators are most often responsible for consumer loyalty. The quality of the services provided on the guided tour has a direct influence on the formation of the experience of the tourism destination and the satisfaction of consumers with the purchased and used service. A quality tourist experience is created as a result of the interaction between tourists and service providers, local residents and other tourists.
By developing virtual tourism, additional contents created in the destination contributed to its competitiveness on the tourism market. Virtual tourism products or VR tours represent and will represent content that will be developed as a complement to traditional forms of tourism, because virtual tours and digitization are a trend in the development of tourism worldwide.

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[6] The DiMSUE project is financed by the Ministry of Culture of the Republic of Serbia and co-financed by the City of Užice. The project holder is the Western Serbia Academy of Applied Studies. All information about the project is visible through the link https://stari-grad.uzice.rs/

[7] The *life seeing* concept is an important aspect in animating tourists in the destination. It is based on discourse and visualization. It is applied in all types of tourism, which indicates that it can be organized on different topics. It is closely related to the concept of storytelling, with which the guide or curator tells a story about the site being visited in an interesting way.

[8] The *life participating* concept also represents an important aspect in animating tourists in the destination. The concept can be subsumed under active vacation in the destination, because it implies the participation of tourists in the activities of the resident rural population, which indicates that it is closely related to agritourism.

[9] The concept of *storytelling* is one of the modern trends in the promotion of attractions in the destination. It is represented in almost all types of tourist movements and is related to all types of guided tours, in closed and open space. In addition to tourist guides, the concept is also applied by specialized/expert guides (curators in museums, galleries, halls, commercial organizations), who provide information and guide guests through objects of cultural, economic, historical and other significance.

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ENVIRONMENT AND SUSTAINABLE DEVELOPMENT. MECHATRONICS. OCCUPATIONAL SAFETY AND HEALTH AND FIRE SAFETY. SMART MANAGEMENT SYSTEMS. GRAPHIC ENGINEERING. DESIGN. TRAFFIC ENGINEERING. BIOTECHNOLOGY AND HEALTHCARE. MECHANICAL ENGINEERING. ECOTOURISM AND RURAL DEVELOPMENT.

INCENTIVES FOR AGRICULTURE IN THE CITY OF BELGRADE

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Abstract: *Agriculture is one of the most important branches of the economy of the Republic of Serbia and the city of Belgrade. The aim of the paper is to present and analyze the current financial incentives in the territory of the city of Belgrade, which are included in the programs of the Secretariat for Agriculture of City Administration of the City of Belgrade. These incentives are aiming the development of agriculture and rural development of the capital. These incentives are pay out from the budget of the city of Belgrade through several public calls. The largest part of these incentives is used by agricultural farms on the outskirts of city municipalities. To develop agriculture in the city of Belgrade, it is necessary to increase allocations for this type of subsidies, considering that many farms that apply remain below the line that indicates the expenditure of all funds. The method of description, content analysis, comparative method, and descriptive statistics methods were used in the work.*
Keywords: *incentives, agriculture, Secretariat for Agriculture, rural development.*

1. INTRODUCTION

According to the Farm Structure Survey 2018. [1], the total number of agricultural holdings in the territory of the Belgrade region was 30,033, and the utilized agricultural area covers an area of 145,533 ha. Dominants are farms with smaller agricultural land of up to 5 ha, which make up 77.8% of all agricultural farms and dispose of 31.1% of used agricultural land. There are the fewest farms with property over 100 ha, only 0.1%, and they have at their disposal 20.3% of the total used agricultural land. Fields and gardens are the most represented in the total used agricultural land with 77.5%, followed by meadows and pastures 10.7%, and then perennial crops with 10.43%.
Our country is known for possessing suitable natural resources for the development of agriculture, primarily related to soil quality, favorable climatic conditions, and availability of water resources. However, insufficient agriculture investment in the past led to the fact that natural resources cannot be fully utilized. Investment in agriculture and rural development is an important factor in increasing the volume and quality of production [2]. Greater incentives for agriculture are needed, which should be implemented with the national and regional incentives at the local self-governments level such as City of Belgrade.
The great importance of agriculture for the development of most cities and municipalities in Serbia has influenced the fact that about 110 municipalities/cities support the development of agriculture in their territory with their own budget funds. Budgetary funds for the agricultural sector allocated by cities and municipalities vary, both in terms of share in the total budget and purposes. The law regulates the obligation to coordinate measures to support agriculture and rural development, which will be financed from the budget of local self-government units, with the Ministry of Agriculture, Forestry and Water Management [3].

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The aim of the paper is to present and analyze the incentives that the City of Belgrade, as a unit of local self-government, allocates for agricultural holdings, through the programs of the Secretariat for Agriculture of the City of Belgrade.

2. RESEARCH RESULTS

2.1 The call for applications of Secretariat for agriculture

Based on Article 13 of the Law on Incentives in Agriculture and Rural Development [4], the Decision on the Budget of the City of Belgrade for 2023 [5], Article 54 of the Statute of the City of Belgrade [6], the City Council adopted the Support Program for the implementation of agricultural policy and rural development policy for the year 2023, with the prior consent of the Ministry of Agriculture, Forestry and Water Management to the Program. Based on the adopted Program, the conclusions of the Mayor of the City of Belgrade, decisions were made on the announcement of all five Public Calls. Five public calls are announced:

1. Public call for submission of applications for the allocation of incentive funds in the field of fruit growing, vegetable growing and arable farming in the territory of the city of Belgrade for the year 2023 [7].
2. Public call for submission of applications for the allocation of incentives for the purchase of agricultural attachment machines in the territory of the city of Belgrade for the year 2023 [8].
3. Public call for submission of applications for the allocation of incentive funds in the field of beekeeping in the territory of the city of Belgrade for the year 2023 [9].
4. Public call for submission of applications for the allocation of incentive funds in the field of animal husbandry and milk processing on farms in the territory of the city of Belgrade for the year 2023 [10].
5. Public call for submission of applications for the allocation of incentive funds for the purchase of tractors in the territory of the city of Belgrade for the year 2023 [11].

The value of incentives in the period from 2015 to 2023 tends to grow. The only years when the value of incentives was reduced were the years when our country, like most of the world, was affected by the Covid 19 pandemic and when the reduced activity of both the economy and agriculture caused the budgets for this type of incentives to be directed to the health sector. The total value of incentives by year is shown in Graph 1, from which it can be seen that the first years when incentives in this form were introduced into the program of the then Secretariat for the Economy, within which the Directorate for Agriculture functioned, and from which it was transformed into the Sector through systematization and consequently to the independent Secretariat for Agriculture, the incentives amounted to slightly over 16 million dinars, so that in 2023 the budget for incentives would be valued to almost 450 million dinars. The number of applications from agricultural farms for subsidies exceeded the planned budget for these purposes every year, as well as in 2023, when 1,651 agricultural farms applied, and 1,120 received subsidies. For this reason, a further increase in the budget for this type of subsidy is expected.

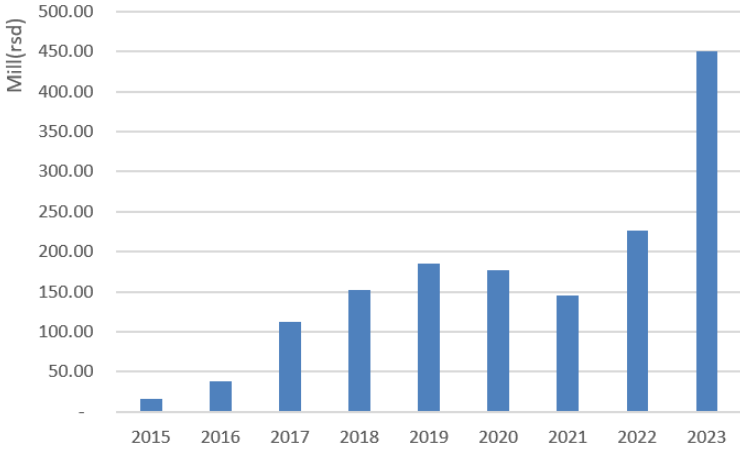

Figure 1. Value of incentives per year
Source: *Internal documentation of Secretariat for agriculture*

Table 1 shows the types of costs for which Incentive funds are selected and the maximum amounts of acceptable costs:

Table 1. Types of eligible expenses and maximum amounts
Source: *Internal documentation of Secretariat for agriculture*

EQUIPMENT	QUANTITY	MAXIMUM AMOUNT (RSD)
Fruit growing, vegetable growing and arable farming		
anti-hail nets with drip irrigation system	from 0.25 ha to 1 ha	1,550,000.00
greenhouses with a drip irrigation system, or a sprinkler irrigation system	from 0.03 ha to 0.10 ha	1,500,000.00
wire fences for fencing perennial fruit plantations	from 0.25 ha to 5 ha	1,400,000.00
drip irrigation system for irrigating fruit plantations	from 0.25 ha to 5 ha	750,000.00
hydrant with or without water flow meter	1 pc	125,000.00
drip irrigation system with hydrant with or without water flow meter	from 0.25 ha to 5 ha	875,000.00
electric scissors for pruning fruit	1 pc	200,000.00
typhon with or without rain wings for irrigation of field crops, outdoor vegetable crops and industrial plants	1 pc	1,000,000.00
vacuum cleaner for collecting stone fruits	1 pc	350,000.00
Attachment machines		
Attachment machine for tractor	1 pc	500,000.00
Beekeeping		
Equipment and machines for beekeeping more closely defined in the Public Invitation	Several pcs	120,000.00
Animal husbandry		
Quality breeding heifers	3 pcs	750,000.00
Quality breeding sheep or goats	30 pcs	750,000.00
Animal husbandry equipment	Several pcs	400,000.00
Milk processing equipment	Several pcs	300,000.00
Tractors		
Tractor up to 60 kW with cab or protective frame	1 pc	1,000,000.00

Incentive funds are implemented on the territory of all 17 city municipalities that belong to the city of Belgrade as a local self-government. Table 2 shows the total amounts as well as the number of agricultural farms from the city municipalities that received incentives. Also, there is an average amount of subsidies that agricultural farms have received in certain municipalities. Here it can be seen that the peripheral municipalities achieved a higher number of incentives per farm, but this can be attributed to the number of farms that applied and received a subsidy for the purchase of tractors, which is 1,000,000.00 dinars, so this had the effect of increasing the average amount of subsidies per farm. Consequently, municipalities where there is a greater number of beekeepers or where this type of agriculture is more developed, will have a smaller amount of average subsidy because the maximum amount of incentive for beekeepers is 120,000.00 dinars.

Table 2. The number of subsidies by municipality in the territory of the city of Belgrade
Source: *Internal documentation of Secretariat for agriculture*

Municipality	Amount (RSD)	Number of farms	Average amount per farm
Mladenovac	131,600,006.05	242	543,801.68
Grocka	81,607,836.20	163	500,661.57
Lazarevac	51,255,290.77	138	371,415.15
Obrenovac	40,387,102.50	129	313,078.31
Sopot	39,266,745.70	98	400,681.08
Surčin	19,233,708.26	54	356,179.78
Palilula	18,123,365.33	44	411,894.67
Voždovac	13,660,748.18	42	325,255.91
Barajevo	13,499,290.12	56	241,058.75
Zemun	12,917,571.06	37	349,123.54
Čukarica	7,425,224.13	38	195,400.64
Savski Venac	5,824,168.13	9	647,129.79
Zvezdara	4,263,417.60	13	327,955.2
Rakovica	4,119,441.33	27	152,571.90
Vračar	3,617,173.34	8	452,146.67
Novi Beograd	2,181,039.45	17	128,296.44
Stari Grad	494,968.00	5	98,993.6
In total	**449,497,096.20**	**1,120**	**401,336.69**

As shown in Table 2, the largest number of subsidies was achieved by peripheral municipalities, given that there are many agricultural farms on the territory of these municipalities, which dispose of significant areas of agricultural land. Central municipalities in the city of Belgrade, such as Stari grad, Vračar and Savski venac, which objectively do not have agricultural land, and are on the list of municipalities where farmers received subsidies, are mentioned for the reason that the address of the agricultural holding is given as the address of the owner of the holding which in these cases is on the territories of these Municipalities, and not related to where the agricultural land is located. For this reason, it is logical to conclude that these agricultural farms from the central municipalities are predominantly located in the outskirts of the city of Belgrade, where there is also agricultural land that is cultivated.

3. CONCLUSION

Local self-government subsidies at the level of the city of Belgrade are implemented through the programs of the Secretariat for Agriculture. In 2023, 1,651 farms applied to five public calls implemented by the Secretariat for Agriculture, while 1,120 of them received subsidies, which indicates the need to increase the budget of the Secretariat for Agriculture to meet the needs of farms for this type of incentive [3]. Also, what is noticeable is that for many farms, the lack of large holdings is something that slows down further development and increase of productivity, in this regard, further consolidation of agricultural land is needed to overcome the problems of unprofitability of small holdings. A further increase in the budget for subsidies should go in the direction of channeling funds into public calls for the purchase of tractors, which would modernize agricultural mechanization in agricultural farms in the Belgrade region, and since the maximum subsidy for a tractor is 1,000,000.00 dinars, in this way the average amount would also increase subsidies per agricultural holding.
A further direction of research related to the subject of subsidies would be to compare the amount of subsidies, the distribution of subsidies by municipalities and the types of subsidies that change by year. It would also be important to investigate the effect of subsidies on the economic well-being of agricultural farms and the economic performance achieved by farmers in agricultural production. This

refers to the way in which the new mechanization acquired through the subsidy program affects the increase in profitability and more efficient work on the farm. The question opened by this work is whether the current level of subsidies is sufficient or whether it is necessary to increase their amount and, if so, to what extent. All these questions could be further topics of research in this area.

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ENVIRONMENT AND SUSTAINABLE DEVELOPMENT. MECHATRONICS. OCCUPATIONAL SAFETY AND HEALTH AND FIRE SAFETY. SMART MANAGEMENT SYSTEMS. GRAPHIC ENGINEERING. DESIGN. TRAFFIC ENGINEERING. BIOTECHNOLOGY AND HEALTHCARE. MECHANICAL ENGINEERING. ECOTOURISM AND RURAL DEVELOPMENT.

THE ROLE AND SIGNIFICANCE OF CULTURAL-HISTORICAL HERITAGE IN THE DEVELOPMENT OF CULTURAL TOURISM – EXAMPLE OF THE MILEŠEVA MONASTERY

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Abstract: *The Mileševa Monastery is the focal point of the Mileševa River canyon, abounding in heritage sites. Rich and unique cultural and historical heritage in this area is determined by the strong role of the Mileševa Monastery compound. Its values can be assessed from the aspect of material heritage, permeated with intangible (spiritual) heritage, set in a specific protected natural area. Cultural heritage can play a decisive role in defining culture and tourism development policies by taking into account the management of cultural values and their harmonisation with other types of tourism. Interaction between cultural and natural heritage, i.e., tangible, intangible and landscape values, calls for the integrative approach to protection and preservation of this area by introducing and also improving the concept of cultural landscape. The significance of cultural heritage can greatly affect the appeal of a tourist destination. This paper aims to point to the potentials of cultural and historical heritage, which will add to creating cultural and tourist identity of this area both in the local and international tourist markets.*
Keywords: Cultural tourism, Cultural and historical values, Development, Improvement, Preservation, Cultural heritage, Mileševa

1. INTRODUCTION

In accordance with the Law on Cultural Property [1] (*The Official Gazette of the Republic of Serbia* No. 71/94, 52/11- other law and 99/11- other law), the Mileševa Monastery, along with the Church of the Ascension of Christ, have been awarded the status of protected immovable cultural property. In 1947, the monastery was protected as cultural monument, while it was back in 1979 that it was categorised as a Monument of Culture of Exceptional Importance. It is the endowment of King Vladislav and dates back to the first half of the 13th century. This monastery was home to the relics of Saint Sava from 1236 to 1594. The Mileševa Monastery monumental thirteen-century frescoes stand for a masterpiece of Serbian and European art. They bear the portraits of several rulers from the Nemanjić dynasty and the composition The Myrrh-bearers at the tomb of Christ. In 1377, the coronation of King Tvrtko I Kotromanić took place in the monastery. Apart from the Mileševa Monastery, the town of Hisardžik, also known as Crna Stena (*Black Rock*), stands out as a location of cultural value. Along with its surrounding area, it was protected as a cultural monument in 1947. This mediaeval fortress, featuring stone walls and towers, was erected on an inaccessible rocky cape, a cone-shaped limestone outcrop, on the left bank of the Mileševka River. The first mention of it, as the town of Mileševac, was in the mid-fifteenth century. Since the second half of the 15th century, it was under the control of the Turks and since the 17th century it also became known as Hisardžik, with a small town at the foot of the fortress. Additionally, in the territory of the Municipality of Prijepolje, several sites of archaeological value have been identified, as well as some structures that belong to building heritage and enjoy previous protection, such as: the Ružica Church (archaeological site), the

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Cave Church (a group of hermit cells), Crkvina, Aljinovići (archaeological site), the primary school building (building heritage), the village graveyard (archaeological site), and the watermills on the Sopotnica River (traditional building technique). Other significant and valuable cultural monuments have also been registered, these not being included in the system of protection (the Church of Saints Peter and Paul, the Church of Basil of Ostrog, the Church of the Davidovac Monastery, the Church of the Kumanica Monastery, the Catholic church in Prijepolje, the Ibrahim Pasha Mosque in Šarampovo and the "Big" or Mahmut Bey Mosque). In the early 1990s, by decision of municipal authorities, a regime of protected area was introduced around the monastery, with three different levels of protection: I, II, and III. The Mileševa Monastery compound is situated in the Mileševka River basin. The importance and significance of the monastery is additionally highlighted by the fact that it is situated in the immediate vicinity of the Special Nature Reserve of the Mileševka River canyon. In accordance with the relevant Decree of the Government of the Republic of Serbia [2] (*The Official Gazette of the Republic of Serbia* No. 104/14), pursuant to the provisions of the Law on Nature Protection [3] (*The Official Gazette of the Republic of Serbia* No. 36/09, 88/10, 91/10 – corr. and 14/16), the reserve was declared Protected Area of Exceptional Importance.
According to the data provided by the Statistical Office of the Republic of Serbia, the total number of tourists in the Republic of Serbia for the year 2021 was 2591293, of which 1720054 (about 66%) were domestic and 871239 (about 34%) were foreign tourists. Prijepolje belongs to the region of Zlatibor and, based on data, this municipality has recorded the least number of visitations in comparison to other municipalities of the region, in the aforementioned year. The total number of overnight stays is 2.3 for domestic and 1.6 for foreign tourists. This is an insignificant per cent, less than 1% of the overall tourist visitations [4] (Општине и региони у Републици Србији, 2022). According to the official data of the Ministry of tourism and Youth that applies to the categorized facilities in the Republic of Serbia (until October 2023), the Municipality of Prijepolje does not possess any such facilities [5].

1.1 The Mileševa Monastery

The Mileševa Monastery belongs to the „Raška school" group of monuments and is one of the many endowments of the Nemanjić dynasty members. The main monastic church, which is dedicated to the Ascension of Christ, was presumably built in the third decade of the 13th century, following which frescoes were painted [6, 7, 8]. Prince Vladislav, the second son of Stefan-the-First-Crowned, erected the church as his own mausoleum. The relics of Vladislav's uncle, Saint Sava, the founder of the Autocephalous Serbian Church and its first Archbishop, were kept in this monastery for a period of time [9, 8, 10]. Once it was built, Mileševa became the second most important Serbian church. The only church whose reputation was greater than that of Mileševa was Studenica, the endowment of Stefan Nemanja, who was Vladislav's grandfather and the progenitor of the dynasty. As is the case with other endowments of the Nemanjić family members, in addition to its role as a place of worship, Mileševa served the purpose of glorifying the cult of the ruler.
Originally, Mileševa was a single-nave church with a single dome a semi-circular apse on its eastern and narthex on the western side. To the left and the right of the central part of the church, there are two rectangular choirs, which initially may have served as vestibules. The proskomedia and the diaconicon were built somewhat later, next to the apse, and by the year 1236, an exonarthex was built on the west side, along with two lateral chapels. It was erected at the request of the ktetor's uncle, Saint Sava, whose relics were brought to Mileševa from Tarnovo, Bulgaria, in 1237 [6, 7]. The exterior parts of the church are influenced by Romanesque art, which is indicative in the remains of the sculptural decoration [8], as well as on the representations of models of the original church held by the ktetor Vladislav on the frescoes in the nave and the narthex [6].
Although its original appearance changed substantially, the Church of Mileševa has an enormous historical and artistic importance. Apart from its appearance repeating some of the earlier Nemanjić endowments (Studenica and Žiča), it is also home to some of the most fascinating frescoes of the time, which bear witness to the power of its ktetors. A noteworthy fact is that the programme of the

fresco decoration in Mileševa was created by Saint Sava [11, 12], while Vladislav commissioned the best artists from Greece to paint the walls of his endowment. Following the example of Studenica, they decorated the walls with frescoes in which they replicated the appearance of mosaic, while for representing the scenes in the nave, they used a golden background.

What is striking about the Mileševa Monastery frescoes is their outstanding monumentality. The monastery has several portraits of the Nemanjić family members, one of which is an exceptional portrait of the ktetor, Vladislav. This portrait is positioned directly above his sarcophagus, on the south wall of the nave. Vladislav is represented while, led by the Theotokos, bringing a model of the church to an enthroned Christ. Apart from this portrait, another one, of distinct beauty is the portrait of Saint Sava, shown in the Nemanjić family tree. The portrait is on the eastern wall of the narthex. Next to him is Stefan Nemanja, the progenitor of the dynasty, shown as a monk. Other members of the dynasty are painted one after the other on the northern wall: the then king Stefan-the-First-Crowned with his sons, Radoslav, co-ruler at the time, and Prince Vladislav, who is again shown here with a model of the church in his hand [13].

Still, what the Mileševa Monastery is most famous for is the fresco of The Myrrh-bearers at the tomb of Christ, i.e., the figure of the angel depicted in it, after which the entire composition was named and is known as The White Angel. This fresco is positioned above the grave of Vladislav, the ktetor, on the south wall of the nave [8]. Since the exonarthex served as a place for the tomb, where the relics of Saint Sava were kept for a period of time, the whole space is decorated with the episodes of the Last Judgment [6, 14].

2. THE CONCEPT OF CULTURAL TOURISM

Culture and tourism stand for and are a reflection of any nation's identity, which is confirmed by innumerable examples of famous tourist destinations in Europe and the rest of the world alike. In terms of appeal, the development of tourism and the creation of a successful tourism product have often been based on culture and heritage. Extensive tourist movements have mainly been driven by cultural content, which is why it is important to promote cultural values and legacy as part of historical heritage that should be valorised and included in the most current developments of modern tourism. Today, modern cultural tourism is recognised as an important factor of economic and social development. This is reflected in the fact that rich countries, and those that are less rich, improve and develop their tourism strategies, which are, to a large extent, based on promoting cultural values and attractions. Furthermore, one of the main tasks is to identify potentials and limitations in terms of the development of this form of tourism, as well as possibilities for a sustainable utilisation of cultural values.

The term cultural tourism has been present in relevant sources for quite some time, with many definitions of this term that define it in an almost identical manner. It is mainly related to exploring a new region and its residents. The most widely-quoted definition of cultural tourism is that by the author Richards [15], according to whom cultural tourism is "the movement of persons to cultural attractions away from their normal place of residence, with the intention of gathering new information and experiences to satisfy their cultural needs". The same author says that cultural tourism represents "all movements of persons travelling to experience culture through cultural heritage attractions, art and culture events, art, and drama away from their normal place of residence" [16]. Adams [17] describes cultural tourism as "leisure travel for the purpose of personal enrichment", i.e., a much-wanted exploration and quest for something new. Local authors explain cultural tourism as a form of tourism which includes various historical, artistical, religious, ethnic, sporting, recreational, etc. content [18]. According to some authors, cultural tourism is about learning, experience, and recognising resources and activities of other cultures [19]. The World Tourism Organisation also provides a definition of cultural tourism as "movements of persons for essentially cultural motivations such as study tours, performing arts and cultural tours, travelling to festivals and other cultural events, visits to sites and monuments, tending to raise the cultural level of the individual and giving rise to new knowledge, experience and encounters".

All this leads to the conclusion that the concept of cultural tourism encompasses a broad range of material and spiritual dimensions of culture. It includes a multitude of activities such as tours of cultural heritage sites, historical sites and monuments. It additionally includes exhibitions and concerts, participation in traditional customs and festivities, learning about local gastronomy, learning about the lifestyle of local people, etc. [20]. Cultural tourism offers possibilities of learning about different cultures through hands-on experience of such cultures' values and heritage, this possibly making cultural heritage the main drive of tourism industry in Europe. Thorburn [21] deems that Europe's cultural heritage is one of the oldest and most significant generators of tourism, which has to date kept a central role in the European tourism industry, while Bernandini [22] concludes that cultural tourism, in a broader sense, deserves to enjoy preferential attention as a special field of development policies.

Cultural tourism poses multiple challenges, this fact making it very complex. There are also various aspects underlying it (economic, tourismological, educational, and organisational), which define it in different manners (see more in: [23]). Also, to be able to understand it more clearly, Csapo [24] has made a distinction between the most important forms and elements of cultural tourism which are thematically grouped in accordance with desired activities, such as: tourism based on cultural heritage, cultural thematic routes, cultural city tourism, ethnic tourism, events and festivals, religious tourism, and creative tourism.

3. POTENTIALS FOR DEVELOPING AND IMPROVING CULTURAL TOURISM

The Municipality of Prijepolje, in which the Mileševa Monastery compound is situated, possesses diverse and versatile cultural and natural values. Tourism is subject to continuous change, hence it is necessary for it to be well-organised, but what is also required is to strive strongly to enhance and improve our own potentials. Potentials have been recognised by the local self-government and identified as part of relevant documents describing plans for strategic development. The Tourism Development Strategy defines 18 prioritised tourist destinations based on the criteria of infrastructure and suprastructure resources that have been built to date, availability and realised tourism-based turnover, all of these elements being relevant in terms of creating a full range of tourism products. With its cultural and natural content, Prijepolje belongs to the Tourist Region of West Serbia. Bearing in mind its rich cultural and historical heritage, nature attractions, a large number of highly appealing tourist destinations and sites that are located in a small area, tourism represents one of the industries with the strongest potential. To use comparative advantages this region possesses, it is necessary to have a well-devised plan for the development of tourism.

In regards to tourism potentials, this area is rich in cultural and historical heritage. The area used to be at the crossroads of different cultures and civilisations, caravan routes crossed this region, as well as pilgrims. The region stands for a kind of tourist attraction where cultural-historical and nature motifs permeate (the Mileševka River canyon, Mileševa Monastery, the mediaeval town of Mileševac, Sava's hermit cells, the Hisardžik mosque, Sopotnica River cascades, etc., the slopes of Mounts Jadovnik and Zlatar). Apart from the Mileševa Monastery, as the most significant cultural and religious monument, there are some other cultural monuments that must be mentioned due to their importance and value (the Church of Saints Peter and Paul, the Church of Basil of Ostrog, the Church of the Davidovac Monastery, the Church of the Kumanica Monastery, the Catholic church in Prijepolje, the Ibrahim Pasha Mosque in Šarampovo, and the "Big" or Mahmut Bey Mosque). We should also note some cultural structures that commemorate several events from WWII (the Boško Buha Memorial Centre in Jabuka, the ruins of the Partisan hospital, the 4th December Memorial Complex, the Rushdia Museum). The most significant forms of tourism feature the following: cultural-historical, picnic tours, adventure tours, transit tourism, agritourism, there is also religious tourism, rural tourism, tours that focus on special interests and recreational activities in the pristine environment (cycling, trekking, hiking, geo-tours, etc.), cultural events and festivals, etc.

According to the Spatial Planning of the Special Purpose Area document, spatial organisation of offered tourism products and services will be organised in the following tourism zones: zone of

cultural and religious tourism (the Mileševa Monastery, with the mediaeval town of Mileševac, Sava's hermit cells, the Hisarsdžik Mosque), zone of the Special Nature Reserve of the Mileševka River canyon, zone of the Natural Monument Sopotnica Cascades (with a visitor/educational centre, and recreation infrastructure /marked mountain and cycling tracks), and zone of rural tourism [25].
The strongest opportunity for developing and improving cultural tourism of the Mileševa Monastery is to create an integrated tourism offer for this area in which natural and cultural-historical motifs are intertwined, which as such can attract both local and foreign tourist as well as individuals who enjoy recreational activities. It is necessary to encourage development and create thematic mountain and trekking trails that promote cultural-historical heritage of religious structures, archaeological sites, the Mileševka River canyon, Sopotnica River cascades, and other natural values (geological heritage and geodiversity). Development of educational tourism should also be encouraged through presentations and popularisation of cultural and natural values of protected areas (via publications, collaboration with tourist boards, mountaineering and other associations, organised visits, etc.). Also, it is necessary to make use of a reasonably good accessibility to this area via the IB-class state road and international railway, as well as the vicinity of urban centres, such as Prijepolje, Priboj, Nova Varoš, tourist destinations Zlatibor and Zlatar, but also other attractions in the region surrounding this area, as well as some centres in the neighbouring Republic of Montenegro.

4. TOURIST VALORISATION OF CULTURAL HERITAGE

Cultural heritage of a country and its local community is important potential that can be exploited for tourism purposes. With tourist offers of cultural heritage, tourists are provided access to tangible and intangible heritage that has a huge impact on a diversified range of overall tourism offer, but at the same time generates higher revenue in a particular tourist destination [26]. Tourist valorisation of cultural heritage allows for a promotion of cultural heritage as well as economic shift in terms of independent revenue generation of cultural goods [27]. By harmonising tourism and cultural heritage, we encourage a more adequate management of cultural goods, provide a better quality of use, consequently increasing regional and local tourism demand [28].
The main prerequisite for successful tourism and a stronger appeal of the Mileševa Monastery and the surrounding area is a well-devised strategy for tourist valorisation of cultural heritage. Tourist valorisation is an integral part of tourism-geographic research of relative natural and anthropogenous values that are of significance for the development of local and foreign tourism in a location, tourist destination, region, or country. It stands for a complex assessment of mentioned values and it is significant for the science of tourismology and operational capacities [29:5]. The concept of tourist valorisation refers to the appeal of tourist destinations with a broader social significance, which may result in financial benefits, but with the significance they bear, they represent benefit in themselves. Tourist valorisation and tourist appeal are directly connected. This as a rule means: the higher the appeal, the higher the value [30].
For the purpose of performing tourist valorisation of the Mileševa Monastery compound and the surrounding area, one of the options is to apply the quantitative-qualitative method. This is one of the most commonly used methods since it gives ample leeway in terms of research and assessments. It is based on six indicators [31]: tourism-geographic position, artistic values, cultural-historical significance, tourist value of the ambience, tourist appeal and recognisability, design, furnishing and fittings of facilities and their compatibility with tourist potentials, all of which are relative to the assessment of tourist value of complementary motifs at the same destination, for the purpose of determining complementarity or competitiveness of other motifs and consolidating tourism offer.
The result of tourist valorisation stands for tourist value of cultural goods. Based on the above-mentioned indicators, valorisation of said elements is carried out for the purpose of establishing an overall tourist value. Valorisation may be performed with the application of the comparative method [32], it being based on: a comparison of tourist attractions that belong to the same type, establishing elements based on which it will be possible to perform valorisation and comparison. The system of

comparison takes into account the most strongly acknowledged motivations and the application of the principle of complementarity in the form of valorisation and motivations of other types.
On the basis of results to be obtained via tourist valorisation, it would be possible to appropriately rank the Mileševa Monastery and the surrounding area and thus in multiple ways assist and contribute to the implementation of planned cultural tourism in this area and a wider area alike. It would additionally contribute to making cultural tourism more marketable in the local and international tourism markets. This has a decisive role since structures, sites, etc. with the highest determined tourist value become prioritised, especially in terms of investment in accommodation facilities, and hospitality facilities in general, as well as investment in infrastructure facilities. Once analysis has been performed and tourist value of a particular structure has been established, further directions for the development of tourism will be defined. A noteworthy fact is that the use value of tourism facilities, sites, etc. is not a clear economic indicator, but rather a basis for applicative action, after which economic effects ensue [31].

5. CONCLUSION

The Mileševa Monastery is one of the most significant cultural-social monuments, which reflects the identity of the local community and our country. We should note the fact that there is no real cultural tourism at the Mileševa Monastery and the surrounding area. The strongest limitation in this context is that it belongs to cultural goods for which there is no developed programme with a cultural content, nor is there a comprehensive range that includes both cultural and natural values in the surrounding area, which could attract a higher number of both local and foreign tourists. The task and the objective of tourist valorisation of the Mileševa Monastery is to ensure, via evaluation, classification and ranking of tourist values in the market, that cultural tourism becomes self-standing. Furthermore, the objective is to promote and present values of Mileševa's contractive zone, to define the content of tourist stays, improve material furnishings, and adjust to the local environment. Tourism values, along with the views of the local community and visitors alike, do have a rightful place in the tourism market and, each in their own way, contribute to the accomplishment of social and economic effects of receptive tourism. In terms of their number, cultural-historical and artistic importance, monasteries in Serbia account for the most important category in Serbia's cultural heritage. They tell stories of events of historical significance, events that were significant for national identity and culture of all peoples who lived in this region [33]. Therefore, the Mileševa Monastery deserves to be the leader of tourist offer and cultural tourism on a much larger scale than has been the case until now.

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THE POTENTIAL FOR RURAL DEVELOPMENT IN THE BRANIČEVO DISTRICT THROUGH THE TOURIST SIGHTS

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Abstract: *In Serbia, rural development is an integral component of the economic, social, and environmental growth of numerous regions. Almost half of the population of Serbia lives in rural areas, which make up even three quarters of the country's territory. Braničevo District has an exceptional natural, social and archaeological potential for the development of tourism. Since the Paleolithic, when some of the Homolj caves were inhabited, through a rich prehistory and antiquity, to the Middle Ages, more than a thousand archaeological sites have been registered in this territory. Furthermore, a number of geographical features, cave systems, river sources, historical sites, monasteries, spas, and other resources continue to be underappreciated. The sights of the city of Požarevac – the memorial park Čačalica and the Ljubičevo stud farm – are of special value. According to global trends, rural tourism can significantly reduce poverty and improve quality of life. In this paper, researchers attempted to examine the variety of tourist attractions offered in the Branievo district and to bring attention to less known locations as potential hotspots for tourism and rural development.*
Keywords: Braničevo District, rural development, tourism, arhaeological sites

1. RURAL DEVELOPMENT OF BRANIČEVO DISTRICT

Rural areas can be characterized as places where many people spend most of their working time on farms, with abundant and relatively cheap land, and with high transaction costs associated with remoteness and poor infrastructure to most of these areas [1]. There is a long tradition of classifying rural areas according to agroecological potential, based on the analysis of soil attributes, landforms and climate. In most rural areas, agriculture is the main source of income for the population. One of the pillars of rural development and one of the key sectors with a strong potential for diversification of the Serbian rural economy and rural development is sustainable rural tourism. International trends show that rural tourism has a key roleplay in rural communities in raising the quality of life, social struggle and economic inequalities and degradation. Rural areas can be characteredcan be described as the combination of natural and cultural landscapes, natural and cultural heritage, and activities developed by the local population [2]. For the overall rural development of the Braničevo district, in addition to infrastructure projects, it is necessary to pay more attention to the rich cultural heritage that this region abounds in. Given that the tourist destination is the basic element of tourism development [3]. Braničevo District has a high potential to include tourism as an additional or main

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source of income for the population of this region, in addition to agriculture as the primary activity in Serbia.

The Branicevo District is is one of 30 Serbian districts [4]. located in its northeastern part (Figure 1) and covers an area od 6,864km2 [5]. It include eight municipalities (Municipality of Veliko Gradište, Požarevac, Golubac, Malo Crniće, Žabari, Petrovac, Kučevo, Žagubica). It has about 250,000 inhabitants.The seat of the district is the town of Požarevac, a well-known crossroads, through which numerous roads still run today. The cultural sights of Požarevac are: National Museum (the first built after the Belgrade Museum), Tulba Ethnopark (unique museum in nature), Picture gallery of Milena Pavlović - Barili (famous Surrealist painter and poet). The city is also recognizable for the Čačalica Memorial-park as well as the Ljubicevo stud farm (one of the oldest and most famous stud farms in Serbia). In addition to the sights of the municipality of Požarevac, the sights of other municipalities located within the Braničevo region are Viminacium, Belovode, Ram fortress, Golubac fortress, Gornjak and Tumane monasteries, the Kalište, the Margum itc. All this shows of the enormous potential of this region, which is located among the great rivers along which cultures have changed over the centuries. The Braničevo district is home to the largest number of archaeological sites in Serbia [6]. Lower areas occupy the north-western part, the valleys of the rivers Danube, Velika Morava, Mlava and Pek. The biggest part of the area is covered by hills and lower mountains (200–1000 m), of which the highest is Mt. Beljanica (above 1000 m), occupying the southeastern part of the province [7].

Figure 1. Braničevo District
Source: (orig.)

2. VIMINACIUM – THE HEART OF THE ROMAN UPPER MOESIA

Viminacium is an archaeological site and a cultural property of exceptional importance for the Republic of Serbia and specially for the Branicevo District. This archaeological site is located on the right banka of Mlava river, near the Danube, in the field of Stari Kostolac and Drmno villages [6]. This ancient Roman city and military encampment covers an area of 220 hectares in the inner city, extending to over 450 hectares in the wider city region [8]. It is located today under cultivated arable land and artifacts and fragments of objects from Roman times are scattered in the furrows of agricultural fields. In the 2006 Viminacium Archaeological Park was established and 2009. entire area of the fortified ancient city and legionary fortress, along with its close surroundings, was defined as a site was borders and protections regimes. Located on cultural routes and the most important European corridrs, the Viminacium Arhaeological park is the main promoter of tourism development in the Požarevac area today [9]. The old Roman city of Viminacium was created in the period around

the new era, the Roman culture flourished, with the Roman conquests. The peak of that period was when Viinachium was the capital of the province of Upper Moesia. What is important for the archaeological heritage of Braničevo is the fact that Viminacium was the starting point of the great road that led to Constantinople. The archaeological site "Viminacium" located near the church has been attracting a lot of attention from archaeologists and art lovers from all over the world in recent years [6]. On the banks of the Danube in Kostolac, a port for large passenger ships, established in 2006, transports tourists from all over the world [10]. Given that the popularity and archaeological importance of Viminacium is still in its infancy, it is expected that with the continuation of the excavation of this imposing locality, the development of this rural area will flourish.

3. BELOVODE - THE LARGEST SITE OF VINČA CULTURE IN EUROPE

The prehistoric archaeological site of Belovode, from the time of the Vinča culture, dates back to the 5th and 6th millennium BC and is one of the largest sites in Europe from that period. It is located in the territory of the municipality of Petrovac na Mlava, in the atar of the village of Veliko Laole, it covers an area of 100 ha. The settlement existed from 4500 BC to 3800 BC when it was destroyed by fire. According to numerous indicators, copper ore was smelted and processed for the first time in European history in prehistoric Belovode, so this locality is considered the cradle of European metallurgy [6, 11,12].

4. KALIŠTE - ROMAN FORTRESS IN STIG PLAIN

Near today's village of Kališta, in the municipality of Malo Crniće, on the right bank of the river Vitovnica, there are the remains of a large Roman city, which was recorded on old Roman maps as Municipium, is preserved. Today, this city is covered by layers of the fertile Stig plain. The city was eighteen Roman miles from the ancient metropolis of Viminacium, located at the confluence of the Mlava River and the Danube. It was located on the route of the main Roman road that connected Viminacium with Nis (ancient Nais), the hometown of Emperor Constantine. The traces of that Roman road can still be followed today through Stig from Stari Kostolac, through Drmn, Bradac, Bratinac, Salakovac, Crnić, Batuša and Kališta. Numerous cult icons made of stone and metal were found in the City itself, which testify to a developed spiritual life. In the wider area of the site, Roman cemeteries were discovered, in which a variety of archaeological material was found, which testifies to the complex funeral rituals and the lively trade connections of this part of the Empire with other parts of the empire. The archaeological complex in Kališta is still waiting for researchers who will extract the gems of the past from the depths of the centuries [6].

5. MARGUM - ROMAN CITY

The Roman city of Margum is located near its confluence with the Danube, near the present-day village of Dubravica. During the time of the emperor Marcus Aurelius, Margum was given the status of a municipium, and numerous objects from prehistory, antiquity and the Middle Ages were found in German. A large amount of jewelry, made of gold, silver, bronze and semi-precious stones, has been found at the Margum site. Throughout history, cultures have changed in Margum, from prehistory, antiquity, to the Middle Ages [6].

6. THE FAMOUS RAM FORTRESS

The remains of the medieval Ram fortress is located in the village of Ram on the Danube bank, between Veliko Gradište and Kostolac, near an erstwhile, Roman military camp and urban settlement of Viminacium.The fortress was built by Turkish sultan Bajazit II in 1483 and possessed a major strategic importance from the ancient times [13,14] and is one of the best examples of military architecture from Turkish period [15]. Ram fortress had great strategic importance until 1521, when

the borders of the Turkish empire expanded far to the north.In 2019, this fortress was restored and thanks to it, the small town of Ram, located on the right bank of the Danube, regained its tourist importance.

7. THE GOLUBAC FORTRESS - WHERE THE DANUBE IS THE WIDEST

Despite the fact that the Golubac region is positioned in the widest part of the Danube and has a prominent medieval Golubac fortress at the entrance to the Đerdap gorge, the largest on the river, the population and development of this region have been declining for decades. The municipality has lost more than 55% of its population since the end of the Second World War [16,17,18]. The Golubac fortress is one of the best-preserved Serbian medieval fortresses and one of the most beautiful and famous on the Danube. Under it, the remains of the Roman road are still visible today. This fortress was built on a place of strategic importance, where even traces from prehistory and antiquity have been preserved [6]. It is presumed that the fortress was built in the 14th century on the earlier military-defensive ancient Roman fortification, whose visible remains are at the base and in the immediate surroundings of the fortress. Golubac Fortress was proclaimed a cultural monument of exceptional importance in 1979, under the protection of the Institute for the Protection of Cultural Monuments [19]. Taking in account the previous facts regarding natural and cultural heritage in Golubac area, the potential for its use in tourist economy is obvious.

8. GORNJAK AND TUMANE MONASTERIES - ORTODOX SHRINES

In recent years, with the increasing popularity of religious tourism in the world, religious objects of the Republic of Serbia have gained importance [20]. Ždrelo Monastery, later called Gornjak, is located on the banks of the Mlava, under the steep cliffs of Ježevac Mountain, and is the endowment of the Serbian Prince Lazar. It was built in the period 1376-1380. Due to its specific geographical position, in the Homoljska region, located a little off the main roads, the features of old culture, folk customs and traditional architecture have been preserved. It is considered that the history of the monastery is also the history of this region - it was demolished and burned, its valuables were looted, but it sprung up again [6]. The Tumane Monastery is located in the Braničevo diocese, 9 kilometers from Golupac, in a picturesque area area, surrounded by a forest, in front of which the clear river flows Tuman river. It is suitable for the development of not only religious tourism, but also other types of tourism such as: geotourism, event tourism, excursion tourism, etc. [21].

9. KRUPAJSKA AND MLAVA RIVERS - THE MOST BEAUTIFUL SOUND OF HOMOLJE

The sources of two rivers in the Braničevo region are particularly interesting: the source of the Mlava river, in Žagubica itself, at the place where the northern section of Beljanica descends into the Homoljska basin, and the source of the Krupajska river, about 35 kilometers from Žagubica. Both springs were protected in 1979 as nature monuments of national importance. The Krupajska river once flowed out of the cave with a strong force accompanied by a roar, and today it is blocked by a concrete constitution for the needs of the mill that is still working today. As a result, a pond was created in front of the cave partially submerged her opening. Near the source is a strong thermal spring with a water temperature of 26.5˚C [22].

10. CEREMOŠNJA CAVE - THE PEARL OF THE HOMOLJE MOUNTAINS

The region of Eastern Serbia is a highly dominant karst terrain with numerous geological and geomorphological features, especially caves. Ceremošnja cave is located in the Homolje mountains, of eastern Serbia, which are parts of the larger Carpato-Balcanian mountain range. The cave is divided into five halls, with the Strugar Stream running through it. The Strugar Stream connects the Ceremosnja Cave with the nearby Bigar Cave. In addition to these two caves, the Ravnistarka cave

also contributes to the speleological wealth of this region. The speleotourism potential of these caves still remains fully unrevealed. [23, 24].

11. MEMORIAL PARK ČAČALICA - GREEN URBAN LUNGS OF POŽAREVAC CITY

Memorial Park Čačalica which was originally planned and designed in memory of patriots who laid their lives for the people of Braničevo District during the WWI and WWII, has become a green oasis of Požarevac city [25]. In the last few decades Čačalica with 26.6 ha of green areas and with over 28.000 of trees and undergrowth has been providing the inhabitants of Požarevac with clean air and at the same time it has been preserving plant and animal diversity [26]. Today, Čačalica is a real small arboretum which 17 species of tall conifers, 6 species of low and ground cover conifers, 70 tall medium-sized deciduous trees, 24 deciduous shrubs, 3 evergreen shrubs and 3 roses [27]. The ecological association "Friends of Čačalica" has big conceptual plans for its arrangement as a Mountain house, recreational center and observation point, drainage canals restoration, aquatic biotopes preservation and plant diversity protection [26].

12. LJUBIČEVO STUD FARM - THE PRIDE OF THE CITY OF POZAREVAC

Ljubičevo stud farm is one of the oldest in the territory of Serbia. It is located on the right bank of the Great Morava, 5 km from the town of Požarevac. It was founded in 1860 by order of Prince Miloš. It was created with the aim of improving horse breeding from the best horse breeds. Later, Prince Miloš's son Mihailo named this 300-hectare property "Ljubičevo", after his mother, Princess Ljubica. The stud farm is connected with the tourist and sports event "Ljubičevské Equestrian Games", a traditional event that is held every year at the Požarevac Hippodrome in the first week of September and which regularly gathers a large number of domestic and foreign visitors [28].

13. CONCLUSION

Rural tourism is one of the main branches of rural development. It can be said that rural tourism in Serbia is still in the development phase. In addition to the continuous presentation of new products and rural tourism destinations, it is necessary to work on the marketing of the already known ones. Braničevski region certainly represents one of the largest archaeological sites in the world, but on the other hand, insufficiently used rural tourism inevitably leads to weak rural development in this region. Greater promotion of both the natural and cultural assets is necessary because they still represent its greatest untapped potential.

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ENVIRONMENT AND SUSTAINABLE DEVELOPMENT. MECHATRONICS. OCCUPATIONAL SAFETY AND HEALTH AND FIRE SAFETY. SMART MANAGEMENT SYSTEMS. GRAPHIC ENGINEERING. DESIGN. TRAFFIC ENGINEERING. BIOTECHNOLOGY AND HEALTHCARE. MECHANICAL ENGINEERING. ECOTOURISM AND RURAL DEVELOPMENT.

PROTECTION, DEVELOPMENT AND MANAGEMENT IN A PROTECTED NATURAL ASSET - ANALYSIS OF THE PETNIČKA CAVE

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Abstract: *The tourist potential of the a protected natural asset Petnička cave is an obvious. The imposing long subterranean karst relief from with the Banja spring, and significant archaeological traces from the younger stone and bronze age represent a well-known tourist destination in the wider area of the Valjevo mountains. Staying in a part of preserved and unpolluted nature creates suitable conditions for the development of scientific, educational, sports, recreational, cultural, transit and excursion tourism. The paper used the index of recreational potential and rating, which is a suitable for the geoecological evaluation of landscapes that are important for tourism, sports and recreation. The essence of this method is that when valuing the Petnička cave we have an initial value in points to which points are added or subtracted that express the quantitaive and qualitative characteristics of the protected biological property. The cave is a classified based on the obtained balance of points into from one of 10 categories (the most valuable part of the landscape to extremely unfavorable parts). It is determined on the basis of physical characteristics, aesthetics, educational and scientific values, carrying capacity of accommodation, and accessbility of space. Based on the research results, the Petnička cave has a category value of 152 points and is considered the most valuable part of the relief.*
Key words: Protected natural asset, Index of recreational potential and rating, Petnička cave

1. INTRODUCTION

The Petnička cave with the hot spring Banja is among the first speleological objects in Serbia that were the subject of geomorphological and archaeological research by many researchs. The first written document about this cave can be found in the works of Joakim Vujić, who visited the cave in 1826, and already noticed the intermittent character of the hot springs and "figures of animals" [1,2,3]. After him, numerous authors describe more detailed research and systematic presentations in their works: Vladimir Karić [4], Jovan Cvijić [5], Branislav P. Jovanović [6,7,8], Kuzmanović [9], Milojević [10] and Kličković [11,12,13]. Vrelo Banje, due to its values and specificity, was included in the Geoheritage Objects Inventory of Serbia (2005), within the list of Hydrogeological objects. In the immediate vicinity, significant archaelogical traces were discovered that testify to the exictence of a human settlement during the stone and bronze ages. Water phenomena are an integral part of the natural environment, and their representative forms are geoheritage objects. Based on previous experiences, considerations, and studies in the available literature, the hydrological properties of numerous geolocalities have been incompletely processed and evaluated as a separate or unique phenomenon. In the Inventory of Geoheritage Objects of Serbia, hydrological phenomena are classified into two groups: geomorphological and hydrogeological. Based on this, the idea to

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create a new independet group, which would bear the commom name - Objects of hydrological heritage [14].
The Natural Monument "Petnička cave" has a total area of 8.10 ha, of which private property (7.82 ha), state property (0.25 ha), and village property (0.03 ha). It was protected for the first time in 1950. It belongs to the second category of a protected area of great importance, and according to the classification of the International Union for Conservation of Nature (IUCN) to the third category of natural monuments or phenomena [15].
The Petnička cave is located southeast of the town of Valjevo (7.5 km) in Valjevo Podgorina, on the very border of the villages of Klinci and Petnica. The speleological system is presented with two entrances and the total length of the examined channels is about 580 m. It consits of two main speleomorphological units, which are determined according to their position and size: Lower (Big) and Upper (Small) caves. With the expansion of the urban settlement, in partially becomes a part of the new urban entity, but it has still preserved the characteristics of a village/rural setllement. It was created by the erosive work of the underground flow of Banja, i.e. the abyssal part of the Zlatarski stream, which in the first stages of the morphological evolution of the cave stood out at the opening of the Upper cave, and then descended with all its erosive force towards the surronding terrain [16,17]. A significant role in the morphological shaping of cave channels was played by the processes of collapsing the ceiling and walls. This is how the vigleds in the Concert hall were created, although according to Branislav P. Jovanović [6] they are of a combined way of origin. He believes that the wiglleds originally represented the point of emergence of the underground river and that they got their present appearance and physiognomy through the later processes of flooding. During that period of construction, two opposite processes operate simultaneosly in the channel: erosive and accumulative. On the side, rolling away rock pieces and blocks, the cave channel grows in width and height. On the other hand, rock blocks and rock fragments occupy more space on their new bed than on the primary bed, and because of this, the cavity of the channel is reduced and there is backfilling. All together with the construction of saliva, stalactites and stalagmites and the introduction of other material from the surface of the terrain threatens to bury the cave channel [6].

2. NATURAL AND ANTHROPOGENIC TOURIST VALUES

About 400 m from the entrance to the Petnička (Upper) cave, you come across the gate of the newly built water factory (Vujić). To the right of the main entrance to the cave is the Church of the Assumption of the Blessed Virgin Mary. On both sides are arable fields under corn, wheat and small vegetable/orchards. The slopes of the limestone elevation of the Osoja hill, which rise to the south of the cave, are covered with bushes and forest. The banks of the river Banja overgrown with three trunks, and on the left side there is a captured spring for the needs of the Research Station Petnica. The small bridges were built, the first is at the very entrance to the vaulted part of the Lower cave, and the second is downstream from the water mill. Nearby there is a board with a small guide about the cave and a staircase leading to the Upper cave. An archaeological site was discovered in that place, which was protected by the state in 1949 [17].
In 1988, the Petnička cave was arranged for tourist visits. A pedestrian path with a total length of 550 m was built, of which 414 m is in the cave itself. The path enables a circular tour of the cave from the entrance to the Lower cave to the Concert hall, then through Visoka to Medveđa hall, then to the exit from the Upper cave, in order to reach the starting point of the Lower cave through the steep slope of the hill. The narrowing formed between the area of the Lower cave and the Concert hall is protected by metal gates to prevent air flow. In the meantime, the cave and the immediate surroundings were neglected and devastated under the influence of the anthropogenic factor. The importance of revising the protection of Petnica cave is reflected in the preservation of natural/primary and cultural/created values, the affirmation and presentation of this space based on the principles of coordinated development for wider social communities, the scientific public and other interested parties [17,18].

The Natural Monument "Petnička cave" includes the second protection regime. The following activities are prohibited: entering the cave without a proper permit (a certain number of tourist/visitors), breaking, removing and damaging cave jewelry (stalactites and stalagmites), destroying cave fauna and flora (biodiversity), building infrastructure/superstructure, industrial, commercial, residential and tourist facilities, use of toxic chemical substances (in liquid and solid state) of oil derivatives and other dangerous substances, change of the existing morphology/physiognomy and physical - geographical features of the terrain, hot springs of Banje and capturing of springs for water supply needs of individual households. The manager of the protected natural property "Petnička cave" is the hotel tourist joint - stock company "Sloga" AD Valjevo, which through its activities so far has shown the ability to handle business.

The torust potential of the protected nature area is evident. The underground karst form (cave/pit) of intersting morphology/physiognomy and considerable/imposing length with the hot spring Banja, signifacant archaeological traces from the younger stone and bronze age represent a well-known tourist origin of the wider area of the Valjevo mountains. Staying in a part of preserved and unpolluted nature near the district center of Valjevo creates favorable conditions for the development of scientific, educational, sports, recerational, cultural, transit and excursion tourism. What will really be the socio-economic effects of the development and the concept of sustainable use of the area of the Natural Monument "Petnička cave" depends on the interests, motivation, engagement and ability of the local community, i.e. the resident population to unerstand the availability of an area of exceptional natural features (authenticity, recognition and representativeness). If cooperation, connection and engagement are absent, only people from science and the profession, casual visitors and local (domicile) population will known the Petnička cave. From the hospitality facility "Vujić", which is located in front of the entrance to the Lower cave, during the season (spring, sumer and autmun), when visits are more frequent and a larger number of visitors come, the existing infrastructure cannot fully meet the needs and demands of tourists. It is necessary to build similar of larger capacities at a slightly greater distance from the hot springs of Banja and cave. This would not endanger the aesthetic part and damage the natural environment of the Nature Monument. Due to its morphological, physiognomic, physical, geographical and hydrological characteristics, the cave represents an underground form of karst relief that is of particular importance for tourism, relaxion, nature conservation, science and education enthusiats (in the immediate vicinity of the Research Station Petnica, which is known outside border of our Earth).

Paleontological/geomorphological and archaeological traces found in its immediate vicinity/surroundings represent the cultural identity and authenitcity of this area. The assessment of the value of a protected natural asset is carried out on the basis of the main characteristics (originality, representativeness, rarity, diversity, integrity, attractiveness and preservation), function and importance. Petnička cave and its immediate surroundings represent a unique combination of all the mentioned features and according to most criteria have a high ranking in the evaluation scale. The concept of protection and sustainable development of tourism of the Natural Monument "Petnička cave" is based on the maintenance and improvement of primary characteristics, landscape features and coortinated/balanced "ecological" development. The basic functions are: educational, health/healing - recreational, scientific - research, tourism and development.

The *educational function* is based on raising the awareness of the population (local/domicile) about the importance of the protected area of nature and its potential, i.e. resources (natural and anthropogenic).The most effective way is the establishment of the Center for Sustainable Development, which is locted in the town of Valjevo and represents the training of the local (domicile) population and their active involvement in protection, promotion, marketing, formation of tourist services/content and sustainable management through education and educational programs (workshops, fairs, congresses/conferences). The *health/healing - recreational function* implies a stay in a preserved part of nature that possesses natural and cultural values i.e. primary and created. Favorable climatic characteristics (climatic elements and factor) are a condition for the development of sports and recreational tourism (visits by speleologists, adventures and enthusiasts) and

excursions/transit tourism. The *scientific research function* of a protected natural asset should represent a polygon of complex scientific research with the aim of tourism valorization/evaluation and monitorin of natural and created values. The *development function* is detrmined by the boundaries of the protected natural property and the established protection regime, which are in accordance with the preservation of natural landmarks.

3. METHODOLOGY IN WORK

The application of general methods will make it possible to determine the interdependence of tourism and the environment, that is, the connection between autochthonous (untouched) nature on the one hand, and tourist trends and their consequences in the study area itself, on the other hand. Tourism is significantly more than any other economic (branch) activity conditioned by the quality and preservation of the environment, i.e. natural and anthropogenic tourist values as the basic motives and indicators for attracting tourists and presenting on the tourist market. The analytical method consists in the mental disassembly of complex forms of knowledge into their simple and simple constituent parts, contents and elements. It includes the analysis of the existing bibliography and reference literature (domestic and foreign) related to tourism in protected natural resources and includes criticism of existing literature and work procedures, as well as the determination of elements/factors that are significant for solving certain problems. The synthesis method is the final stage or part of the complete (overall) analytical-synthetic method of knowledge. A closer connection between analysis and synthesis consists in the fact that analysis and synthesis not only complement each other, but they also pass into each other, that is, one cannot do without the other. The synthesis method defines the links, connections and relationships between the analyzed phenomena processes in the studied area and in this way conclusions are formed and proposals are made about the role of protected goods in the overall tourist offer of the northwestern part of Central Serbia.
The index of recreational potential and raiting is a method that is suitable for the geoecological evaluation of landscapes that are important for tourism, sports and recreation/relaxation. The essence of this method is that when evaluating the Petnička cave, we have an initial/base value in points which points are added or subtracted that express the quantitative and qualitative feautures of the landscape, i.e. the protected area. The cave is classified, based on the obtained balance of points, into one of 10 categories (the most valuable part of the landscape to extremely unfavorable parts) [19]. The recreational potential and bonitation index method is based on geological, geomorphological and hydrological data.

Table 1. Evaluation of Natural Monument "Petnička cave"
Source: *Authors, 2020*.

Starting points 100			Assessment category
Physical - geographical (natural/original) characteristics Petnička cave	Length of the cave in m/km	10	
	Terrain morphology and physiognomy	10	
Aesthetic, educational, scientific and educational characteristics	Cave jewelry (stalactites and stalagmites)	8	
	Other (soils, wiggleds, ceilings, water regime, climatic characteristics)	8	
Carrying capacity	Total number of tourists who do not endanger the protected nature object/limited number of tourists/visitors	9	
Accessbility to the main entrance and auxiliary entrance	passable/impassable ground	7	
Access to the cave	Distance from national/regional/local road	–10	
	Cave slope/terrain configuration	5	
	Access/arrangement/information boards (regional/local path)	5	
Total points		152	10

The recreational potential and bonitation method is determined based on physical characteristics, aesthetics, educational, scientific and educational value, carrying capacity, accessbility and availability. The Petnica cave has a category value of 152 points and is considered the most valuable part of the relief. Based on a survey of visitors and local residents, it also has significant aesthetic values (stalactities and stalagmities, see the spring Vrelo).

4. CONCLUSION

Speleotourism represents an affirmative/specific type of tourism, which includes visiting underground facilities, organized and unorganized caves. Since ancient times, caves have an extremely strong attractive power for people. It lies not only in their appearance and beauty, but in the totality of the subjective experience of each person individually. Organized visits to caves in Serbia, and thus the begininngs of the development of speleotourism, date well before the first arrangement of caves for tourist visits [20].

Petnička cave represented solid tourist potentials that must be valorized and promoted at the national, regional and local level (fairs, seminars, conferences and congresses). Greater investment in infrastructure/superstructure and participation in the development of projects, strategies, studies and spacial plans of special purpose areas is necessary. In order to clearly define the goals and objectives of the planned development of tourism of the protected natural asset Petnička cave, the concept of sustainable development (ecological, socio-economic and cultural) is apllied. Through training, improvement and education programs, it is important to inform the decision makers about preoorganized (program and plan) ecotourism, because otherwise due to unplanned, irresponsible and not excessive lack of interest, the degradation and devastation of the landscape, i.e. discruption of the natural environment, which is impossible to bring to the primary/base state. The positive experiences of protected natural resources should represent an example for the future development of environmental tourism in Petnička cave, which must be planned long-term on an integral basis and adapted to the characteristics of the environment.

Activities to protect the natural environment should be seen in the following priorities: measures to prevent and suppress harmful disturbances, degradation, devastation in natural environments and the wider environment, maintenance of natural resources and their rational, realistic and objective use. As a result, it is necessary to take a closer look at the problem and come up with solutions and conlusions for each appropriate space individually. Of course, the best protection is the one that causes the least degradation and devastation of the area, i.e. air, water and soil pollution, but the principle of the concept of active protection can be implemented and applied during more intensive tourism development, especially in the planning phase of tourist flows, shops and activities [21,22].

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THE FAUNAL DIVERSITY OF MEMORIAL PARK ČAČALICA

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Abstract: *The Previous studies on the fauna diversity were included only the identification and determination of the presence of phytophagous insects based on the traces on leaves and tree bark. Forest litter was not investigated. To gain a better understanding of the fauna diversity this study included the research which was conducted on forest litter and the surface layer of soil in order to determine the presence of living organisms in this forest stratum because this was the only way to obtain a more comprehensive picture of the biodiversity of this microhabitat. As the aim of this Paper is to collect and analyze various species of invertebrate and vertebrate fauna in order to create a preliminary list of species present at several locations within Memorial Park Čačalica, the scientific material was collected by using various research methods. Identified species that belongs classes Insecta, Diplopoda, Chilopoda, Malacostraca, Gastropoda and Aves are shown further in this work.*
Keywords: Memorial Park Čačalica, Faunal diversity, Biodiversity, Species

1. INTRODUCTION

Biodiversity is a concept that, since its inception until today, has been attracting increasing attention, not only from the scientific public, but also from a wider perspective. Thanks to negative phenomena such as "erosion of biodiversity", the protection and preservation of biodiversity represent a necessary need of humanity as an irreplaceable resource that ensures the survival of the human species. Despite the negligence towards the environment in general, it is nature that makes every effort to restore balance in its system. The authors discover a place in the immediate vicinity of the city of Požarevac where faunal diversity develops spontaneously - the Memorial Park Čačalica. Memorial Park Čačalica, which was originally planned and designed in memory of the patriots who laid down their lives for the residents of Braničevo District during the I and II WW, has become a green oasis over time. For the last several decades, Čačalica has provided the citizens of Požarevac with clean air and at the same time preserves plant and animal diversity.

2. THE FAUNA OF MEMORIAL PARK ČAČALICA

2.1 Materials and methods

During September, October and November in 2022, analyses were conducted at several locations at Memorial Park Čačalica in order to collect samples for determining the diversity of fauna. Images of the locations including microhabitats and coordinates are shown further in this work. (Figures 1&2).

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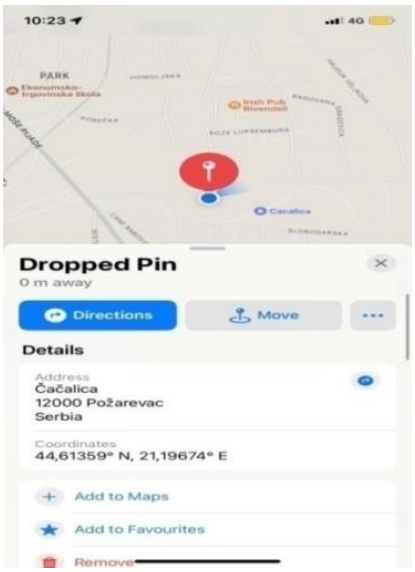

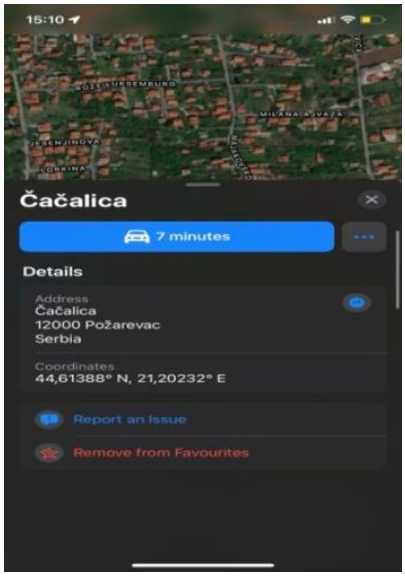

Figures 1.&2. Location coordinates where the research was conducted
Source: Original author's work

Faunistic quantitative and qualitative parameters for assessing species diversity include the following: Richness (S), Rarefied richness (ES), Abundance (N), and Shannon-Wiener diversity index (H') [1]. An inventory of fauna diversity is carried out using the relative method and the number of animal populations in a certain transect is determined. The micro-, meso- and macrofauna of invertebrates in the forest litter and the surface layer of the soil are collected, and by setting traps with different groups of pheromones and attractants, the species of vertebrates present are determined. Modern methodological procedures for examining biodiversity provide a comprehensive overview of all types of fauna living on Čačalica. The scientific material was collected by using various research methods [2, 3, 4]:

1. Collecting faunistic material manually under the rocks, fallen and upturned trees, in crevices in rocks and cracks in the soil, as well as in other potential microhabitats that could serve as a refuge for invertebrates.
2. Sampling the surface layer of soil together with fallen leaves and vegetation (soil litter) and sieving it through larger mesh sizes on a white background.
3. Setting traps with pheromones – 10-15 traps (plastic cups) were placed about 5 meters apart at each examined location and they were emptied once a month.
4. Using entomological nets in order to collect flying insect groups.
5. Setting traps with various attractants for larger invertebrates as well as vertebrate species.
6. The collected and identified material was preserved in 70% alcohol or 4% formaldehyde.

2.2 The Results and Discussion

The soil fauna as an important component of Earth's biocenosis is extremely rich in most ecosystem types and constitutes a significant portion of overall biodiversity [5].The soil fauna includes macrofauna, mesofauna and microfauna. Spatial distribution of soil macrofauna and mesofauna communities is influenced by both abiotic and biotic factors [6, 7].
Insect identification was carried out according to Mihajlović, 2015; Schwenke (edit.), 1970; Pavićević et al., 2015. After the determination of collected material, it was observed that the highest prevalence of macrofauna representatives from the phylum Arthropoda and Mollusca was found at all examined locations and the species from the phylum Annelida were also collected. Among arthropods, the largest number of species belongs to the class Insecta, with the following orders: Hymenoptera, Diptera, Hemiptera, and Coleoptera. Determination was done at the taxonomic level up to the species level and the results are presented in Table 1.

Table 1. Overview or representatives of Arthropod
Source: Original author's work

Class Insecta	ordo Hymenoptera *Formica rufa*, Linnaeus, 1761 (Formicideae) *Vespa crabo*, Linnaeus, 1758 (Vespideae) *Apis melilifera*, Linnaeus 1758 (Apideae)
	ordo Diptera *Musca domestica*, Linnaeus, 1758 (Muscideae)
	ordo Hemiptera *Aelia acuminata*, Linnaeus, 1758 (Pentatomideae) *Pyrrhocoris apterus*, Linnaeus, 1758 (Pyrrhocorideae)
	ordo Coleoptera *Zabrus tenebroides*, Goeze, 1777 (Carabideae) *Coccinella septempunctata,* Linnaeus, 1758 (Coccineillidae) *Ips amitinus,* Eichhoff, 1871 (Curculionidae) *Phaenops cyanea*, Fabricius, 1775 (Buprestideae) ordo Dermaptera *Forficula smyrnensis*, Audinet-Serville, 1839 (Forficulideae)
Class Diplopoda	ordo Julida *Julus terrestris*, Linnaeus, 1758 (Julideae) *Pachyiulus hungaricus*, Karsch, 1881 (Julideae)
	ordo Glomerida *Glomeris marginata*, Villers, 1789 (Glomerideae)
Class Chilopoda	ordo Geophilomorpha *Geophilus flavus*, De Geer, 1778 (Geophilideae)
Class Malacostraca	ordo Isopoda, Laterille, 1817

All the collected arthropod species are characteristic of surface soil horizons, forest litter and the A horizon (up to 10 cm depth). What has been observed and significantly emphasized is the presence of several groups of phytophagous pests and predators, typically found in agroecosystems - *Aelia acuminata*, Linnaeus, 1758, *Zabrus tenebroides*, Goeze, 1777, and *Coccinella septempunctata*, Linnaeus, 1758. There area large number of yards, private gardens, as well as agroecosystems in the immediate vicinity of the examined locations, which clearly involve the occurrence of these groups of organisms. Additionally, on the basis of pedological analyses conducted in 2020 as a part of the project "Project Program and Management Basics for Memorial Park Čačalica", a deficiency of nutrient elements in the soil and increased acidity were determined. Such characteristics are not a contributing factor to the growth of conifers in the examined locations, which makes them more vulnerable and easily susceptible to parasite attacks.

The species *Aelia acuminata*, Linnaeus, 1758, is a characteristic parasite on most representatives of the Poaceae family, especially the genera *Festuca*, *Poa*, *Agrostis*, *Dactylus*, *Lollium*, and *Bromus*. The *Carabidae* family, with its large number and functionality, represents a dominant group involved in reducing the number of pests in agroecosystems [8, 9]. A typical representative of this family observed at the location of Memorial Park Čačalica is *Zabrus tenebroides*, Goeze, 1777.

One of the most significant economic pests native to Europe and prevalent in Memorial Park Čačalica is *Ips amitinus*, Eichhoff, 1871. The species was collected at the examined locations around the black pine and it primarily parasitizes spruces (*Picea spp*.) and pines (*Pinus spp*.), sporadically firs (*Abies spp*.) and European larch (*Larix spp*.). It is prevalent and cosmopolitan in 16 European countries. This species is listed on Annex IIB Directive 2000/29/EC as a protected species in Ireland, Greece, and the United Kingdom.

The family Coccinellidae, Latreille, 1807, are natural enemies of aphids and play an important role in agroecosystems in ecologically grown crops [10]. The species from this family, which is in the protected category, *Coccinella septempunctata* was observed beneath the pine trees bark (Figure 4). The predatory species *Forficula smyrnensis* was also collected beneath the pine bark.

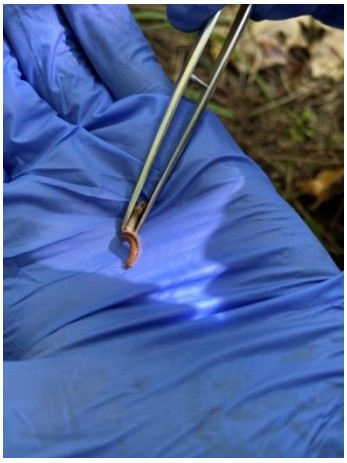

Figure 3. *Julus terrestris*
Source: Original author's work

Figure 4. *Coccinella septempunctata*
Source: Original author's work

All the collected species of millipedes from the classes Diplopoda and Chilopoda (Figure 3) are a characteristic population of the macrofauna in the surface soil layer. From the phylum Annelida, the presence of the species *Lumbricus terrestris*, Linnaeus, 1758, was observed at the examined locations. Considering the recorded representatives of the order Hymenoptera, it is important to mention the cosmopolitan species *Formica rufa*, Linnaeus, 1761. Ants are numerous , diverse and widely distributed from arctic to tropical ecosystems and they are one of the dominant groups of faunal biomass on the planet constituting about 10% of it [11]. Representatives of the phylum Mollusca are shown in Table 2.

Table 2. Overview of Mollusca Representatives
Source: Original author's data

Class Gastropoda	*Helix pomatia*, Linnaeus, 1758 (Helicideae) *Cepaea hortensis*, O.F. Müller, 1774 (Helicideae
	Arion hortensis, A. Férussac, 1819 (Arionideae)

The widely distributed species of snails, *Helix pomatia*, Linnaeus, 1758 were observed at all examined locations. It is a protected species and it is on the Red List of European Fauna (IUCN, CORINE) [12].
It is essential to emphasize that as a part of the results of this study, a species of slugs from the family Arionidae, *Arion hortensis*, A. Férussac, 1819, was identified. The mentioned species represents a significant pest as well as an invasive species in agricultural production and most of the damage to cereal grains in cultivated crops in Europe is caused by the species *Arions sp* [13].
Even more favorable conditions have been created for the ornithofauna because birds are easier to care for and self-sustain as the forest matures and grows.
The recorded presence of bird fauna is shown in Table 3.

Table 3. Overview of Ornithofauna Representatives
Source: Original author's data

Class Aves	ordo Passeriformes *Turdus merula*, Linnaeus, 1758 (Turdidae) *Garrulus glandarius*, Linnaeus, 1758 (Corvidae) *Corvus cornix*, Linnaeus, 1758 (Corvidae) *Parus major*, Linnaeus, 1758 (Paridae)

	ordo Columbiformes *Columba palumbus*, Linnaeus, 1758 (Columbidae)
	ordo Galliformes *Phasianus colchicus*, Linnaeus, 1758 (Phasianidae)
	ordo Piciformes *Dendrocopos major*, Linnaeus, 1758 (Picidae) *Fringilla*, Linnaeus, 1758 (Fringillidae) *Passer domesticus*, Linnaeus, 1758 (Passeridae) *Hirundo rustica*, Linnaeus, 1758 (Hirundinidae) *Delichon urbicum*, Linnaeus, 1758 (Hirundinidae)
	ordo Accipitriformes *Buteo buteo*, Linnaeus, 1758 (Accipitridae)
	ordo Falconiformes *Falco tinnunculus*, Linnaeus, 1758 (Falconidae)

According to the observations made by using the visual method, the most numerous species are *Delichon urbicum* (urban swallow) and *Hirundo rustica* (barn swallow), *Passer domesticus* (house sparrow), *Dendrocopos major* (great spotted woodpecker), which thrives in this location, *Corvus cornix* (hooded crow), *Columba palumbus* (wood pigeon) and others. The beauty of this man-made environment is enhanced by the songs of bird species like *Fringilla* (finch), *Turdus merula* (blackbird), *Parus major* (great tit) and *Garrulus glandarius* (Eurasian jay). Due to the proximity of agroecosystems, the presence of *Phasianus colchicus* (pheasant) is also noticeable. Among more interesting inhabitants of this forest complex are certainly *Buteo buteo* and *Falco tinnunculus*. *Buteo buteo* (common buzzard) is the most common bird of prey in Serbia. The conservation status of kestrels (*Falco tinnunculus*) is “nearly threatened” (IUCN 3.1) [14, 15].

3. CONCLUSION

Due to the diverse and rich diversity, the established research staff and students of the Academy of Applied Technical Studies Belgrade (Department of Applied Engineering Science Požarevac) in cooperation with the Ecological Society "Friends of Čačalica" intensively conduct numerous scientific researches of biodiversity. It is planned to continue the started research, the results of which are presented in this Paper, with the aim of a more comprehensive inventory of the entire faunal biodiversity of this area. One of the advantages of this type of analysis model is, of course, monitoring, that is, continuous monitoring of the existing state and possible changes, all with the aim of protecting and improving this natural place and conserving the biodiversity that inhabits it.

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Student paper

CULTURAL HERITAGE OF ITALY

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Abstract: *The topic of this paper is the cultural heritage of Italy, which is important not only for Italian culture, but also for the entire world cultural heritage. In this, the three crowns of Italian literature are mentioned, namely Dante Alighieri, Francesco Petrarch, and Giovanni Boccaccio. They create the foundations of the Italian language and literature. The importance of the contribution of the three crowns is shown because with them the development of the national language in Italy begins, and until then Latin was the only one in use. The issue of language was very important for the Italian people, and with the works of Dante, Boccaccio and Petrarch, the issue of language began to be resolved, which significantly influenced the further development of culture, literature, and language in Italy. In addition, the paper will clearly show how important the works of the three crowns are for the whole world and represent a universal cultural heritage until today.*
Keywords: Literature, Culture, Dante, Petrarch, Bocaccio

1. INTRODUCTION

In the *trecento*, that is, in the 14th century, communal society disintegrated, and the vernacular entered into literature. Dante Alighieri, Giovanni Boccaccio, and Francesco Petrarch are the most important for the beginning of the Italian language, who were the first to use a language that would be understandable and accessible to everyone. Namely, until that moment Latin was the language spoken on the Apennine peninsula, and there were, as today, many dialects, understandable only to people in the regions where they are spoken. The three crowns of Italian literature will significantly influence the development of the Italian language.

Figure 1. *Dante, Petrarca, Boccaccio*
Source: www.ravennatoday.it

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2. DANTE ALIGHIERI

Dante Alighieri was born in 1265 in Florence and died in 1321 in Ravenna. He was the greatest poet of the Middle Ages and represented the culmination of the medieval worldview and the basis of the modern Italian language. If we look at the late Middle Ages, most poetry was in Latin and was only available to the rich and educated. Dante was the first to advocate for writing in the *volgare*, which is why his works *The New Life* and *The Divine Comedy* stand out because they were published in Tuscan. The *New Life* is a work he wrote when he was inspired by the platonic love of Beatrice, and it was written in the spirit of the sweet new style (*dolce stil nuovo*).
Dante's *Comedy* represented plurilingualism in language and contained about thirty thousand words. As Dante was key to the formation of the modern Italian language, many called him the father of the Italian language precisely because of this. In addition, in Italy he is addressed as *il sommo poeta* - the supreme poet. *The Divine Comedy* depicts the holy trinity as it consists of three parts: Hell, Purgatory and Paradise. The poet gave the name comedy because it is a narrative work in verse that begins sadly and ends happily. The very attribute divine was added by Boccaccio. Dante is the most important name in the history of Italian literature because he was the first to study the *volgare*, that is, the vernacular. The key work, besides the *Divine Comedy*, is *De volgari eloquentia*. It was written in Latin and in this work, Dante defended the Vulgar. In addition to literature, Dante was also politically active. In order to be able to do the same, Dante started to study as a pharmacist and doctor. At the age of 18, Dante met Guido Cavalcanti, Cino da Pistoia and Brunetto Latini. Together they became representatives of *dolce stil nuovo*.

Figure 2. *Dante Alighieri*
Source: www.worldhistory.org

Dante's importance is also reflected in the fact that he combined religious themes with historical-political ones. By combining these two themes, Dante has placed himself in the position of an observer of this world. In this way, Dante represents the link between heaven and earth [1].
It is noted that Dante possesses stylistics that were not seen in any European language until then. His ability is reflected in the fact that he brings these stylistic figures into mutual relation. Although there were writers before Dante, his language that he used really left a mark and from the very beginning he composed a richer and better expression than his predecessors, which left a mark on the further development of the Italian language [2].

Dante is the name that mentions it as the beginning of the development of the *volgare*, that is, the Italian language that will be accessible to everyone and that everyone will be able to understand. With that, he opened the door to his successors who followed his path and thus reached their goals and made literature accessible to all layers of society.
His goal was for the reader to see what he saw then, and that's why his language is very simple. He uses very few metaphors. He mostly used allegory because he wanted to convey his thoughts to other countries, outside of Italy itself, and this method of allegory contributed to his simple expression being heard as far as possible [3].

3. FRANCESCO PETRARCA

Francesco Petrarch was born in 1304 and died in 1347. He was an Italian poet who wrote in the vernacular and in Latin. He was crowned with a laurel wreath in Rome and thus became *poeta laureatus*. He also dealt with the problem of language, like Dante. Most of his works are in Latin because he believed that these were more sublime works and that he would be most famous for them. He was a distinct perfectionist and re-read his works and revised what had already been written. His most important work is the Canconiere, which is a collection of songs and is a characteristic of the Renaissance. Petrarch had a great influence on the entire epoch and on later generations who were called Petrarchists. In relation to Dante, Petrarch had unilingualism in his work. He was looking for an ideal form and threw out all the forms that he considered not useful for one grammar and one poetry. Like Dante, Petrarch also had his muse. Her name was Laura de Noves.

Figure 3. *Francesco Petrarca*
Source: www.florenceitaly.org

Petrarch was a writer who was driven and inspired by love. His great influence can be seen in the refinement of language and poetry. He used different forms, but he was still recognizable by it. He significantly influenced the development of Italian poetry, including his later followers – Petrarchists [1].
Petrarch is certainly the poet who most influenced the development of Humanistic and Renaissance culture. He becomes the first great court poet in Italy. Although he was in favor of Humanism, he often turned to the Middle Ages and looked for answers in classical Roman culture [4].
Canconiere represents the intertwining of the real and the ideal, the instinctive and the spiritual, and despair and hope alternate. Petrarch conveyed his love for Laura through the poetic word, through the poetic myth. In his work, the aesthetic function and the very method of the creative process can be observed [5].

4. GIOVANNI BOCCACCIO

Giovanni Boccaccio was born in 1313 and died in 1375. He was a writer and humanist. Petrarch had a great influence on Boccaccio's spiritual development and literary work. His works are important because in them he combines life in castles with the city environment. Boccaccio is the progenitor of Italian prose. He was a great admirer of Dante, and thus Boccaccio turns to multilingualism, i.e., a variety of language that adapts to the interlocutor. Through his works, Boccaccio also shows the realistic society of the three-year-old and in this way, he simultaneously praises and criticizes.
The Decameron is the first Italian narrative work. The plot begins with a description of the black plague in Florence, which raged in 1348.

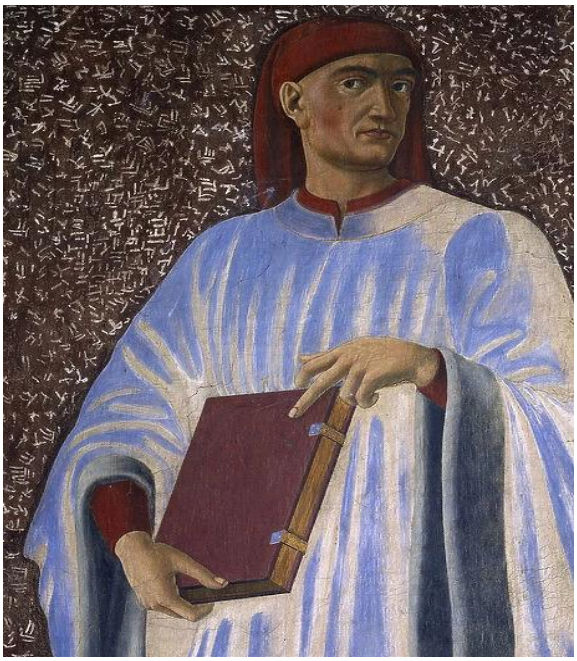

Figure 4. *Giovanni Boccaccio*
Source: www.brown.edu

Unlike the others, Boccaccio is the first to master sensory phenomena. He has a conscious understanding of art and encompasses it in one language. Boccaccio's linguistic art is based on the rhetorical shaping of prose, and the style borders on the poetic. Boccaccio created Italian artistic prose and the first prose of post-antique Europe. Through his work, Boccaccio presents teachings about love and nature. He represents real characters in his work who live on earth [2].
If we look at it from the genre side, it can be concluded that Boccaccio introduced many genres through his work, such as legends, parables, Provençal novels, Italian Novellino, chronicles, novels of chivalry. In addition, he introduced ancient and folk traditions. Thanks to his humanistic position, a broader view of the world emerges [6].
As it all began with the story of the spread of the national language, Boccaccio's Decameron is presented as a realistic depiction of a society in various aspects of life. That world is real and earthly, and thus the work itself is closer to the readers. The greatest value of his work is reflected in the harmony between the material and the moral, which was transformed into poetry [4].

5. CONCLUSION

The paper shows the importance of the three crowns of Italian literature, Dante, Petrarch and Boccaccio. From the data already mentioned, it is clear that these three great men significantly influenced the creation of the Italian vernacular, but not only that, but they also left a significant mark on other European literatures.

In the fourteenth century, it was very brave to come forward with the view that Latin should be reduced in use and that a language that would be understandable and accessible to all should be used more. The Church had a great influence in that period, and its official language was Latin, which is still maintained in the Catholic Church today. In addition, Dante, who started writing in the vernacular, was remembered for his beginnings and struggles that proved to be worth every effort.
It was very brave and ahead of its time to fight for the *volgare* and look for a common language. These three writers represent the Italian spirit that has lasted until today. Not only the language is learned from their works, but they brought us closer to the period of life in which they lived and thus left their mark in history, culture and literature.
Dante, Petrarch and Boccaccio represent a turning point in the creation of the Italian language as unique and comprehensible to all, and that is why their work is of exceptional value and importance, both for Italian and for all European literature, because they proved that literature is the best way to reach all people.

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Student paper

ITALIAN CINEMATOGRAPHY

Sara Ilanković[1], Faculty of Philosophy, University of Novi Sad

Abstract: *The paper presents Italian cinematography through different historical periods. Each period significantly influenced the further development of both film and other cultural spheres in art. The work talks about the important representatives of each movement of Italian cinematography and gives the essential characteristics of that creative period. Similarities or differences in film art throughout the centuries were determined by the comparative method. The paper highlights the most important names of Italian cinematography, especially directors and actors who have left a mark on culture even today, which significantly influences contemporary cultural creations. The aim of the work is to bring closer the importance of film in Italy, but also in the world, and thus point to an important sphere in the development of everyone. The work is based on historical facts that describe certain eras, but also on different attitudes and opinions regarding topics that appear in Italian cinematography.*
Keywords: Italy, cinema, film, culture, history

1. INTRODUCTION

Italy represents many cultures. The Apennine peninsula is responsible for many cultural treasures that have left their mark on the whole world, starting from early history and continuing to the present day. Italy possesses all seven arts and from each we can extract world famous and important works.

Figure 1. *Mole Antonelliana, Torino*
Source: www.museocinema.it

Here is also the film as an art that has made Italy famous all over the world. Different genres, actors and directors had a great influence on the development of film and this is reflected even today. The importance and traces of Italian cinema can be seen in many productions. Also, it is important to note that Piedmont is one of the regions that has great importance for the development of the film industry. Thus, the capital of this region, Turin, has the Museum of Italian Film, Mole Antonelliana, which even in modern times revives all those artists who are important for the identity and development of Italian cinema. Movies are certainly sources of various information and illustrate the life of a nation, state or a certain era in which it was lived. Italian film represents a unique core and deals with expressive processes that are connected by forms, expressions, general places and myths. Italian cinematography shows that it has no desire to be industrialized, nor to conquer the future, but connects time with the present and other arts such as literature, theater and other artistic traditions [1].

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2. LANGUAGE OF ITALIAN FILM

When looking at the language of the film, that linguistic material can be divided into three categories:

1. The language of the film - the oral material is on its own;
2. Language in the film - shows the degree of influence of everyday language on the film;
3. Language from the film - the contribution of the film to everyday speech.

In addition to this, there are also divisions of languages through historical periods. In those years, changes occur from a linguistic point of view, and thus it can be divided into three parts:

1. Oral film (1896-1905);
2. Written film (1905-1930);
3. Reproduced film (from 1930 onwards).

Oral film is primarily associated with films that were intended for entertainment in the squares. This custom dates to the 19th century when there was still no sound and subtitles were read publicly. The second period, i.e., the written period, is characterized by the insertion of written text during film scenes. If the films were shown throughout the country, there were subtitles in Italian [2].

3. FILM AND TELEVISION

Because historical and social reasons, film and television in Italy are very closely related. The need to find a common language required the showing of television content, including foreign content, in Italian. When television was created, there was also an explosion of film offerings, which was greater than in other countries. In the 1960s, the film received a place of honor on television. Many authors have proven themselves at their best by documenting on television. There are Bernardo Bertolucci, Ugo Gregoretti, Gianni Amelio, Ljiljana Cavani and many others. At that time, Rai also allowed directors from the theater to show themselves on television and Strehler and Skvarcina became famous there. Some directors come to television just from the movies and there are Renato Castellani, Vittorio Cotafavi, Roberto Rossellini, Franco Rossi. In the 1970s, the first television films appeared, such as *Stregone di città, Semmelweis* [2].

Figure 2. *La vita è bella (1997)*
Source: www.britannica.com

If we talk about topics that appear on television content, they are usually topics that will be interesting and close to the viewers. The viewership of certain content depends on who it is intended for and how much it will interest the viewers. From the very beginning of cinematography, it was important to choose a theme that would be seen every day and that would make viewers look forward to the sequel.

Screenwriters do not possess any scientific instrument with which they can really study a society. The creators of the feature program adopt descriptions and behaviors in society and translate them into current stories and thus directly transmit social circumstances through television [2].

4. THE IDENTITY OF ITALIAN CINEMA

The screen becomes an opportunity to change the history and geography of the nation. Thanks to D'Aanuncio, Gavacconi, Caserini, Gallone and Pastrone, the historical film starts to conquer the world audience. These films conveyed Italian history and culture, but also talked about the coming war period. In the period between 1912 and 1915, the films Last Days Of Pompeii, Cleopatra, Salambo, Julius Caesar, Spartacus were made [2].

Figure 2. *Gli Ultimi giorni di Pompei*
Source: www.raiplay.it

Italian producers set out to conquer the audience using the combined power of masters of literature and art: Dante and Gabriele Rossetti, Giotto and Dore, Manzoni and Pietro Cosa, Shakespeare and Puccini, Verdi and Verga and many others. The combination of literature and film gives success to Italian cinematography, and it develops rapidly. Literature and other arts become vehicles for better success [2].
If we look at neorealism, its goal was to cover the territory of Italy. With this step, he strives for universality. The protagonists then become people who were invisible until then. It is believed that the film can tell all the stories of everyday life and describe the different lives of people found throughout Italy [2].

5. CONCLUSION

The work shows the beginnings of Italian cinematography. It talks about the origin and development of film, television and the film industry in general in Italy. This is a topic that can be viewed from multiple angles, a topic that has many names that have influenced Italian film and television. This

work shows only some of the important producers who were important for further development. The importance of literature and other arts that are connected with the film and thus make it special is shown.

The importance of Italian cinema can be seen even today because, both in Italy and in the whole world, the first names of Italian cinema left their mark. Movies are the best way to learn about the culture and mentality of a people, and they are still very important in this regard.

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MECHATRONICS

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TOWARDS A THEORY OF DIGITAL TWINS: FUNDAMENTAL DEFINITIONS

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Abstract: *Digital twins are not simply conceived as simulation models of their physical counterparts, differently they are developed as means for better understanding and control of the physicsl entity. A unifying theory that systematically defines the core functions bridging the gap between the digital and physical entities is missing. This absence represents the main limitation of digital twins and is also cause of misunderstandings. This work describes 17 fundamental definitions of digital twins to fruitfully work in close interaction with their physical counterparts. Functions are described in terms of scope, inputs, and outputs.*
Keywords: digital twin, simulation, smart manufacturing, industry 4.0

1. INTRODUCTION

The variety of functionalities that digital twins can potentially offer is very large encompassing different application fields from aerospace to urban traffic [1]. This extremely large spectrum of digital twin use cases has caused a multitude of scientific contributions and market studies from several disciplines, each one with its own terminology, models, and approaches [2,3]. Also, digital twins are subject to international standardization efforts [4]. However, a general theory describing the relationships among digital and physical twins is still missing. Despite the rapid proliferation of digital twin applications across various domains, a significant gap exists in the form of a comprehensive theoretical framework that depicts the services of digital twins and their physical counterparts. This absence becomes more critical in light of the diverse terminologies, models, and disciplinary approaches that currently characterize the emerging paradigm on digital twins. Thus, this paper aims to define the fundamental functions that establish the connection between physical entities and their digital counterparts. In this work, we try to be as general and independent from any application domain with the aim to start building the theoretical background of a digital twin theory. The structure of this paper is shortly described. Next section contains a set of general definitions to delineate digital twins and their physical counterparts in their main characteristics. Section 3 describes the functions that digital twins use to provide their services. Conclusions and outlook are drawn in the last section. Readers with interest in deeper knowledge of the features, models, and services of digital twins are referred to the recent advanced tutorial contained in [5].

2. GENERAL DEFINITIONS

This section introduces the fundamental concepts of physical entities and digital twins, establishing the foundational understanding necessary for the subsequent theoretical development.

2.1 Physical entity

Digital twins were conceived to enhance the management of tangible real-world objects. To better define the boundary the physical counterpart of a digital twin, the following definition is proposed:

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*Definition 1 (**Physical entity**). A physical entity is a material object that evolves or operates with time.*

A physical entity encompasses products (e.g., engines, valves), systems (e.g., machine tools, production systems, logistic systema), environments (e.g., buildings, lakes), and biological systems (e.g., parts of the human body, plants). Broadly, digital twins model resources. Although immaterial entities like stock markets could potentially benefit from digital twins, we exclude them from this study for the sake of simplicity. This definition extends the ISO standard [5] by incorporating the concept of temporal evolution or operation of the physical entity. Indeed, a physical object that remains static does not necessitate the support of a digital twin.

Physical entities, or simply entities hereafter, possess properties or attributes that characterize them, as detailed in the following definition:

*Definition 2 (**Property**). A property of a physical entity is the information about its characteristics.*

Properties encompass geometrical attributes (e.g., shape, macro and micro dimension), physical attributes (e.g., weight, colour), chemical attributes, mechanical attributes, etc, depending on the entity's nature. For sake of generality, properties include variables, attributes, and constant parameters. As per Definition 1, entities can be time-dependent due to degradation, interaction with other entities, or internal processes. This implies that entities may modify some of their properties and behavior over time; observing the same entity at different time intervals may reveal variations.

A pivotal concept useful for distinguishing among different situations of the same entity is the concept of state:

*Definition 3 (**State**). The state of a physical entity is the information encapsulating its dynamic status through a set of variables, attributes, and parameters.*

The state of a physical entity can change continuously with time or discretely according to its nature. For instance, a tank's liquid level changes continuously, while a robot's software reconfiguration could be a singular event.

Observing a physical entity's state is challenging due to location and cost constraints. Satellites orbiting in space and offshore wind towers cannot be easily accessed. In manufacturing, halting a production line for machine degradation assessment might not be efficient. To overcome these constraints, sensors are typically employed to infer the entity states. Sensors are devices that observes and measures a physical property of a natural phenomenon or process and converts that measurement into a signal [5]. For standard digital twin applications, assuming fully observability of the state is often impractical, making partial observability the norm. When the state is not observable, the term *latent state* is also used to indicate the lack of observability. Simple digital twin applications benefit from accurate sensors, enabling continuous state assessment of physical entities.

In general, the physical entities relevant for digital twins provide functions for the external environment. For instance, electric motors generate shaft torque, manufacturing systems produce goods, city buses provide transportation. Throughout their operation or natural evolution, entities release traces of information, referred to as the footprint of the physical entity as introduced in the following definition:

*Definition 4 (**Footprints**). The footprints of a physical entity are the information regarding its manifestations.*

Examples of footprints are the heat dissipated by the electric engine and the torque it provides, the number of parts produced by the manufacturing system with their quality measure, the carbon emissions of the bus with the time to reach the destination.

Depending on the nature of the physical entity, footprints may be sensed, collected, and digitized for analysis. The subset of the acquired footprint is termed observable as specified in the following definition:

*Definition 5 (**Observations**). Observations are the sensed footprints of a physical entity.*

Observations are clearly a subset of footprints, and not all the footprint of a physical entity can be observed, nor they need to necessarily be observed. When the state is observable or partially observable, sensor measurements of the state are part of the observed footprint.

2.2 Digital twin

Grieves (2014) introduced the first concept of digital twin in the early 2000s [6]. In the proposed concept, the main features were the continuous synchronization between physical entity and digital twin, the granularity of the analysis level, and the long term coupling of the two twins along the whole entity's lifecycle. Since then, many other definitions have been proposed in recent literature to emphasize specific digital twin features such as the integration and interconnections of digital twin's elements, the digital counterpart, the predictive capabilities, and the descriptive power. Barricelli et al. classified 75 papers according to their digital twin definitions from manufacturing, aviation, and healthcare domains [7]. Other definitions of digital twins that are more customized for manufacturing, aviation, and healthcare domains can be found in [8,9,10]. A simple and context independent definition of digital twin is proposed in the following:

Definition 6 (***Digital Twin***)*: a temporally updated digital representation of the physical entity*.

This definition comprises the three fundamental features of digital twins [5]:

- *Digital*. The increase in computational power, data accessibility, and availability of modeling software environments, have created the ideal conditions to develop digital representations of physical systems affordable with cost and time. This feature is universally recognized by literature, i.e., the digital twin is a set of instructions coded in a computer program to describe the physical system behavior.
- *Descriptive*. The main purpose of the digital twin is to provide information and knowledge about the physical entity, e.g., about its state, its emerging behavior, its trends, or anything that may help the manager of the physical entity to understand and improve its performance.
- *Synchronous to physical*. The digital twin should be able to describe the physical entity at any moment. This feature implies the state changes of the physical entity being transferred to the digital twin in real time.

Digital twins are used to emulate the behavior of physical entities in specific conditions, to make predictions, estimate future performance, and more in general to enhance the control of entities. This process is a computer experiment in which the digital twin uses its models for producing quantitative results. These results are termed emulation results as delineated in the following definition:

Definition 7 (***Emulation results***)*: The emulation results are the output of the digital twin obtained through the replication of the physical entity behavior in a controlled digital environment*.

In essence, digital twins are software applications that manipulate sensed data collected from the physical entity, use digital models to make analysis, and communicate their response to entities and environment. Thus, digital twin models must be multidimensional encompassing the current knowledge about the physical entity, the digital representations that can be used to provide functions, the data and the communication for their transfer [5]. The following definitions delineate the dimensions of a digital twin model.

Definition 8 (***Knowledge model***)*: A knowledge model comprises the information concerning the characteristics and behavior of the physical entity*.

Knowledge models represent the most updated understanding of physical entities. Digital twins help to improve these models through the observations and analysis collected and performed throughout the operation or natural evolution of physical entities. This knowledge can be used entirely or partially to represent the behavior of physical entities in digital models depending on the granularity requested by the analysis. The following definition is taken from the ISO standard [4]:

Definition 9 (***Digital model***)*: A digital model is a data element representing a set of properties of an observable physical entity*.

The most intensive use of digital models is for simulating the entity behavior in specific contexts. In general, multiple digital models can be used to describe the physical entity, each dedicated to a specific behavior. The choice of which model to use depends on the purpose of the analysis. Digital models produce quantitative analysis of possible entity behaviors. Parameters fitted using knowledge models are used in digital models.

An element that physical entities and digital twins have in common is data. In fact, physical entities generate data through their emitted and sensed footprints. Digital twins make use of entity observations to build the knowledge necessitated by digital models to replicate the behavior of physical entities. As a consequence, a data model is needed and a concise definition is needed:
Definition 10 (***Data model***)*: A data model is a structured representation of data and the relationships between data elements in a digital twin*.
Since data flow from physical to digital and in most advanced applications from digital to physical, the presence of a communication model in digital twins is mandatory.
Definition 11 (***Communication model***)*: A communication model is a structured representation of how information is transmitted, received, and interpreted between the physical entity and the digital twin.*
The communication model comprises the connection protocols for data transfer, and it largely depends on the application context. The frequency of connection can be high in the guide of autonomous vehicles, medium in a fish farm, or low in a production scheduling of a cast iron plant. Cybersecurity must also be taken into account because sensible data may be exposed to malware during their transferring.

3. FUNCTION DEFINITIONS

This section provides definitions for the functions characterizing physical entities, digital twins, and their interactions.

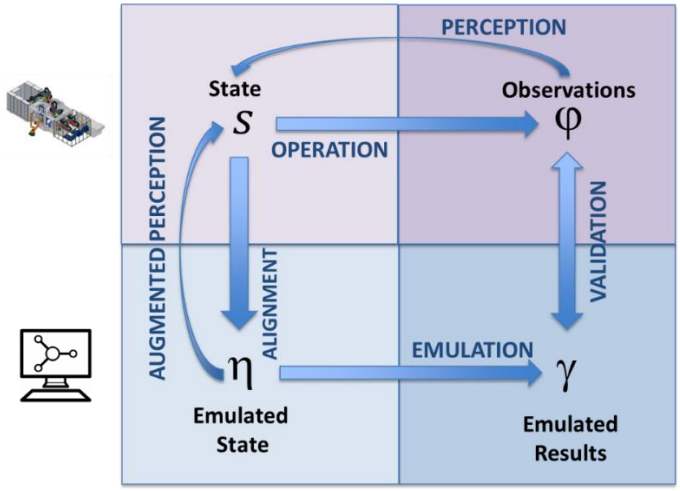

Figure 1. *Functions of physical entity (top) and digital twin (bottom).*

3.1 Physical entity

The functions in this section only characterize physical entities and are typically used without digital twin applications.
Definition 12 (***Operation***)*: The operation function f models the evolution of the physical entity that releases observed footprints φ from a specific state s. Formally, $\varphi = f(s)$.*
Through the support of the digital twin it is possible to control the physical entity, this is represented with the control variable u. To consider that physical entities frequently interact with the external environment, variable d is used to capture disturbances and noises from the environment. Making explicit controls and disturbances in the operation function can be useful for a better understanding of the physical entity $\varphi = f(s; u, d)$.
From the definition, it is evident that the non-observable footprints are not of interest, or are costly to observe, or may not be measurable at all. For these reasons, only φ rather than the whole footprint appear in function f. Key performance indicators such as cost, quality, efficiencies, and effectiveness

can be calculated using the emitted observations. If the state, or part of it, is observable then it can be added to the observation vector φ.
Modifying function f means changing the physical entity. When modification is made to maximize a performance indicator of the physical entity, we say the physical entity is improved. Optimization and control are embedded in variable u. For instance, a pure reinforcement learning approach uses observations φ to find optimal values for u. Using digital models in optimization and control corresponds to simulation-based approaches.
Definition 13 (***Perception***)*: The perception function h models the process of state inference based on the observed footprints φ. Formally, $\hat{s} = h(\varphi)$ where φ is used to infer the latent state s.*
Specifically, function h helps to make a guess about the actual state s of the physical entity. Perception is typically used in robotics and agent theory to infer the status based on observations.

3.2 Digital twin

A major use of digital twins is to replicate the physical entity behaviors for retrospective analysis, online optimization and control, and predictions. The following definition delineates the emulation function of digital twins:
Definition 14 (***Emulation***)*: The emulation function g models the process of physical entity replication in a controlled digital environment. Formally, $\gamma = g(\eta)$ where η is the emulated entity state and γ the emulated results.*
Modifying function g means changing the digital models of the digital twin. When modification is made to maximize a performance indicator of the physical entity, we say the digital twin is used to simulate changes of the physical entity in the digital environment. A model of noises and disturbs might be necessary to better emulate the behaviors of the physical entity. To consider the control of the entity, digital models make explicit the control variable u and this can also be reflected in the function together with the disturb $\gamma = g(\eta; u, d)$.
Emulation is the main pillar of digital twins. Through emulation, computer experiments can be executed in the digital world. This avoids experimenting with the physical entity and prevent from performance losses. Benefits can be knowledge improvement (the knowledge model is improved as the digital twin learns), control, and optimization of the physical entity.
Construction of emulation functions can be automated leveraging techniques such as system identification and process mining that build formal models from observations φ. With the same purpose, machine learning approaches builds nonlinear regression functions that explain the observations released by physical entities.

3.3 Interaction physical entity vs digital twin

The functions in this section only characterize the interactions between physical entities and digital twins. Synchronizing digital to physical is mandatory for digital twins because it allows a continuous alignment of the digital entity with the physical one. The following defines the alignment function:
Definition 15 (***Alignment***)*: The alignment function l synchronizes the state of the digital twin to the entity's state s. Formally, $\eta = l(s)$.*
Since the entity's state might be non-observable, the alignment can be executed using the perceived state $\hat{s}$ instead of the latent state s. If the entity's state can be observed, even after having incurred a cost, then the observed state is used for synchronization [11].
Digital twin models must always be valid to avoid jeopardizing its contribution. A validation function is needed to execute online validation of the digital twin models:
Definition 16 (***Validation***)*: The validation function checks the validity of digital models by comparing observations φ to emulated observations γ.*
Validation encompasses digital models, parameters, and variables used by the digital twin for emulation.

Digital twins can also be used for perception through execution of computer experiments as described in the following definition:
Definition 17 (***Augmented Perception***)*: The augmented perception function* m *uses the digital twin emulation to perceive the entity state. Formally,* $\hat{s} = m(\eta)$ *where* η *is the emulated state.*
An improved state perception leads to a better control and for this reason augmenting perception can be relevant in some applications.
These interactions between the physical entity and the digital twin underline the synchronization, alignment, and validation processes that ensure the accuracy and effectiveness of the digital twin's emulation capabilities.

4. CONCLUSION

This paper is a seminal work for putting the basis of a digital twin theoretical framework. The main result is a set of 17 definitions that comprise general concepts as well as the fundamental functions that are used by the digital twin to provide services. These definitions will help to better develop digital twins and their related services. The main limitations of this work are the lack of an illustrative example that would help to transfer the contents and the absence of details in the description of the functions. These limitations will be tackled in future works together with a description of related research challenges.

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MECHANICAL ENGINEERING. ECOTOURISM AND RURAL DEVELOPMENT.

AN ANALYSIS OF A PROCESS OF DECENTRALIZED CONTROL OF A ROBOT POWERED BY A DIRECT CURRNET MOTOR

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Abstract: *The subject of this paper is the analysis of the process of decentralized control of the movement of the joint of a robot powered by a direct current motor. In the case of this control, a double integrator with local speed coupling is used. In the control facility itself, more control variables are observed and such control is called cascade where the inner loops have the best regulation, while the speed decreases when going to the outer loops. After the calculation, the transfer function of the coupled ratio of the internal contour is obtained, and then the analysis of the transition process was performed through the display of relevant indicators. Regardless of which automatic control synthesis method is applied, it is important to know the poles of the system that are closest to the imaginary axis, i.e. the dominant poles. The transfer function of the control object is analyzed from the point of view of determining overshoot, delay time, rise time, fall time, the moment of overshoot occurrence, oscillation period, phase lead and gain lead.*
Keywords: Robotics, Direct current motor, Mechatronics, Control systems, Synthesis

1. INTRODUCTION

Making the movement of the robot has a lot of specifics, unlike the control of other automatic control systems. When it comes to controlling the movement of the robot, it can be free, for example when the top of the robot moves freely in space, and contact when the robot maintains contact with the environment during movement, [1]. Compared to linear equations with one input and one output that occur in automatic control models, the dynamic model of robot motion is far more complex and is represented by a second-order matrix differential equation, [2-3]. The dynamic model of the robot's movement is highly non-linear, and in case the robot has rotary joints, then the fields in the matrices contain trigonometric expressions as a function of the current position of the joints [4-5], as well as the positions of the joints' speed, which represent centrifugal and centripetal forces, i.e. Carioles forces. It should be taken into account that since the robotic mechanism changes its inertia during its movement and represents a kinematic chain, the movement of any joint has an impact on the load on the other joints. All these mentioned factors, as well as the fact that the joints of the robotic system move simultaneously, indicate that the management of a robotic system of the kinematic chain type is one of the most complex management tasks. When moving the top of the robot regardless of whether it is carrying a tool or not, internal and external coordinate management is used. When controlling the internal coordinates, a closed system of automatic control is formed, and in the return branch there is a measuring device that measures the positions of the joints, based on which an error signal is created, which should be as small as possible in order to achieve the desired movement of the joints, i.e. the top of the robotic system. The disadvantage of this approach is manifested in the fact that the position vector of the top of the robot is not measured directly because it does not participate in the formation of the error signal, which can be overcome if the management by external coordinates is applied, where the error signal is formed on the basis of the given reference movement and the measured realized movements of the top of the robot.

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In this paper it is applied the analysis of the process of decentralized control of the movement of the joint of a robot powered by a direct current motor.

2. DECENTRALIZED MODEL OF ROBOT DYNAMIC

In the literature [6-7], the model of the robot system which is usually presented includes only the dynamics of the mechanical structure of the manipulator, where the driving forces and moment represent the input to the model, and the output is the position of the joints. A dynamic model of actuators in the form of electric motors or pneumatic or hydraulic cylinders is used to create driving forces and moments, [8-9].
The actuators are placed directly in the joints, or they are placed in those positions where the dynamic properties of the robotic system will be preserved. The robot as an object of a closed system of automatic control consists of three subsystems, which are the actuator, transmission and manipulator, [10-11]. The transmission from the actuator to the joint of the robot is carried out via belt transmission, screw spindle and similar forms of transmission, [12].
A complex mathematical model of robot behaviour, in addition to the manipulator model, should also contain actuator and transmission models, whereby the output from the model represents the joint position vector denoted by q(t). In the literature, it is often the case when a direct current motor with a permanent magnet is used for the actuator, that it is placed directly in the joints of the robot, where the energy is transferred from the motor to the joint via a reducer. When applying the reducer, the dynamics model is linear and stretched, and the dynamics of the engine becomes dominant in relation to the joints. In the decentralized control of an industrial robot by joint movement, the system itself is considered linear, while the nonlinear coupled part is viewed as a disturbance, and the control of the robot is reduced to n individual joint control tasks, so that the management of a multivariable system is reduced to the management of a single joint with one input and one output.
The decentralized robot dynamics model is given by the following equation, [6]:

$$\tau = \bar{H}\ddot{q} + F_v\dot{q} + d(q, \dot{q}, \ddot{q}) \tag{1}$$

where $\tau(t)$ is vector of generalized forces or moments, $\bar{H}$ is constant diagonal matrix containing the averaged values of the joints' own inertias, $q(t)$ is vector of generalized coordinates, $\dot{q}(t)$ is vector of generalized speed, $\ddot{q}(t)$ is vector of generalized acceleration, and F_v is the diagonal matrix containing the coefficients of viscous friction for each joint of the manipulator.
Equation (1) represents a linear uncoupled system, and the problem of controlling an industrial robot is reduced to n individual tasks aimed at controlling one joint. Taking into account that $q(t)$ represents the coordinates of the joint position of the robot, when displaying the structural block diagram of the linear model of one joint, it is observed that the feedback loop is closed according to the achieved position of the joint.
The desired value of the joint position in a closed automatic control system is a reference value in the mark $q_{ref}(t)$, the part of the system that is framed by a broken line is an object, and the influence of the rest is seen as a disturbance and is marked with d.
Structural block diagram of the linear model of one joint is shown in Figure 1, [6].

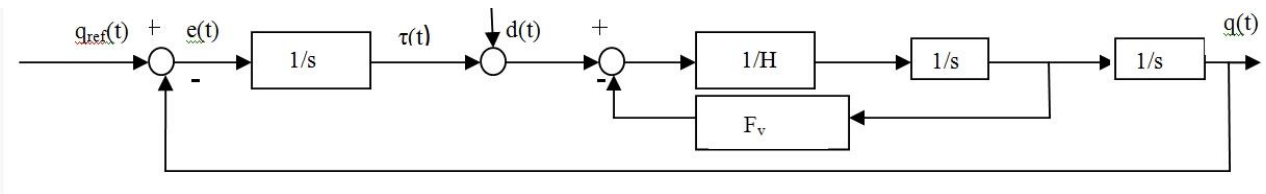

Figure1. Structural block diagram of the linear model of one joint [6]

The transfer function of an object can be shown in the form:

$$W_o(s) = \frac{K_0}{s(1+sT_0)} \tag{2}$$

where K_o is the gain and T_o is the time constant of the object:

$$K_o = \frac{1}{F_v}, T_o = \frac{\bar{H}}{F_v} \tag{3}$$

The transfer function of the entire system is shown by the following formula:

$$W(s) = \frac{W_{gg}(s)}{1+W_{gg}(s)} = \frac{\frac{K_o K_p}{T_o}\left(s\frac{K_D}{K_p}+1\right)}{s^2+s\frac{K_o K_p+1}{T_o}+\frac{K_o K_p}{T_o}} \tag{4}$$

where K_p is the proportional and K_D is the differential action gain. It is observed that the denominator of the transfer function of the system is of the second order and that the coefficients depend on the parameters of the PD regulator.

3. ASSESSMENT OF DYNAMIC BEHAVIOUR IN THE TIME DOMAIN

Primarily, a certain quality of dynamic behaviour is required from technical systems, which is manifested through bounce and/or frequency response indicators. The poles of the transfer function of the system that are closest to the imaginary axis in the complex plane *s* have a decisive influence on the appearance of the transition process, and they are called dominant poles, and if the system is of a higher order, then the influence of the poles, whose real part is six times greater in absolute value from the real part of the dominant poles to the transitional process can be ignored.
Dominant pole pair for robot system is:

$$s = -2 \pm j8 \tag{5}$$

The complex number *s* can be represented as follows:

$$s = \sigma + jw, j^2 = -1 \tag{6}$$

where σ represents the real part and *w* the imaginary part of the complex number *s*.
In polar coordinates, if the Euler form of the complex number is used, it can be written:

$$|s| = \sqrt{R_e^2(s) + I_m^2(s)} = \sqrt{\sigma^2 + w^2} = w_n^2 \tag{7}$$

where w_n is the natural frequency of the system.
Considering equations 5, 6 and 7, the natural frequency of the system can be expressed as:

$$w_n = \sqrt{\sigma^2 + w^2} = \sqrt{4 + 64} = 8.24s^{-1} \tag{8}$$

and the system damping is given by:

$$\varsigma = \frac{\sigma}{w_n} = \frac{2}{8.24} = 0.242 \tag{9}$$

The dominant time constant T_d is:

$$T_d = \frac{1}{|\sigma|} = \frac{1}{|-2|} = 0.5s \tag{10}$$

and the time of calm T_s is:

$$T_s = \frac{4}{\varsigma w_n} = \frac{4}{0.242 \cdot 8.24} = 2.0s \tag{11}$$

The moment of occurrence of the leap is:

$$t_{\Pi} = \frac{\pi}{w_n\sqrt{1-\varsigma^2}} = \frac{\pi}{8.24\sqrt{1-0.242^2.}} = 0.392s \tag{12}$$

The oscillation period is:

$$T = 2 \cdot t_{\Pi} = 0.785s \tag{13}$$

4. CONCLUSION

The aim of this paper is the analysis of the process of decentralized control of the movement of the joint of a robot powered by a direct current motor. It is presented the decentralised model of robot dynamic and a double integrator with local speed coupling is used. The problem of controlling an industrial robot is reduced to *n* individual tasks aimed at controlling one joint. Structural block diagram of the linear model of one joint is shown and the transfer function of industrial robot is calculated. After the calculation, the analysis of the transition process is performed through the display of relevant indicators. The dominant poles are chosen, and the analysis is presented from the point of view of determining overshoot, delay time, rise time, fall time, the moment of overshoot occurrence, oscillation period, and phase lead and gain lead. The obtained values are within satisfactory limits for this stable industrial robot system.

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PRIMARY CRITERIA FOR SELECTING GEARBOXES FOR AXES OF 6-AXIS INDUSTRIAL ROBOTS

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Abstract: *The choice of mechanical power transmissions is one of the key tasks in robotics engineering. Their characteristics largely affect the final performance of industrial robots. Since each axis has a specific function, each one of them needs a different gearbox. This paper analyses the main factors to be considered when selecting gearboxes for a 6-axis robot.*
Keywords: 6-axis industrial robots, high precision gearboxes, selection criteria

1. INTRODUCTION

The fourth industrial revolution brought about tectonic changes in large industrial systems, especially in electronic, automotive and metal processing systems, where robots perform various tasks such as material transport, machine servicing, welding, polishing, painting, assembly, control, packaging, sorting, palletizing... [1,2,3,4]. In order to perform most of these tasks, the robot needs to have six degrees of freedom, three for positioning and three for orientation of the end effector in space [5]. Since the rotational speed of the actuator is high compared to much slower mechanical rotation of the joints, it is necessary to significantly reduce the rotational speed and increase the torque. This is achieved using gearboxes, which greatly affect the final performance of industrial robots. According to available research data, gearboxes account for as much as 35% of the total robot costs, actuators account for 20%, and controllers only for 15% [6].
Since parts of a robot are in continuous motion, speeding up and slowing down, gearboxes in joints need to provide not only high rated torque and emergency stop torque but also high acceleration. In industrial robots, positioning accuracy and repeatability are very important. Positioning accuracy is the difference between the requested and the obtained position, while repeatability is the ability to achieve the same requested position over and over again. Although these two characteristics are interrelated, repeatability differs from accuracy and is usually much more important. In order to achieve a repeatability of ± 0.02 mm for an industrial robot with a reach of up to 700 mm, the robot needs to have an angular repeatability of only ± 5.9 $arcsec$ in the base axis [7]. In order to achieve this level of repeatability without the use of expensive high resolution encoders, it is necessary to use zero backlash gearboxes and not the conventional ones. Another major disadvantage of conventional gearboxes is the limitation of the gear ratio in single-stage gearboxes. In order to have an optimal reduction in rotational speed and increase in torque, i.e. to achieve the reduction ratio of 1:171 or 1:220, as needed in the joints of some industrial robots [8], it is necessary to install multi-stage gearboxes. Furthermore, one should not leave out low efficiency of conventional gearboxes, which has a negative impact on energy efficiency [9].

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At present, only high precision reducers can meet all the requirements including high accuracy and repeatability, zero backlash, high torsional rigidity, a combination of high torque and low weight (torque density), high efficiency and high gear ratios without taking up much space. The most widely used high precision reducers are rotate vector (RV) reducers, which are based on cycloid gears, and harmonic reducers [10,11]. Both reducers have high gear ratios, but since RV reducers have a higher load capacity they are usually installed in more loaded joints (base, shoulder, elbow). Harmonic reducers are compact and simple in structure hence they are usually installed in less loaded joints (forearm, hand). At the moment, RV reducers make up 60% and harmonic only 15% of all the reducers used in industrial robots [6]. This paper analyses the main factors to be considered when selecting gearboxes for axes of industrial robots.

2. REQUIREMENTS IN SPECIFIC AXES

In industrial robots, each joint can rotate in a specific axis (Figure 1). Generally, in a 6-axis robot, axis 1 allows the robot to move its arm to the left or right, axis 2 (shoulder) provides the ability to move the upper arm back and forth, axis 3 (elbow) allows the forearm to be raised and lowered, axis 4 allows the rotation of the forearm, axis 5 (wrist) enables the raising and lowering of the hand, axis 6 enables the rotation of the hand [12]. Since each axis has a specific function, each one requires a special gearbox.

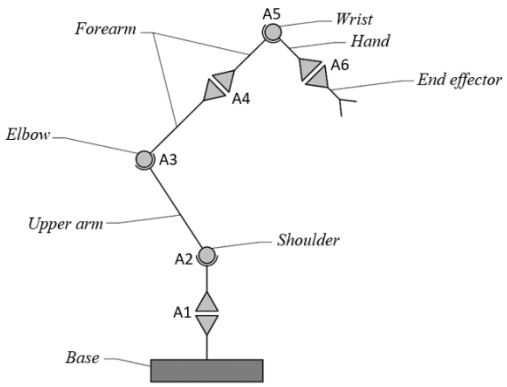
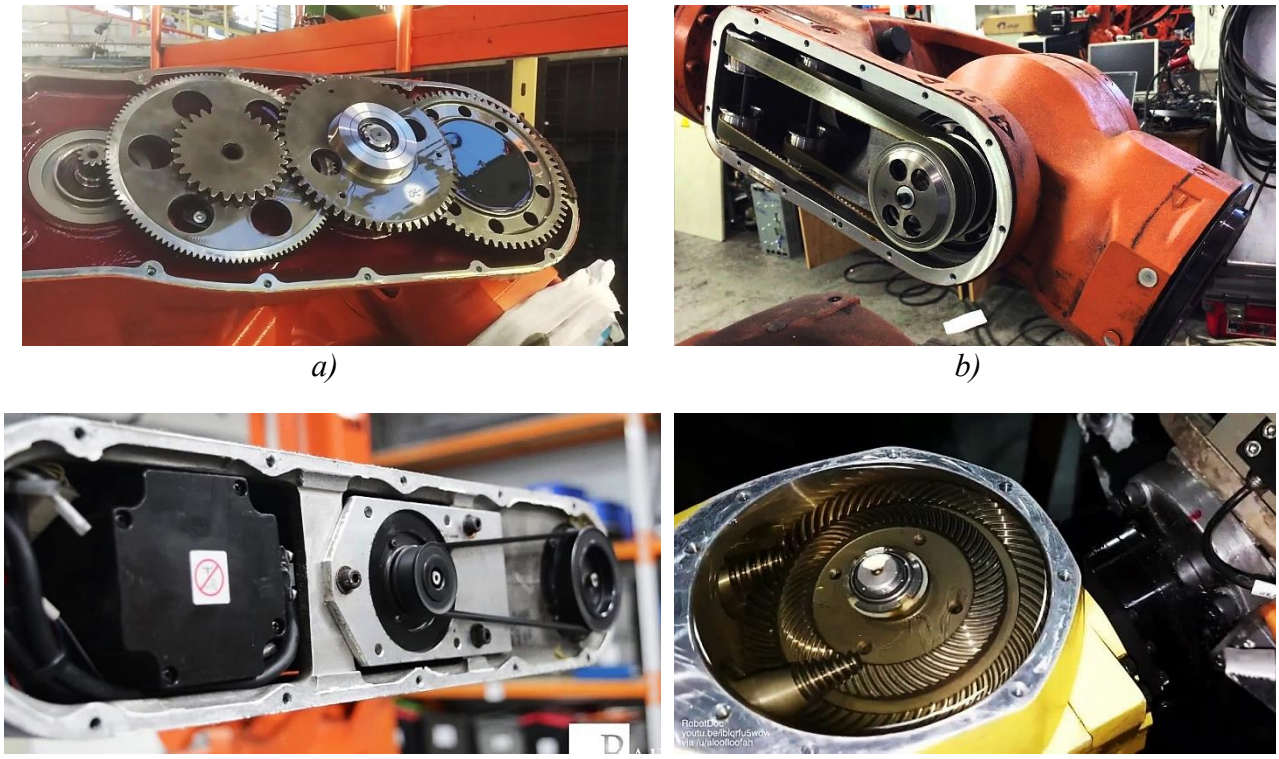


Figure 1. Kinematic structure of a 6-axis robot

When a load is applied to the end effector of a 6-axis industrial robot, the largest moments occur in the first joints. Due to the large lever arms, the rotation of the first joints have the greatest effect on the end effector positioning errors [13]. Therefore, gearboxes in axis 1 must have solid and robust construction in order to provide the necessary stability at high tilting and bending moments. In order to enable internal routing of power and data cables, as well as of supply hoses for painting or welding robots, it is necessary to use hollow shaft gearboxes.
Since axes 2 and 3 are also subjected to large loads when the robot moves, especially axis 2 which carries 70-75% of the total robot weight [14], their gearboxes need to provide high torques and have high torsional rigidity. Here, the cables and hoses are not routed internally but externally, so hollow shafts are not necessary. Since actuator weights also have negative effects on the load of axes 2 and 3, they are very rarely placed directly next to the gearboxes for axes 4, 5 and 6. For these three axes, they are mounted externally in the direction of axis 4. As a result, there is a need for intermediate transmission systems whose main role is to transfer the torque from the actuators to the remote gearboxes [15]. To date, several different construction solutions have been implemented. They are shown in Figure 2 [16]:

- In *IRB 6620* robots with a payload capacity of up to 150 kg in axis 5 - raising and lowering the hand, *ABB* uses cylindrical gear pairs which provide higher torque but much lower precision (Figure 2.*a*).
- In *KUKA KR5* robots with a payload capacity of up to 5 kg, the actuators and the gearboxes in axes 5 and 6 are connected by toothed timing belts (Figure 2.b).

- In *Yaskawa Motoman MA1400* robots with a payload capacity up to 3 kg, the actuator and the gearboxes are also connected by toothed timing belts, but here the actuators are not too far away from their gearboxes (Figure 2.*c*).
- *FANUC* uses special hypoid gears with a payload capacity of up to 12 kg in *M-10iA* robots (Figure 2.*d*).



a) *b)* *c)* *d)*

Figure 2. Intermediate transmissions from the actuator to the joint gearbox in axes 5 and 6: a) *ABB*; b) *KUKA*; c) *Yaskawa Motoman*; d) *FANUC*

In general, for rotation of the forearm (axis 4), it is necessary to use gearboxes with high torsional rigidity and slightly lower torques. They often need to have hollow shafs to allow installation cables to be passed through the gearbox. For axes 5 and 6, more compact and lightweight gearboxes with solid shafts are used, although in axis 6, it is sometimes necessary to use a hollow shaft, depending on the actuator in the end effector [17].
All these requirements for gearboxes in robot axes are summed up in Figure 3.

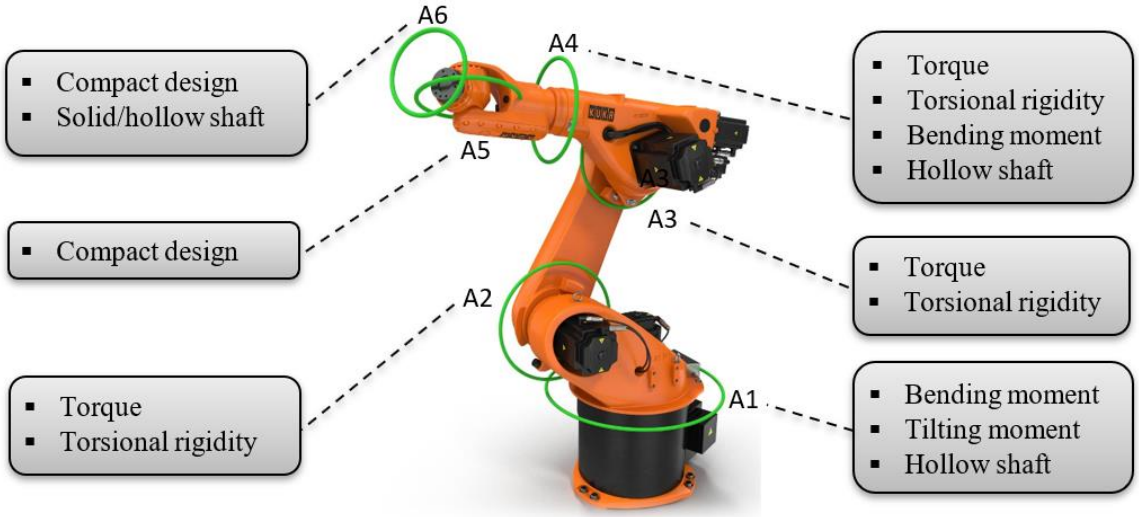


Figure 3. Gearbox requirements for axes of industrial robots *KUKA KR 60-3*

3. A COMPARATIVE ANALYSIS OF CHARASTERISTICS IN SPECFIC AXES

A comparative analysis of the characteristics of a 6-axis industrial robot axes with a payload of up to 150 kg is shown in Figure 4 [17]. Other important robot characteristics include the loss of hysteresis/lost motion below 1 $arcmin$, speed and acceleration above 100 $°/sec^2$, positioning accuracy and repeatability less than 20 $arcsec$. The trend lines are formed based on the mean values of the quantities. It can be seen that the highest torques are required in axes 2 and 3, while the highest torsional rigidity is needed in axis 4.

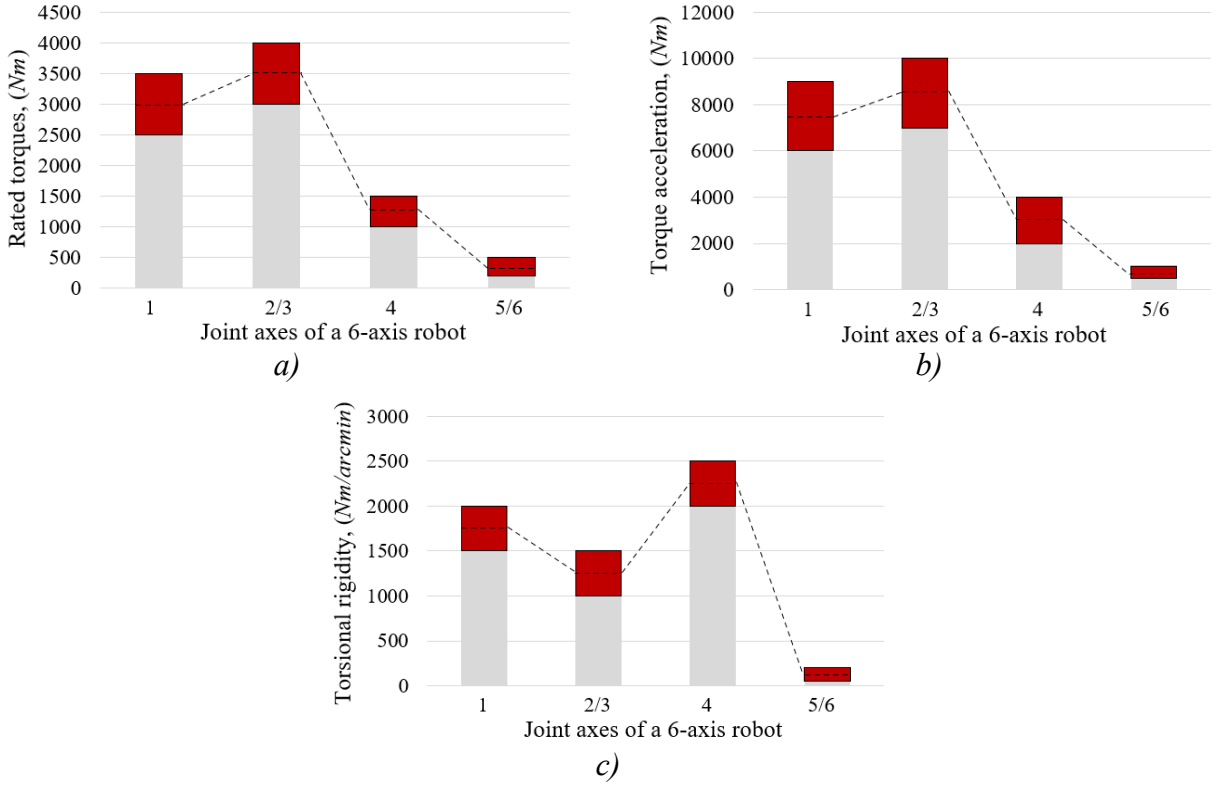


Figure 4. Comparative characteristics of gearboxes in axes: a) rated torques; b) torque acceleration; c) torsional rigidity

4. CONSLUSION

This paper analyses the main factors to be considered when selecting gearboxes for joints of a 6-axis robot. Since gearboxes have a great impact on final performance of industrial robots including speed, acceleration, payload, positioning accuracy and repeatability, the gearboxes generally need to have zero backlash, high torsional rigidity, high torque density, high efficiency and high gear ratios without taking up much space. Each axis has a specific function, therefore, each axis needs a specific gearbox. Considering the fact that the largest loads occur in the first axes: base, shoulder and elbow (especially in the shoulder which carries 70-75% of the total weight of the robot), these axes require gearboxes with high torque density. For other axes, more compact gearboxes can be used, except for axis 4 which requires high torsional rigidity.

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MQTT PROTOCOL IN THE IOT

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Abstract: *MQTT (Message Queuing Telemetry Transport) is the main Machine-to-machine (M2M) communication protocol in Industry 4.0. It provides data exchange within a complex network of remote connected devices. Protocol MQTT represents a completely open source publish/ subscribe communication model, with fast response. It is an application layer protocol, intended for the transmission of short messages and suitable for Internet of Things (IoT). Data transfer to/from the Internet using MQTT is made over the TCP/IP stack. MQTT is a high-performance protocol, which keeps each connection open and reused in scheduled communication when needed. MQTT protocol is a reasonable option for data transfer between small-size devices with low energy consumption, where lower bandwidth has to be utilized. MQTT is used in automotive, manufacturing, telecommunications, oil and gas industry, etc. This protocol is a standard for the IoT data transmission, because it is simple, efficient, scalable, reliable, secure, and well supported. High level of data security can be provided through selective encryption, using the Transport Layer Security and Security Socket Layer or TLS/SSL cryptographic protocols. MQTT in Industrial IoT (IIoT) is a adaptable solution for M2M communication - it enables devices to exchange sensor's data, machine status, or alerts and allows receiving control commands.*
Keywords: MQTT Protocol, Internet of Things - IoT, Industrial IoT - IIoT, Machine-to-machine - M2M Communication, Industry 4.0.

1. INTRODUCTION

Industrial automation is nowadays omnipresent and a commercially viable to be implemented in manufacturing and process industry. Utilization of sophisticated technologies like Internet of Things (IoT) can provide improved performance in practice and better integration of production with business systems. The IoT and Machine-to-machine (M2M) are innovative technologies that require messaging protocols and connectivity to transfer information from and to some remote locations.

MQTT (Message Queue/Queuing Telemetry Transport) is an application layer protocol, primarily aimed to send/receive short data messages. This messaging protocol is supported by main public cloud services: Amazon Web Services, Microsoft Azure and Google Cloud. MQTT protocol is of the open source type and it is suitable for connecting the IoT and Industrial IoT (IIoT) devices. This message protocol enables reliable data transfer over unreliable networks. There is no message queuing. High level of security can be obtained. MQTT protocol has been released in 1999. and is successfully in operation since [1]. MQTT can have stable run in bandwidth-constrained networks.

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MQTT is characterized by the following features: small code footprint, low power consumption, small bandwidth, decreased latency, use of publish/subscribe procedure. Other known protocols, which are not of publish/subscribe type, require new connection to be established each time between networked devices so this two would be able to communicate. The large amount of IIoT applications relies on MQTT. Implemented in a factory such applications usually utilize equipment of various vendors, numerous sensors and devices (called MQTTY clients) networked with a central server as a control unit (referred to as a MQTTY broker). [1, 2]

2. THE IOT AND IIOT

IoT stands for Internet of things, i.e. Internet of dedicated, 'intelligent' devices, called things, deployed and used to exchange real-world data over Internet or other networks without the need of a person to initiate communication. IoT refers to the collection of networked devices that are able to communicate autonomously over the Internet [3]. The IoT operation is enabled through a communication of physical devices over cabled or wireless networks, enhanced with data analytics and advanced cloud computing technology. The basic process of how IoT operates is as follows: a group of physical devices is networked through cables or wireless links, both between each other and to a central area (various network architectures can be used); the devices collect data from the environment using some type of sensors; these data are then stored in the cloud or in a local memory on the device; the data are then processed (often using machine learning - ML, and artificial intelligence - AI); the processed data are used by the same physical devices to perform some predefined actions [3].
The IoT has either consumer or private, enterprise and social implementations. When is used properly, the same enables different industries to accelerate growth, transform economies and achieve higher level of competitiveness and efficiency [3]. With the IIoT, manufacturers can ensure increase of efficiency over the value chain, ranging from operations and engineering to product supply and services. Inherent benefits of the IIoT, include: asset optimization, smart monitoring, a predictive maintenance and most importantly, intelligent and informed decision-making. All these had rapidly made the IIoT an irreplaceable technology. Different technologies, like big data, sensor data, M2M communication, ML, and automation are present and in cooperation in the IIoT [3].

3. INDUSTRY 4.0

Industry 4.0 is a new concept that changed the way companies operate, manufacture, supply products or services and enhance all these processes [4]. With integrated innovative technologies, including IoT, 5G and 6G networks, cloud computing, AI and ML, production and operations can be considerably improved. The so-called smart factories are contemporary plants equipped with sensors, embedded software and robotics with high level of autonomous automation. Collecting and analyzing data from various enterprise systems is utilized and hence more informed decisions can be made. These digital technologies lead to higher automation, enabling predictive maintenance, self-optimization, higher efficiency level and faster responsiveness to customer's requests or needs. Developing smart factories that provide many new opportunities transformed manufacturing industry to Industry 4.0. Exploiting the high-tech IoT devices in smart factories leads to higher productivity and improved quality of end product or service. By applying ML algorithms, it is possible to detect some errors immediately or early, to prevent equipment downtime or losses and make optimized, planed repairs on demand. Industry 4.0 technologies can be applied within almost all industry types, including discrete and process manufacturing, oil and gas, mining and other. [4]
The IoT is the key innovative and supporting technology for transformation of traditional factories into smart factories in Industry 4.0 [5, 6]. The strategy of 4^{th} industrial (r)evolution is focused on implementation and converging information-communication technologies (ICT). The goal is to achieve the intelligent factory (smart factory), which is characterized by adaptability, resource efficiency, and ergonomics, as well as the integration of customers and business partners in business

and value processes [5]. The final result of convergence is the completely smart factory, which can deliver enhanced productivity, flexibility, agility with real-time decision making [4]. Each object is made intelligent (has built-in web server) and can communicate with any other object regardless of application level or function [5]. Industry 4.0 for Process is an initiative for manufacturing operations and process control that applies increasingly more autonomous automation, while integrating it with business information, execution of manufacturing operations, supply chains and retail to achieve overall higher efficiency of the company. The issues in a system are addressable and immediately solved, on any level of application or function. This improves all aspects of production and service availability across relevant environments for greater overall efficiency of the company [5].
Digital technologies, including IoT, robotics, cloud computing, cyber-physical systems and big data are key for the Industry 4.0 implementation [7]. The Industry 4.0 concept implies complete digitization of all production processes and application of the aforementioned digital technologies to create prototypes, fabricate products, organize production, perform manufacturing and process control, make quality inspection and connect with clients and customers to provide better services [7].

4. OPERATION AND PROPERTIES OF MQTT

MQTT is a lightweight messaging protocol that was developed by IBM and first released in 1999. [8] It uses publish/ subscribe ('pub/ sub') pattern and translates messages between devices, servers, and applications. MQTT has a lot of applications in the IoT [8]: telemetry and sensor networks, home automation, IIoT, asset tracking, energy management, healthcare and wearables. When MQTT protocol is used, connected devices known as "clients" communicate over a server referred to as the „broker". The MQTT broker's task is to handle data transmission between clients [1, 8]. Whenever a MQTT client, here called "publisher", wants to distribute information, it will publish to a particular topic [8]. MQTT operation process is presented in Figure 1 [2].

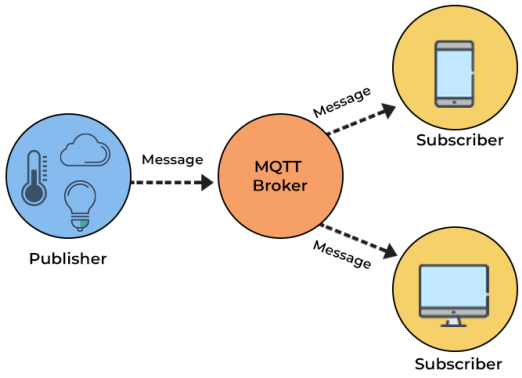

Figure 1. A Diagrammatic Representation of the MQTT Process
Source: https://shorturl.at/AHMNW

The message filtering is a mechanism by which subscribers receive only a subset of all published messages they 'wanted' [9]. There are two forms of message filtering [9]: topic-based and content-based. In topic-based filtering after the message is published the MQTT broker forwards this information to any of the MQTT clients, here called "subscribers" that have subscribed to that topic (Figure 1. [2]). In content-based approach, messages are delivered to subscribers provided that the attributes, or content of the message correspond to the constraints defined by them [9]. Each message sent by MQTT protocol contains a two-byte fixed header [2]. Adding title to it is optional and introducing it makes the message lengthier. The payload of the message is restricted to 256 MB [2].
MQTT is currently available in version 5.0 launched in 2019. [2]. It has on going evolving since its initial development. During this time, significant changes were made, but the primary focus of the protocol has changed from proprietary embedded systems to the open IoT use cases [2]. MQTT is a smart solution for wireless networks that face different levels of latency, due to periodic bandwidth

limitations, or unreliable connections. It's built as a super-lightweight messaging transport, perfect for linking faraway gadgets using minimal code and network resources [2]. MQTT is suitable even for delivery of small code. MQTT is OASIS-recognized standard suitable for IoT communications and data transmission in various industries. The main MQTT applications include [2]: automotive, oil and gas industry, manufacturing, smart cities, remote sensing, home automation, smart farming, wearables, social media platforms, power and ICT. MQTT has been created as a specialized protocol for interfacing with supervisory control and data acquisition (SCADA) systems in the oil and gas industry [2].

MQTT is often used to transport small messages between devices because [2]: it is lightweight and efficient, well-supported, scalable, it provides reliable and secure communication. Message distribution is one-to-many and may scale in terms of customer base without putting publishers or brokers under undue strain [2]. Message queuing can be done by a broker in case of intermittent links. MQTT is utilized in wide range of applications [2], from the IoT and IIoT, to linking cloud environments in the IoT and IIoT. Key reasons why MQTT is well suited for the IoT implementation are [2]: it drives efficiency, enables low network use (as a result of smaller data packets), facilitates efficient data dissemination, unlocks remote sensing and control, delivers messages timely and efficiently, consumes low power, supports multiple modes of communication. MQTT's ongoing development brought significant changes and enhancements to the protocol. In current MQTT version several new features are introduced [2]: message expiry dates, the ability to mask topics, reason codes in case of messaging failure, and load sharing across multiple clients. With MQTT protocol industry is well suited to apply and incorporate IIoT and M2M communication workflows into enhanced IT infrastructure [2].

MQTT uses the TCP protocol for data and message transfer. The three types of messages are usually exchanged by MQTT [2]: connect, publish, subscribe. Both MQTT and Hypertext Transfer Protocol (HTTP) protocols use TCP connections [10], in client-server network architecture. However HTTP servers (unlike MQTT servers) only respond to requests from clients. With MQTT in message exchange, clients can publish and subscribe. Once a connection is established, any number of messages can be sent using MQTT through it, in both directions, data from sensor to back-end, and commands to the end devices [10]. MQTT communication requires [2, 10]: clients (either publishers or subscribers or both), brokers and connections. Clients can't communicate directly - a broker is necessary as a mediator. Each incoming message is filtered by the broker, who then sends it to the appropriate customer[s]/subscriber(s) [2]. MQTT is an application layer message protocol that utilizes TCP/IP stack protocols on the 4th and 3rd ISO/OSI layer (Figure 2. [9]). Reliability of MQTT has three qualities of service [10]: 0 - fire and forget, 1 - at least once, 2 - once and only once. Security can be enhanced by transport-encryption ensured by Transport Layer Security and Security Socket Layer or TLS/SSL protocols [9]. Identity of both sides in communication is assessed by implementing the secure transport protocol. Many IoT devices use TLS with two way authentication to protect sensitive data transmission [9, 10].

MQTT can provide a very high level of security by using TLS/SSL certificates [9]. Again MQTT is run on top of the TCP protocol. MQTT protocol has wide range of applications in contemporary smart factories as well. MQTT communication can be integrated with existing security systems. TLS protocol can provide messages to be sent through a secure channel. MQTT brokers may be enhanced by authorization and authentication. [11]

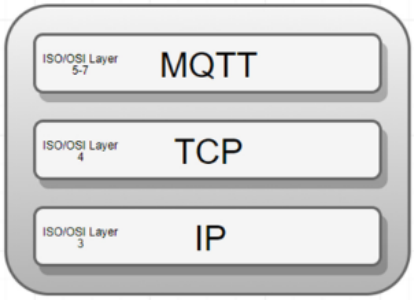

Figure 2. MQTT within TCP/IP communication protocols stack [9]

MQTT can implement intra-factory communications by linking different areas, systems and levels [11]. Intra-factory interactions over MQTT in Figure 3 are represented [11]. Integration of automation and manufacturing, levels 0-3, requires reliable data exchange between various machines, Programmable Logic Controllers (PLCs) and sensors [11]. Further MQTT can be used for exchanging data between SCADA systems and Manufacturing Execution System (MES) [11].

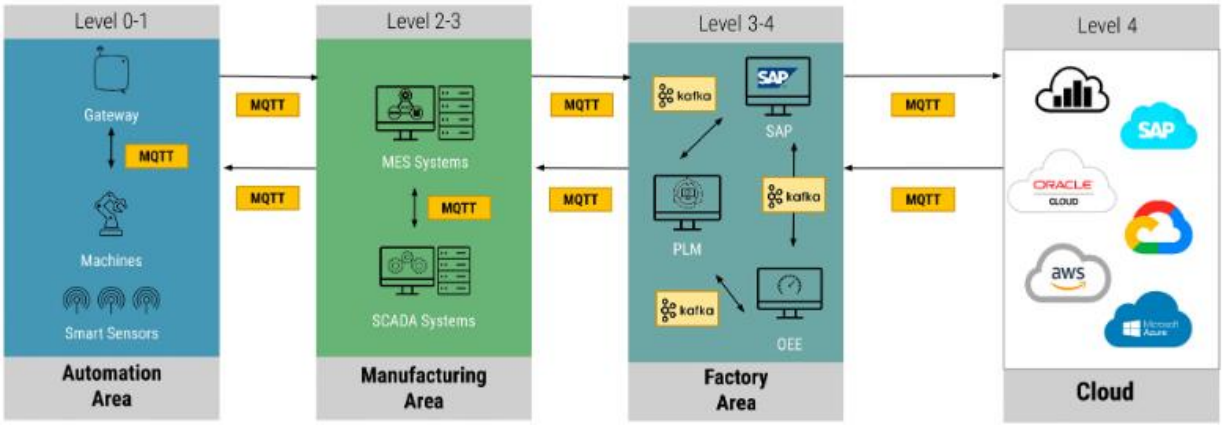

Figure 3. Intra-factory Interactions with MQTT [11]

In the IIoT, there are many sensors and control devices, that exploit unreliable or low-bandwidth networks. It is crucial that MQTT brokers ensure optimal performance and high reliability to meet demands of IoT applications [12]. This is the reason why performance testing is advised. Performance testing is a process of using testing tools to simulate various normal, peak, or abnormal load conditions to test various performance indicators of the system tested [12]. The goal is to verify whether the system can meet the user's expectation, discover performance bottlenecks in the system, and so on. Performance testing of MQTT would establish the relationship between network latency and resulting quality of service (QoS). MQTT is widely used in the various IoT scenarios. It is an asynchronous protocol that implements several types of publishing and subscription [12]: 1-to-1, 1-to-many (fan-out), and many-to-1 (fan-in). There are two main test scenarios for MQTT brokers [12]: 1. Concurrent connection, including number of concurrent connection and connection's rates; 2. Message throughput, for sending and receiving messages, with some performance-affecting parameters, such as QoS, payload size, topic wildcard, etc.

5. CONCLUSION

MQTT is one of the leading protocols suitable for the use in the omnipresent IoT. It is defined as lightweight, flexible network protocol for asynchronous communication. Various devices use MQTT protocol for message exchanges. Messages are of small length, so the data transmission does not overload the network. MQTT relies on publish/subscribe model of communication and requires client(s) (either publisher(s) or subscriber(s)) and server/broker. Publishers send messages regarding specific topics to the broker, while some clients subscribe to selected topics. MQTT performs transmission of messages having one of the three types. All messages are sent to the broker first. MQTT can distribute a published message to many subscribers at the same time. Sending data to commonly applied cloud platforms is also possible.

MQTT protocol is frequently used in M2M communications. This protocol has significant importance in Industry 4.0 implementations. It has features specifically tailored to enable different IoT solutions. MQTT achieves secure communication over networks having constraints. Intra-factory autonomous interactions between machines, devices and software systems are enabled by MQTT on various levels of automation. MQTT provides reliable data exchange in the advanced IoT systems, different services and QoS levels. To achieve specific goals, such as better operation and production management (i.e. process optimization), quality improvements, and predictive maintenance companies need to collect and analyse data and to draw decisions from them.

In the paper MQTT properties, options and applications are elaborated, as well as future trends. It is quite utilized in manufacturing and process control, either in factory's field, or on higher levels of automation and cloud. MQTT has large importance in current and future applications, since it enables sending large amount of data over links with low bandwidth. Moreover it can propel implementations of AI and ML in contemporary production and other industries.

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ENVIRONMENT AND SUSTAINABLE DEVELOPMENT. MECHATRONICS. OCCUPATIONAL SAFETY AND HEALTH AND FIRE SAFETY. SMART MANAGEMENT SYSTEMS. GRAPHIC ENGINEERING. DESIGN. TRAFFIC ENGINEERING. BIOTECHNOLOGY AND HEALTHCARE. MECHANICAL ENGINEERING. ECOTOURISM AND RURAL DEVELOPMENT.

THE POST-QUANTUM CRYPTOGRAPHY AND CHALLENGES IN NETWORK SECURITY AND INDUSTRY 4.0

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Abstract: *This paper highlights the important relationship between Industry 4.0, network security, and the impending quantum computing revolution. The pressing necessity for post-quantum cryptography is explored for securing the massively interconnected networks of Industry 4.0, as quantum computers pose a threat to the fundamentals of current encryption. Examining the vulnerabilities in conventional cryptographic systems, identifying the challenges in implementing quantum-resistant solutions, and emphasizing the value of preventative measures were the objectives. Preserving data confidentiality and integrity is of the utmost significance in the era of Industry 4.0.*
Keywords: Post-quantum Cryptography, Quantum-Resistant Cryptography, Quantum Attacks, Network Security, Industry 4.0

1. INTRODUCTION

The goal of the fourth industrial revolution, or Industry 4.0, is to create an environment in the manufacturing sector that supports autonomous systems, smart factories, and real-time manufacturing ecosystems. Information technologies like cyber-physical systems (CPS), the Internet of Things (IoT), operational technology (OT), cloud computing, automation, big data, and artificial intelligence (AI) are used in Industry 4.0-related initiatives. These initiatives are being carried out in response to the necessity to deal with digital transformation and the rise in competition [1]. A high level of interconnectedness across different equipment, systems, and devices is essential to Industry 4.0. Because of the increasing complexity brought about by this interconnection, it is challenging to monitor and secure all entry points and potential vulnerabilities. Malicious actors have a greater attack surface when there are more linked devices [2]. Organizations in Industry 4.0 need to take a comprehensive approach to network security to solve these problems. This entails making significant investments in reliable cybersecurity solutions, carrying out frequent risk assessments, educating staff members about cybersecurity best practices and new threats, and keeping up with industry developments. Industry, government, and academic cooperation are also necessary to create and exchange information and tactics for preserving Industry 4.0's future. CPSs are a common means by which physical and digital systems are brought together in Industry 4.0. The physical ramifications of attacks on these systems make security lapses even more dangerous [3]. Industry 4.0's widespread use of IoT and OT devices raises several security issues. These devices are often resource-constrained, so security is unlikely to be the producers' first concern. Attackers may use them as points of entry. Threat actors are becoming more sophisticated and are using advanced techniques such as AI and machine learning for cyber-attacks [4]. Detecting and defending against these threats requires equally advanced security measures. Everything mentioned represents a rather contemporary field of research. However, it is necessary to anticipate the future security challenges brought by post-quantum computers and post-quantum cryptography.

A quantum computer is a kind of computer that does computations based on the principles of quantum mechanics. Quantum computers employ quantum bits, or qubits, which can exist in several states concurrently, in contrast to classical computers, which use bits that can only be either 0 or 1. Because

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of this qubit characteristic, certain kinds of computations can be completed by quantum computers far more quickly. For example, factoring huge numbers is one of the mathematical problems that quantum computers can handle that is computationally impossible for classical computers. Although they are still in the experimental stage, quantum computers are not yet commonly accessible. However, creating prototypes and showcasing their prospective capabilities has advanced significantly in recent years. They can completely transform a lot of industries, including machine learning, cryptography, and optimization. Before quantum computers can carry out real computations on a large scale, there are also important technological and practical issues to resolve. However, concerns regarding the security of classical cryptography systems, which rely on the complexity of specific mathematical problems, like discrete logarithms and integer factorization, have been raised by the emergence of quantum computing. This mathematical complexity could be effectively resolved by quantum computers, making many popular encryption techniques insecure. Many of the cryptographic systems in use today, including those that are frequently used to encrypt internet and network communications, could be broken by quantum computers. The goal of post-quantum cryptography (PQC) i.e., quantum-resistant cryptography, is to provide cryptographic algorithms, that will remain resistant to attackers possessing quantum capabilities.

2. FUNDAMENTALS AND CHALLENGES IN POST-QUANTUM CRYPTOGRAPHY

2.1 Review of Conventional Cryptographic Algorithms in Practical Application

In the current digital era, data storage and transmission security has become essential. Cryptographic algorithms have long served as the foundation of information security, ensuring the confidentiality, integrity, and authenticity of sensitive data. The continuous assessment of these algorithms is vital as the digital environment changes, in order to respond to new threats and preserve the privacy and security of data across a variety of applications, such as financial transactions, communication, and data storage. Among the most well-known applied algorithms are: Data Encryption Standard (DES), Advanced Encryption Standard (AES), Rivest-Shamir-Adleman (RSA), Elliptic Curve Cryptography (ECC), and the Rivest Cipher (RC) family. These algorithms illustrate the evolution of cryptographic techniques and their adaptation to practical use cases. When DES was first released in the 1970s, it became the standard symmetric key algorithm. Its significance lies in pioneering the use of encryption for data security. A 56-bit key and a Feistel network structure have been employed in the basic version of the DES algorithm. Later, Triple Data Encryption Standard (3DES) was developed, which increases security by applying the DES algorithm three times to each data block using separate keys. Due to advances in computer power and its vulnerability to brute-force attacks, DES has been replaced in many applications; however, legacy systems in government and financial organizations continue to utilize it to secure legacy data. Although data security was first made possible by DES, AES has proven to be a robust and versatile choice for modern purposes. Since its introduction in the early 2000s, AES has proven to be extremely adaptive to a wide range of security requirements. It provides key lengths of 128, 192, and 256 bits. AES has become the de facto standard for encrypting data in modern applications. It is frequently used to protect data-at-rest in storage devices, secure internet connection via SSL/TLS, and preserve sensitive data in databases. It is appropriate for a wide range of applications, such as online banking, e-commerce, and secure communications, due to its practicality and robust security. RSA is a popular asymmetric cryptography technique that is known for its pivotal role in securing data transmission, digital signatures, and key-exchange. RSA was created in 1977 by Ron Rivest, Adi Shamir, and Leonard Adleman, and its security is based on complexity of the mathematical properties of large prime numbers and modular arithmetic. ECC is an asymmetric cryptographic algorithm that has gained prominence for its high-security properties and efficiency, especially in situations with limited resources like those found in mobile and IoT devices. The difficulty of solving the Elliptic Curve Discrete Logarithm Problem (ECDLP) provides the foundation for the security of ECC. In simple terms, this problem involves finding the discrete logarithm of a point on the curve. The size of the key and the curve selection affect the security of

ECC. Because it is possible to have smaller key sizes without compromising security, ECC is a popular option in situations where efficiency and performance are essential. Due to its effectiveness, ECC is particularly well-suited for devices with constrained bandwidth and processing power. A typical key length for ECC may be 256 bits, which provides security comparable to a 3072-bit RSA key. RC4 and RC6 are members of the RC family and have been used in a variety of applications. For secure email communications and disk encryption, RC6 has been accepted, whereas RC4 is utilized in the WEP and WPA wireless security protocols. The stream cipher known as RC4 became well-known due to its effectiveness and ease of use. It is utilized in applications like VPNs and wireless communication security that call for quick encryption and decryption. Block cipher RC6 provides a high degree of security and adaptability. It is suitable for applications where data needs to be securely stored and transmitted, such as in enterprise-level data protection and file encryption. With its various members, the RC family provides alternatives that strike a compromise between performance and security, making them appropriate for particular uses where speed or data protection is a priority.

2.2 Post-Quantum Cryptography Algorithms and Standardization Process

Among the most well-known and innovative quantum algorithms is Peter Shor's algorithm [5]. It is frequently referred to as Shor's Algorithm and was created in 1994. The ability of this technique to factor huge numbers efficiently has important ramifications for contemporary cryptography. Large composite numbers are mostly intended to be factored into their prime factors. To put it another way, it can divide a big number N into the prime numbers that, when added up, equal N. Large number factoring is a tough computing issue that serves as the foundation for many cryptographic systems, such as RSA. The security of RSA is based on the presumption that factoring huge semiprime numbers is computationally impossible. However, Shor's Algorithm has the potential to efficiently factor such numbers, posing a significant threat to traditional public-key cryptography. The use of quantum period-finding is Shor's Algorithm's primary invention. It makes use of a quantum computer's capacity to assess several values at once in order to determine a modular function's period. Shor's Algorithm deciphers the factors of the number with efficiency by determining the period, which breaks RSA encryption and related techniques. Shor's Algorithm has raised concerns about the security of widely used public-key cryptography systems. For example, the security of RSA-based encryption may be jeopardized by Shor's Algorithm, which theoretically exploits the difficulties of factoring big semiprime numbers. The mathematical characteristics of error-correcting codes served as the foundation for the 1978 proposal of the McEliece cryptosystem, a public-key encryption technique [6]. Consequently, it ranks among the first public-key cryptosystems. Unlike many other public-key encryption schemes, the security of RSA and ECC is not based on number theory, but rather on the difficulty of solving specific mathematical problems that arise in coding theory. The Goppa codes in particular are difficult to decode, and it is believed that decoding a randomly chosen Goppa code in polynomial time is practically unfeasible, even with powerful computing power. This complexity provides the foundation for the security of the McEliece cryptosystem. It is considered safe from quantum attacks even with the introduction of large-scale quantum computers. The larger key sizes utilized in McEliece compared to RSA or ECC can be a disadvantage in terms of key management and storage. Furthermore, compared to other public-key cryptosystems, encryption is less efficient in terms of message size, since it produces comparatively large ciphertexts. These issues have limited its deployment to academic and research settings. Compared to other encryption techniques, it hasn't been widely used in real-world applications, despite providing post-quantum security. Though McEliece continues to be a contender for strong encryption in a world when quantum computers might pose threats to already-existing cryptographic systems, there has been a resurgence of interest in post-quantum cryptography in recent years. However, research is ongoing to address its limitations and make it more practical for real-world applications.

In recent years, there has been an increase in both the quantity and quality of PQC research [6]. Research focuses on candidate algorithms for standardization that have been accepted via each stage.

One of the most promising approaches in the post-quantum era is lattice-based cryptography. It depends on how challenging some lattice-related tasks are, like the Learning with Errors (LWE) problem. NTRUEncrypt and Kyber are two well-known lattice-based encryption methods. The foundation of code-based cryptography is error-correcting codes, which take advantage of the difficulty of deciphering random linear codes (McEliece principles). Distinguished instances of multivariate polynomial cryptography are the Rainbow and HFE schemes. This method makes use of difficult-to-solve systems of multivariate polynomial equations. The Merkle signature scheme and other hash-based cryptography schemes depend on the characteristics of hash functions to offer protection from quantum attacks. Isogeny of Elliptic Curves cryptosystems rely on the property of congruent graphs of elliptic curves over finite fields, or super anomalous congruence graphs, to create a secure system. This is the basis of a number of particular schemes, including the CSIDH key exchange system, which serves as a substitute quantum attack candidate for the Diffie–Hellman key exchange method. The current level of PQC research is succinctly described by the Venn diagram in Figure 1, where the numbers in the circles indicate the number of corresponding references, the red words are the names of potential algorithms, and the circles containing blue words represent the basic principles of encryption.

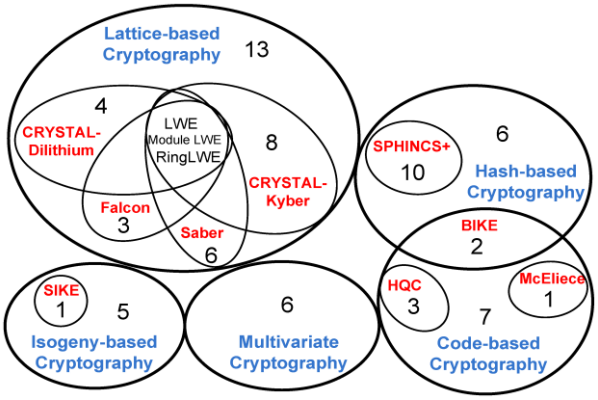

Figure 1. The Venn diagram describes the fields of PQC research
Source: https://www.mdpi.com/2410-387X/7/3/40 [7]

Following several stages of development for cryptography, National Institute of Standards and Technology (NIST) proposed in the 1970s to select a cipher to serve as the nation's common standard. This selected cipher was DES algorithm, launched with a relatively modest key size. That shortcoming led NIST to issue another call for proposals in 1997, which resulted in 50 algorithm proposal for new block codes. The AES algorithm was selected in 2000 and is still commonly used as the industry standard for symmetric encryption. However, the existence of ciphers based on mathematical complexity is now at risk due to the development of quantum computers and quantum cryptography algorithms. Algorithm standardization is a significant post-quantum cryptography challenge. In order to guarantee security and interoperability, NIST started a new process in 2017 to choose and standardize post-quantum cryptography algorithms in an effort to discover algorithms that can withstand the power of quantum computing. NIST has initiated a process to solicit, evaluate, and standardize one or more quantum-resistant cryptographic algorithms [8,9]. Currently, the NIST standardization process is in its fourth round. For the majority of use cases, NIST primarily suggests the CRYSTALS–KYBER (key establishment) and CRYSTALS–Dilithium (digital signatures) algorithms. Furthermore, a standardization of the signature schemes FALCON and SPHINCS+ is proposed. In a fourth round of assessment, candidates BIKE, Classic McEliece, HQC, and SIKE will all continue for further study [9].

2.3 Challenges in Post-Quantum Cryptography

Compared to conventional cryptography algorithms, post-quantum cryptography methods often require more computer resources. It's extremely challenging to maximize their performance while preserving security. The process of switching from classical to post-quantum cryptography is intricate

and needs to be carefully planned and coordinated in order to maintain the security of current systems. While certain cryptographic systems may include quantum-safe features, they haven't been thoroughly examined. It is difficult to ensure their security in practice. The field of quantum-resistant encryption is still developing. Future research might concentrate on enhancing the security and effectiveness of current post-quantum algorithms. Another line of inquiry is how secure communication might be enabled by quantum cryptography. Understanding the potential and constraints of quantum computers in terms of cryptographic system attacks will be essential for developing safe post-quantum algorithms as these machines grow in power. Research is still being done to create useful policies and instruments for using post-quantum cryptography in practical applications.

3. CONCLUSION

This paper has addressed the paramount issue of network security in the context of Industry 4.0, recognizing the imminent threat posed by quantum computing to contemporary cryptographic systems. A comprehensive survey of the weaknesses of conventional cryptography algorithms against quantum attacks, fundamental principles, algorithms, challenges, process of standardization and future directions in post-quantum cryptography has been provided. The advent of quantum computers presents a clear and present danger to the security of data and networks, necessitating a paradigm shift towards post-quantum cryptography. In order to protect the integrity and confidentiality of data in the Industry 4.0 ecosystem, the necessity of taking a proactive stance and pushed for the creation and use of quantum-resistant encryption techniques is emphasized. As the field continues to advance, collaboration between researchers, industry stakeholders, and policymakers will be essential to ensure the security of our digital infrastructure in the post-quantum era.

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CONCEPTUAL MODEL OF A SYSTEM FOR OPTIMIZING THE TEMPERATURE AND HUMIDITY OF HONEYBEE HIVES USING ARTIFICIAL INTELLIGENCE

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Abstract: *The paper explores key challenges faced by bees within their hives when exposed to unfavorable temperature and humidity conditions. High humidity inside beehives can lead to an increased risk of diseases and moisture condensation, while high temperatures can induce stress among the bees and potentially harm the combs. Simultaneously, small and weak bee colonies face additional challenges in addressing these issues due to their limited resources and capacities. This paper presents an innovative approach to addressing these problems using artificial intelligence and sensor modules. Through thorough research and implementation, a system has been conceptualized to monitor conditions within beehives and automatically react using fans to maintain optimal levels of temperature and humidity. Through conceptual testing and analysis, the system effectively assists bees in coping with adverse conditions, particularly applicable to small and weak bee colonies. This approach significantly contributes to the preservation of bee populations and the proper functioning of bee communities. The paper emphasizes the importance of applying technological solutions to improve bee health, which has broader ecological and economic implications.*
Keywords: Artificial Intelligence, Temperature, Humidity, Optimization, Beehive

1. INTRODUCTION

The bee colony, with its intricate and delicate ecosystem, is susceptible to the influence of numerous factors, among which air temperature and humidity within the beehive are of essential significance. These factors play a crucial role in regulating the behavior and health of bees. It is evident that two factors, temperature and humidity, are central triggers of changes within the bee society and potential issues when they reach critical values. High humidity within the beehive poses a severe threat to the bee colony. When humidity exceeds the tolerance threshold, bees become extremely vulnerable. Problems resulting from high humidity include an increased risk of various diseases, disruptions in daily activities, and disturbances in their nourishment. Elevated humidity can create a favorable environment for the development of pathogenic organisms, which can cause significant harm to the bee society. Furthermore, high humidity can lead to moisture condensation inside the beehive, further complicating the situation and inducing stress among the bees.
On the other hand, high temperature also represents a significant threat to the bee colony. An increase in temperature above a certain level can lead to severe disruptions, including alterations in reproductive behavior, reduced honey yields, and, ultimately, endanger the survival of the bees.

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In this context, research and the development of systems for monitoring and controlling humidity, along with temperature within beehives, become a priority for the preservation of bee populations and the enhancement of their health. This study focuses on the development of an innovative solution using artificial intelligence technology and the Internet of Things (IoT) to efficiently regulate environmental parameters in bee hives, ensuring optimal conditions for the bees and contributing to their survival. Through a combination of technical innovations and scientific approaches, this study aims to achieve a deeper understanding and practical solutions for the complex challenges faced by bee populations in ever-changing environmental conditions.

2. RELATED RESEARCH

The relevance of air temperature and relative humidity parameters is highlighted in numerous studies, including [1], which point to the causal relationships these parameters have within the beehive. High temperatures within the beehive can cause a range of problems crucial to the survival of the bee colony. Critical temperature values may vary depending on the bee's developmental stage and activities, but it is generally considered that temperatures exceeding 36°C are critical and negatively affect bee life. High humidity within the hives can lead to various problems for the bees and their social structures. Critical humidity values also depend on the bee colony's developmental stage, but humidity exceeding 80% is usually considered a serious issue. The development of IoT-based monitoring systems used to track and gain insight into the health of bee colonies and beehive management systems [5] allows for instant insights into bee colony activities and the ability to regulate and manage specific parameters to optimize conditions that may cause stress to bee colonies. There is also a wide range of applications for hive control and management [9].

3. BEEHIVE TEMPERATURE AND HUMIDITY REGULATION PROBLEM

Thermoregulation within the beehive is crucial for maintaining optimal conditions for various processes in the bee colony. Bees are capable of maintaining the temperature within the hive in a narrow range, usually between 32°C and 36°C. High temperatures above this range can lead to several issues, such as bee stress and comb melting. An increase in temperature beyond 36°C can cause stress among the bees, resulting in increased energy consumption, reduced productivity, and decreased lifespan of worker bees. At extremely high temperatures, the wax used to build the comb can begin to melt, leading to comb deformation and loss of food storage cells, which can be catastrophic for the bee colony.Problems arising from high humidity may include an increased risk of pathogenic diseases, condensation inside the hive due to high humidity, reduced productivity, and bee colony survival. Elevated humidity can facilitate the growth of pathogenic organisms. Humidity can lead to condensation within the hive, potentially damaging the hive's interior and the bee food stores. Bees may lose access to food due to such issues. Bees are susceptible to stress at high humidity levels, reducing their productivity and longevity, which can ultimately jeopardize the survival of the colony.

3.1 Challenges of small and weak bee colonies

Small and weak bee colonies face particular challenges in addressing problems related to high humidity and temperature. They have a lesser capacity to regulate and are at a higher risk of bee colony collapse. Small bee colonies have fewer resources and worker bees, making them less capable of regulating hive conditions. Weak bee colonies are more susceptible to temperature and humidity issues due to their limited problem-solving capacity. In this context, the application of artificial intelligence and sensor modules can be crucial. A system that automatically monitors conditions within the beehive and adjusts them using fans can be of significant assistance to small and weak bee colonies.

4. IMPLEMENTATION OF SENSOR MODULES, BIDIRECTIONAL FANS, AND MICROCONTROLLERS

Sensor modules on the perceptual layer are positioned at key locations to detect air temperature and relative humidity within the beehive. Sensors are symmetrically positioned at both upper and lower positions to ensure the data's relevance and comparability. In the same manner, we monitor differences in measured values that provide inputs for fan activation. Fans are positioned parallel to the frames to achieve a greater optimization effect. The beehive has two fans that are symmetrically positioned and can operate synchronously or asynchronously, thus acting in opposite or the same direction, depending on the effect they need to achieve (Figure 1). This way, we achieve regulation, specifically for temperature and relative humidity.

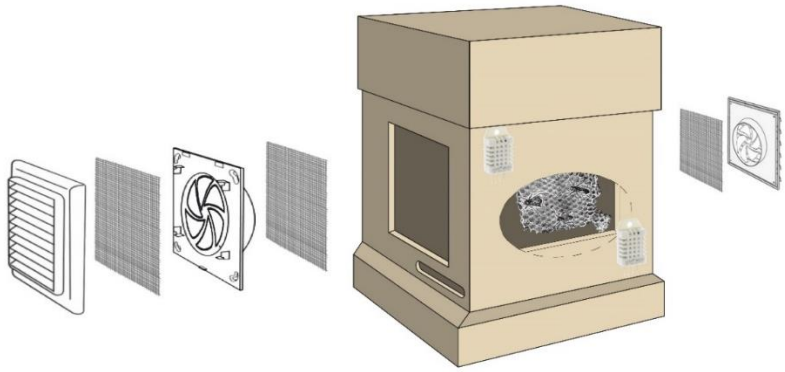

Figure 1. Positions of fans and sensors

The microcontroller module based on the ESPRESSIF ESP32 chipset regulates the operation of sensor modules and fans through relays (Figure 2). Thanks to the possibility of implementing artificial intelligence at lower layers of the IoT architecture, machine learning models are applicable. TensorFlow libraries can be installed on these modules, allowing machine learning models to be applied for monitoring parameters and controlling fan intensity to achieve optimal values inside the beehive.

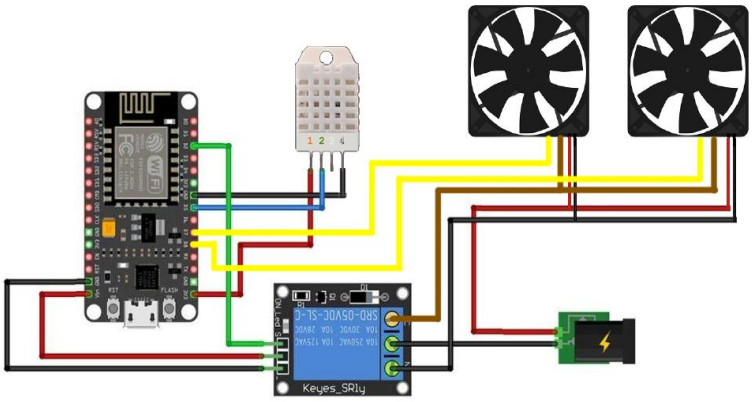

Figure 2. Fritzing connection diagram

4.1 Application of Artificial intelligence modules

The application of artificial intelligence at the EDGE layers of the IoT architecture optimizes the hardware resources' load for beehive health monitoring systems. ESP32 modules meet these requirements with their impressive hardware performance. In this way, self-regulation and predictive control of the beehive can be achieved, especially if the system is controlled via cloud services and application software with alarm features. By using predictive models for preventing unwanted events, the system can be automated, expanding the technology's applications.Based on data collected from the perceptual layer (DHT22 sensor measures temperature and relative humidity), an artificial intelligence model based on recurrent neural networks, an LSTM model, has been created to predict

parameter trends. If the model predicts critical values for a specific parameter, increased temperature or humidity, it activates the fan's movement in a specific direction depending on the parameter and adjusts the fan's intensity and speed. The model makes predictions based on average values within intervals of 20 minutes. As critical values for these two parameters may occur at different times and may overlap, the model recognizes trends and activates the fan's direction and intensity.The LSTM model of recurrent neural networks for time series prediction has already shown excellent results in previous studies. The ability to adjust hyperparameters and include hidden layers, as well as memory cells, provides a significant advantage in modeling predictive values with these models.

5. CONCLUSION

During the test phase with an empty beehive, the system succeeded in optimizing humidity values by 6 percent, while in the regulation of temperature values, it succeeded in optimizing by 4 degrees. Of course, this is a conceptual model, and testing in different times of the day and seasons is yet to come. Testing will also be performed in various situations of the bee colony's activity, different periods of food collection, etc.The fan's operating mode is based on the combination of airflow directions in the beehive, finding the best operating model during value optimization. The results of future research will help develop more precise models and better parameter optimization.

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THE CHANNEL CAPACITY OF WIRELESS COMMUNICATION SYSTEM WITH L-BRANCH SC COMBINING IN RAYLEIGHT SHORT TERM FADING AND CO-CHANNEL INTERFERENCE

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Abstract: *In this paper, an expression for the channel capacity (CC) of the combined L-branch (SC) selection receiver is derived in the presence of Rayleigh small fading and co-channel interference (CCI) also by Rayleigh distribution. Rayleigh fading occurs when there is a large number of objects between the transmitter and receiver on which the signal scatters. Analytical results for CC will be performed in closed form and then graphed for channel capacity. In addition, a machine learning approach based on ChatGPT is introduced to recognize the type of fading based on channel capacity measurements, which is further leveraged for quality of service (QoS) adjustment tuning the corresponding parameters on receiver's side.*
Keywords: ChatGPT, SC combining, Rayleigh fading and interference, QoS, GPU.

1. INTRODUCTION

Wireless communication systems are designed to deliver a message over a wireless channel. The messages sent from the transmitter include a random source and the messages received cannot be predicted with certainty. In addition, wireless channel impairments including thermal noises are expressed as random factors. The characteristics of such a channel change over time, making it difficult to design reliable systems with guaranteed performance. The random process is a very useful model to describe an information source, transmission, and noise. In wireless communication systems, the received signal may be subject to short-term and long-term fading (shadowing). Short-term fading is the result of multi-layered propagation and shadowing of large obstacles and large deviations of the terrain profile between transmitter and receiver [1]. Shadowing is the weakening of the signal due to the specifics of the propagation environment (vegetation, residential areas, ...). As these objects are stationary, the attenuation of the received signal is relatively slow. Thus, the mobile communication channel can be modeled as a Gaussian channel with slow non-selective Rayleigh fading (received signal amplitudes have a Rayleigh distribution) and with a shadow effect, where the distribution of the mean value of the signal-to-noise ratio, SNR, is lognormal) [2].
One of the best techniques for improving the reliability of communication over wireless channels is combining diversity. With this technique, if the signal on one path weakens at one moment, it can be stronger on the other path, so due to the existence of a larger number of paths, the current and average SNR can be significantly increased, and thus the performance of the system improves. There are two

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types of diversity techniques: micro and macro diversity. Microdiversity eliminates short-term fading. In this case, several non-correlated (fading) components are received at the same base station and combined in a certain way, whereby the non-correlation condition is ensured by a distance between the receiving antennas that is greater than λ/2 (e.g. at frequencies greater than 1 GHz, sufficient is a distance of 15 cm). There are various methods of extracting a useful signal, such as: selection of the signal with the highest SNR value (selective diversity SC), phase equalization of all signals and their addition, where each signal is multiplied by a fading parameter determined by measuring the SNR of each signal, i.e. maximum-ratio (MR) combining, and a method that is a special case of the previous one, where all signals are taken with the same weight, better known as equal gain (EG) combining. The simplest of these methods is selective diversity (SC) where, at the reception of L diversity branches, the one with the highest SNR ratio is selected [3]. Macrodiversity reception techniques are represented by spatially separated radio ports (base stations), which serve one cell, receive fading signals with different long-term attenuation. As the attenuation due to the shadow effect at certain ports must be independent, they are located at distances greater than 1 km [4].
This paper presents a micro diversity receiver with an L branch that works through a Rayleigh multiple fading channel and interference also present in the channel. For that case, the channel capacity is calculated at the output of the receiver. The main vision of mobile networks is to achieve massive data transfer with the highest data transfer speeds. The idea is to enable people and machines to access information and services at all times and in all possible situations, leading to enormous improvements in productivity and sustainability in the modern world of communications.

2. CC OF SIGNAL TO INTERFERENCE RATIO AT THE OUTPUT OF SC RECEIVER

In this part, the outage probability of wireless communication system with SC receiver with L branches (L=2, 3…..n) are considered. The received signal experiences Rayleigh fading and the interference on the co-channel channel. The receiver model is shown in Figure 1:

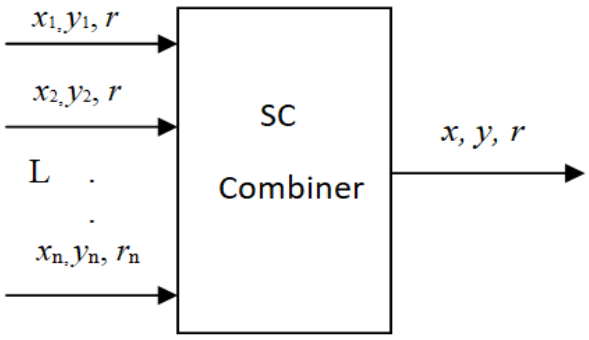

Figure 1. Model of the considered *SC* combiner with *L* branches

The signal envelopes at the receiver inputs are marked with x_1, x_2, …, x_L. The SC combiner selects the signal marked x from the antenna with the highest SNR. The co-channel interference envelopes are marked with y_1, y_2,..., y_L, at each of the L inputs of the SC receiver, where L=2….n, while the corresponding output signal is y. The signal envelopes x_i follow the Rayleigh distribution [5]:

$$p_{x_i}(x_i) = \frac{2x_i}{\Omega_i} e^{-x_i^2/\Omega_i}; x_i \geq 0, i = 1, 2...n \quad (1)$$

where Ω_i is the mean value of the signal power. The signal y_j of the co-channel interference follows Rayleigh distribution and probability density function (PDF) of y_j is:

$$p_{y_i}(y_i) = \frac{2y_i}{s_i} e^{-y_i^2/s_i}, y_i \geq 0, i = 1, 2..n \quad (2)$$

where s_i is the mean value of the interferers power:

$$\Omega_i(x_i) = \bar{x}_i^2, s_i = \bar{y}_i^2 \tag{3}$$

The ratio of desired signal envelope and co-channel interference at inputs of SC receiver is:

$$r_i = x_i / y_i, \; x_i = r_i y_i \tag{4}$$

The probability density function (PDF) of the signal r_i is given by [6]:

$$p_{r_{ij}}(r_{ij}) = \int_0^{+\infty} dy_{ij} y_{ij} p_{x_{ij}}(y_{ij} r_{ij}) p_{y_{ij}}(y_{ij}) = \frac{2 r_{ij} \Omega_i s_i}{\left(\Omega_i + s_i r_{ij}^2\right)^2} \tag{5}$$

Cumulative distribution function (CDF) of r_i is [7]:

$$F_{r_i}(r_i) = \int_0^{z_i} \mathrm{d}t p_{z_i}(t) = \left(\frac{s_i r_i^2}{\Omega_i + s_i r_i^2} \right) \tag{6}$$

At the output of the SC receiver, the ratio signal to interference where i=1,3,…n is equal $r = \max(r_1, r_2 \ldots r_i)$. The probability density function (PDF) of the r at the out-put of the SC receiver with L branches can be calculated by using expression [7]:

$$p_{r_i}(r) = L p_{r_i}(r_i)\left(F_{r_i}(r_i)\right)^{L-1} = \frac{2L r_i^{2L-1} \Omega_i s_i^{\,L}}{\left(\Omega_i + s_i r_i^2\right)^{L+1}} \tag{7}$$

One of the most important measures of system performance is the channel capacity, which, according to Shannon, represents the theoretical upper limit for the maximum data transfer rate at an arbitrarily low bit error probability, without any delay complexity constraints [8]:

$$\frac{C}{B} = \frac{1}{\ln(2)} \int_0^{\infty} \ln(1+r) p_{r_i}(r) dr \tag{8}$$

where C is Shannon capacity given in bits/s, B denotes denotes transmission bandwidth given in Hz. Using the form for the logarithm function [9]:

$$\ln(1+x) = \sum_{i=0}^{\infty} (-1)^i \frac{x^{i+1}}{(i+1)!} \tag{9}$$

we get that the capacity of the channel:

$$\frac{C}{B} = \frac{2L}{\ln(2)} \left(\frac{s_i}{\Omega_i} \right)^L \sum_{i=0}^{\infty} \frac{(-1)^i}{(i+1)!} \int_0^{\infty} \frac{r_i^{i+2L+1-1}}{\left(1 + (s_i / \Omega_i) r_i^2\right)^{L+1}} dr \tag{10}$$

Using form [10; 3.251]:

$$\int_0^{\infty} \frac{x^{\mu-1}}{\left(1+\beta x^p\right)^v} dx = \frac{1}{p} \beta^{-\frac{\mu}{p}} B\left(\frac{\mu}{p}, v - \frac{\mu}{p} \right) \tag{11}$$

where B is the beta function, we get that the channel capacity is:

$$\frac{C}{B} = \frac{L}{\ln(2)} \sum_{i=0}^{\infty} \frac{(-1)^i}{(i+1)!} \left(\frac{\Omega_i}{s_i} \right)^{\frac{i+1}{2}} B\left(\frac{i+2L+1}{2}, \frac{1-i}{2} \right) \tag{12}$$

Numerically obtained results from the expression (12) where w=Ωi/si are shown graphically in Figure 2, which shows the C/B of the signal-interference ratio in relation to the crossing threshold (γ_{th}) at the output of the SC receiver (*i*=2,3. .*L*).

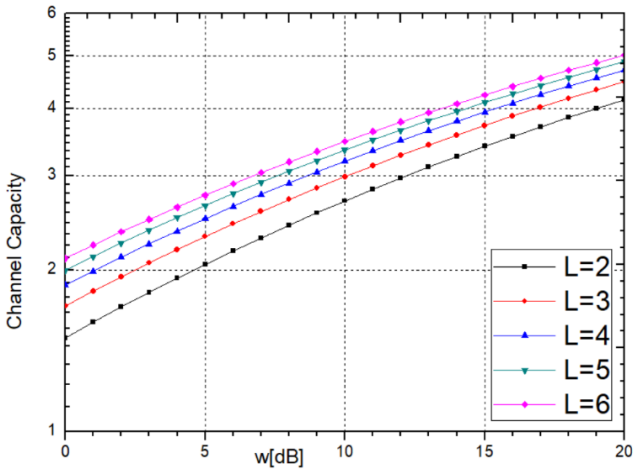

Figure 2. Normalized channel capacity for different values number of branches *L*

Fig. 2 show the channel capacity normalized by channel bandwidth B, depending on the w=Ω/S (dB). If the parameter L increases, the channel capacity increases and the system has better performance.

3. CHATGPT-BASED FADING TYPE CLASSIFICATION FOR QoS TUNING

Furthermore, this paper explores how the trending ChatGPT conversational agent based on Large Language Model (LLM) can be leveraged in order to recognize the type of fading within a given mobile network environment, based on channel capacity measurements. This information is used for Quality of Service (QoS) improvment by appropriate receiver type selection and parameter tunning. The problem is treated as classification, considering that the output is the number which corresponds to fading type. Based on our previous works, several types of fading are covered [11]: η-μ, k-μ, Weibull, Rayleigh and Nakagami-*m*. The proposed workflow is depicted in Fig. 3.

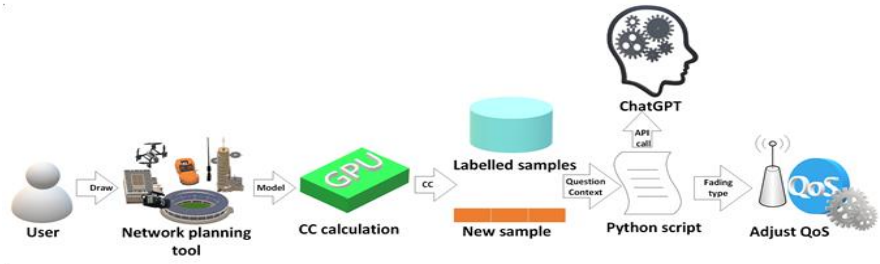

Figure 3. ChatGPT-driven workflow for QoS adjustment based on fading type classification

First, CC is calculated for given mobile network scenario, relying on our mobile network planning and simulation environment [12]. In order to speed up the CC calculations, we make use of GPGPU-based approach relying on graphics hardware for loop paralleliztion, reaching up to 70 times speed up compared to traditional CPU approach [13]. After that, the previously calculated CC value is used among the other input variables: receiver type (such as SC, MG, EG) and measured signal strength at the input of the reciever (x).

Chat Generative Pre-trained Transformer, known to publicity as ChatGPT, represents LLM-driven solution acting as chatbot with capability of dialogue, where users pose questions for given context. Context might include more specific information or additional facts which serve as „hint“ to ChatGPT, considering that the underlying LLM was trained on enormous amount of textual data. It was released publicly in late 2022 by OpenAI organization. Quickly, the curiosity of its users has shown that it is much more caable thatn basic question answering, showing outsanding results for variety of tasks –

from poertry writing and playing board games to program code generation and debugging [12]. Additionally, it has shown potential in area of basic supervised machine learning tasks [14], as it requires much smaller amount of data for training for adjustment than training a model from scratch, as it was already trained on almost whole World Wide Web.
Problem solving based on ChatGPT consists of forming prompts which provide the additional information as context and sending them via REST API to the online service itself. In this case, we make use of Python API, building upon code used for prompt construction and service invocation, as desribed in [14]. In our case, we provide labelled examples for known fading type generated using calculations using expressions, as the one derived in this paper. Context is given in the following form, representing the labelled data samples:

$$LabelFadingType_i = \left(ReceiverType_i CC_i \; X_i \right) \tag{13}$$

When it comes to p rompt itself, we define it as:

$$Classify\left(ReceiverType_i CC_i \; X_i \; BS_i Area_i \right) \tag{14}$$

Problem solving based on ChatGPT consists of forming prompts which provide the additional information as context and sending them via REST API to the online service itself. In this case, we make use of Python API, building upon code used for prompt construction and service invocation, as desribed in [14]. In our case, we provide labelled examples for known fading type generated using calculations using expressions, as the one derived in this paper. Context is given in the following form, representing the labelled data sampl.
Finally, Table 1 gives evaluation results, considering the following aspects: 1) processing time – time needed for classification of a single new observation; 2) minimal context size – least number of labelled examples within context in order to perform classification; 3) accuracy – correct classification ratio per 10 records for given minimal size of context expressed as percentage.

Table 1. ChatGPT Approach to fading type determination : Evaluation Results

Aspect	Result
Execution time	2.21 s
Minimal context	15
Accuracy	85%

According to the achieved results, the proposed apporach seems promising as it performs with satisfiable accuracy for quite small number of labelled examples, giving the additional flexibility of data analysis, considering that model re-training is not required for each small modification of dataset layout (such as introducing additional input variables).

4. CONCLUSION

In this paper, we analyzed the L-branch SC receiver in the presence of Rayleigh fading and co-channel interference. For such a scenario, in this paper, an expression for the capacity of the channel for a signal that is subject to the influence of fading and interference is mathematically derived and graphically presented. Based on the graphic display, we determined that the system has the best performance when the number of system branches is greater than 2. Using the obtained expressions, the probability of the SIR output of the SC receiver for a system with L branches is effectively estimated. Also, in the second part of our work, we showed that the optimal choice of base station minimizes the total costs and provides the best possible quality of service (QoS). According to the obtained results, it is evident that the cost reduction achieved in this way is significant, and it depends on the specific example of the smart city model.

In the second part of the part of the paper, we proposed a novel workflow for QoS adjustment on receiver's side leveraging fading type classification based on trending ChatGPT. According to the achieved outcomes, this approach exhibits satisfiable prediction accuracy even for small number of labelled examples.

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THE OUTAGE PROBABILITY IN SYSTEM LIMITED BY NAKAGAMI FADING AND CO-CHANNEL INTERFERENCE FOR CLASSIFICATION-BASED QoS ESTIMATION

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Abstract: *In this paper, we conducted an analysis of the probability of outage (P_{out}) at the receiver output with selection combining (SC) with L branches of a wireless communication system in the presence of Nakagami-m fading and Nakagami-m co-channel interference (CCI). The mathematical form of the function for P_{out} in terms of the normalized signal-to-interference ratio (SIR) was derived, on the basis of which a graph was drawn for different values of fading and CCI parameters. In the second part of the paper, we propose a classification-based approach implemented in Weka to estimate the QoS level using the P_{out} of the observed system as one of the inputs*.
Keywords: Outage probability (P_{out}), Selection Combining (SC), Nakagami-*m* fading and co-channel interference (CCI), Weka, machine learning.

1. INTRODUCTION

In wireless communication systems, the three main channel impairments are: short-term fading (multipath propagation), long-term fading (shadowing), and the corrupting effect of co-channel interference. Shading or long-term signal variation follows a Lognormal distribution, while short-term signal variations can be described by several other distributions such as Hoit, Rayleigh, Rice, Nakagami-*m*, and Weibull, and others. Considering that interference is significant in today's wireless networks, the channel model in communication systems ignores the effect of receiver noise on system performance. Short-term fading refers exclusively to temporal changes of the communication channel due to the movement of the mobile unit or surrounding objects. In long-term fading, the impulse response of the channel changes much more slowly than the transmitted signal, so that the channel can be considered invariant for the duration of a few symbols of the transmitted signal. The speed of movement of the mobile unit (or objects in the channel) and the rate of signaling determine whether the transmitted signal will be subject to fast or slow fading [1].
The Rayleigh channel model is used in situations where there is no direct optical line visibility LOS (line of sight - los) between the transmitter and receiver, which is typical for urban environments. In intercity zones and suburban areas are used the Rice model, which includes the existence of a los component. Variations in current received signal strength in urban areas can be described quite well by Nakagami and Weibull distribution. Nakagami-*m* model is used to describes the mobile radio

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channel, to model the attenuation of multipath wireless signals and to study the effect of fading channels on wireless communications [3].
In order to improve system performance in case of pronounced fading, the diversity technique is applied. Diversity techniques it is based on the principle of using a large number of copies of the sent signal, which are statistically independent. Most commonly used signal combining techniques after application various techniques are: Selection Combining (SC)-which implies the choice of a branch with with the most favorable signal-to-noise ratio, Maximum Ratio Combining (MRC) – combining with maximum signal- to-noise ratio, Equal Gain Combining (EGC) – combining with equal contribution of all branches, Switch and Stay Combining (SSC)–simple switching combining, as well as various hybrid techniques combining signals[4].
The most commonly used performance indicators are diversity receivers in fading environments are the mean value output signal-to-noise ratio (SNR) or signal-to-interference (SIR), as well as the probability of system outage (P_{out}) and bit error probability (BER). Outage probability-denoted by P_{out} is the probability that the instantaneous error probability exceeds a specified value or equivalently the probability that the output SNR or SIR falls below a certain specified threshold γ_{th} [5].
In this paper chosen channel model Nakagami-*m* was for describing the statistics of multipath fading, due to its simplicity and frequent application. The parameter m is called the fading parameter and can take any value in the interval (1/2, +∞). For *m*=1 the Nakagami distribution becomes Rayleigh's, and for *m*>1 Rice's distribution [6]. On the other side, the second part of this paper considers leveraging the previously derived outage probability expression for purpose of proactive Quality of Service (QoS) estimation, based on classification model implemented using Weka in Java programming language.
The structure of this paper is as follows. After the introductory part (Section I), the analysis of P_{out} of the transmission channel affected by the Nakagami-*m* fading will be presented (Section II) by deriving the closed-form expressions for PDF, CDF, and P_{out} and numerical analysis of the P_{out} for multiple combinations of the fading parameters and different numbers of branches *L* of the SC receiver, will be conducted and results discussed. QoS estimation using classification in Weka will be presented in Section III. The conclusion of the paper is given in Section IV.

2. OUTAGE PROBABILITY OF THE SIR AT THE OUTPUT OF SC RECEIVER

The system considered in Figure 1 is an *L*-branch SC receiver when Nakagami-*m* fading and Nakagami-*m* co-channel interference are present. At the input of the *L*-branch SC receiver (*L*=2, 3,..., *n*) there are *n* copies of the useful signal: x_1, x_2, ..., x_n. Also, at the inputs to the SC combiner, signal components originating from the CCI y_1, y_2, ..., y_n appear. The SC receiver from the *L*-branch selects the signal with the highest SIR from the input antennas.

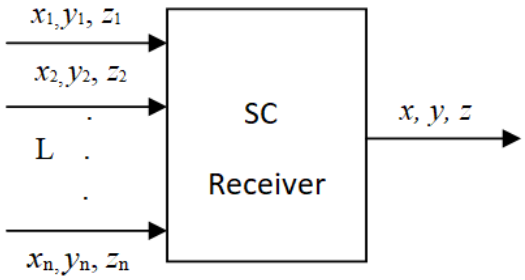

Figure 1. Model of the considered *SC* combiner with *L* branches

Signals at the receiver input have a probability density function (PDF) modeled by Nakagami-*m* distribution [7]:

$$p_{x_i}(x_i) = \frac{2}{\Gamma(m_1)}\left(\frac{m_1}{\Omega_i}\right)^{m_1} x_i^{2m_1-1} e^{-\frac{m_1}{\Omega_i}x_i^2},\ x_i > 0,\ i = 1, 2, ..n \qquad (1)$$

where m is the Nakagami-m short-time fading severity parameter, Ω represents the average SNR represents the average SNR, and $\Gamma(\cdot)$ denotes the Gamma function. The co-channel interference follows Nakagami-m distribution:

$$p_{y_i}(y_i) = \frac{2}{\Gamma(m_2)}\left(\frac{m_2}{s_i}\right)^{m_2} y_i^{2m_2-1} \mathrm{e}^{-\frac{m_2}{s_i}y_i^2},\ y_i > 0,\ i = 1,2,..n \tag{2}$$

where s_i represents the power of interference: $\Omega_i(x_i) = \bar{x}_i^2, s_i = \bar{y}_i^2$. The ratio z_i of the desired signal and the co-channel interference at the i^{th} branch at the SC receiver input is: $z_i = x_i / y_i, x_i = z_i y_i$.
The SC receiver chooses the signal with the highest SIR of all signals (i=2,3,..n) and forwards it to the output: $z = \max(z_1, z_2 ... z_i)$. On each branch at the entrance to the SC receiver, the PDF of the SIR-z_i relationship is [8]:

$$p_{z_i}(z_i) = \int_0^\infty \mathrm{d}y_i y_i p_{x_i}(z_i y_i) p_{y_i}(y_i) = \frac{2z_i^{2m_1-1}\Gamma(m_1+m_2)}{\Gamma(m_1)\Gamma(m_2)}\left(\frac{m_1}{\Omega_i}\right)^{m_1}\left(\frac{m_2}{s_i}\right)^{m_2}\left(\frac{\Omega_i s_i}{m_1 s_i z_i^2 + m_2\Omega_i}\right)^{m_1+m_2} \tag{3}$$

The cumulative distribution function (CDF) of z_i is [8]:

$$F_{z_i}(z_i) = \int_0^{z_i} \mathrm{d}t p_{z_i}(t) = \frac{2(\Omega_i m_2)^{m_2}(s_i m_1)^{m_1}\Gamma(m_1+m_2)}{\Gamma(m_1)\Gamma(m_2)} \int_0^{z_i} \mathrm{d}t \frac{z_i^{2m_1-1}}{\left(m_1 s_i z_i^2 + m_2\Omega_i\right)^{m_1+m_2}} \tag{4}$$

The integral in (4) can be solved by using [9]:

$$\int_0^\lambda \frac{x^m}{\left(a+bx^n\right)^p}\mathrm{d}x = \frac{a^{-p}}{n}\left(\frac{a}{b}\right)^{\frac{m+1}{n}} B_z\left(\frac{m+1}{n}, p-\frac{m+1}{n}\right), z = \frac{b\lambda^n}{a+b\lambda^n}, a>0, b>0, n>0, 0<\frac{m+1}{n}<p \tag{5}$$

where, $B_x(p,\mathrm{q})$ is Incomplete Beta function [10; 8.39] we get that the CDF of z_i is:

$$F_{z_i}(z_i) = \frac{\Gamma(m_1+m_2)}{\Gamma(m_1)\Gamma(m_2)} B_{\frac{m_1 s_i z_i^2}{m_2\Omega_i + m_1 s_i z_i^2}}(m_1, m_2) \tag{6}$$

When interference is present in the environment, P_{out} is defined as the probability that the output SIR of the used combiner will fall below the defined protection ratio, which depends on the applied modulation technique and expected grade of service (GoS). On the receiver output SC with L branch, P_{out} is [11]:

$$P_{out}(z<\gamma_{th}) = \left(F_{z_i}(z_i)\right)^L = \left(\frac{\Gamma(m_1+m_2)}{\Gamma(m_1)\Gamma(m_2)} B_{\frac{m_1 s_i z_i^2}{m_2\Omega_i + m_1 s_i z_i^2}}(m_1, m_2)\right)^L \tag{7}$$

In order to analyze the influence of the SIR parameters on the performance of the considered system, we drew a graph for P_{out} from the expression (7), shown in Figure 2. One of the assumptions is that there is no correlation between the input branches in the SC receiver. Figures were created using Wolfram Mathematica and Origin.

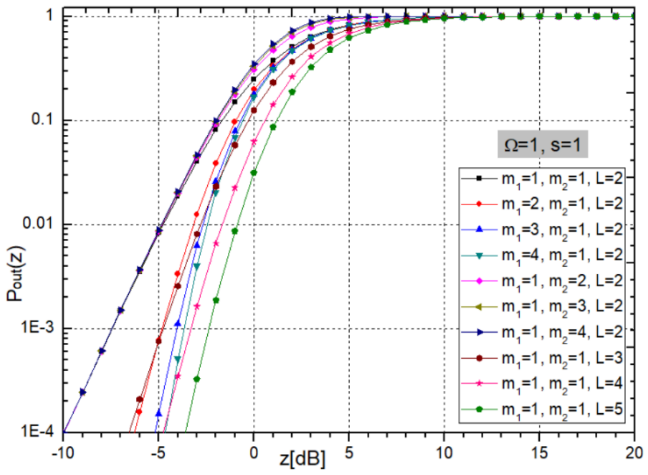

Figure 2. P_{out} of L-branch SC receiver for different values of fading parameters m_1, m_2 and the number of diversity branches L.

From Figure 2, we see that with the increase of parameters m_1 and m_2, the outage probability (P_{out}) of the system decreases and the performance of the system improves. Also, the outage probability of the system decreases with the increase in the number of diversity branches L at the input of the SC combiner, and the system performance improves.

3. QoS ESTIMATION CLASSIFICATION IN WEKA

The potential of artificial intelligence adoption and predictive models has been identified among the key-enablers contributing to progress towards the next generation wireless and mobile networks [12]. This paper introduces an approach to Quality of Service (QoS) prediction leveraging machine learning algorithms, considering the previously calculated P_{out} among the input variables of predictive model. Furthermore, there are also other input factors included: 1) identifier of observed smart city area 2) number of active service users for the area 3) identifier of base station covering the area of interest 4) season number, depicting the period within a year.
On the other side, the target of predictive model represents categorical outcome which illustrates QoS level. This value is a label and has several possible values: "1"–failure or anomaly occurred; "2"–low/insufficient; "3" –normal, "4"–"maximum". Considering that, we treat the prediction problem as multilabel classification. Table 1 depicts the header layout of the training dataset which was generated leveraging our simulation environment [13].

Table 1. QoS Level Dataset Header

Area id	Pout	Num Users		Bs id	Num Season	QoS [1-4]

When it comes to predictive QoS level predictive model implementation, we make use of free to use (under GNU public license) library - Waikato Environment for Knowledge Analysis (Weka) [14] aiming Java programming language. It includes a set of machine learning technique implementation, together with additional features, enabling convenient data preparation, management and visualization. Regarding the algorithms aiming supervised machine learning trained on samples with known outcome (label), it includes several classification approaches - decision tree, decision stump, ID3 and k-nearest neighbors.
In Table 1, summarized evaluation results focused on two aspects–prediction performance (as accuracy – correct sample classification percentage) and processing time required for training of classification model on laptop with given configuration: CPU - Intel Core i5-10300H quad-core 2.50GHz; RAM - 24GB DDR4 and storage - 512 GB SSD. Observed dataset of 50 000 samples was divided into set for training (75%) and test (25%).

In Fig. 3, the full workflow of the underlying approach is depicted. In the first steps, users-defined network models are created based on tools from our previous works [12, 14]. After that, calculation of outage probability is done with respect to this model. Additionally, for this step we make use of NVIDIA CUDA kernels [13] with aim to parallelize loops which gives around 60 times speed-up compared to CPU-only implementation. Once the outage probability values are known, they are used together with variables for training of Weka-based predictive model. Weka's predictive model workflow includes several phases: 1) importing CSV dataset 2) conversion of CSV values to Weka instances 3) target variable selection 4) classification model object instantiation 5) model training 6) model evaluation. After all these steps, the model is finally ready to make predictions on unseen inputs. Finally, based on prediction outcomes, decisions can be taken regarding the operator infrastructure parameter tuning with goal of proactive QoS improvement.

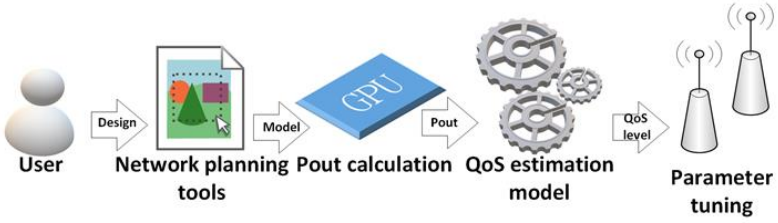

Figure 3. Classifiication-based macihne learning QoS level prediction workflow relying on Weka

TABLE 2. EXPERIMENTS AND EVALUATION RESULTS

Method	**Training** [s]	**Accuracy** [%]
DecisionTable	39.8	96.4
J48	9.1	91.1
DecisionStump	11.5	86.3
iBk	2.4	89.3
Average prediction time [s]	0.08	

Observing the achieved results from Table 2, it can be noticed that DecisionTable method shows the best performance compared to others in terms of prediction quality expressed as accuracy. On the other side, training time required for this approach is the longest among the compared techniques. Moreover, ID3-based J48 method is the second when it comes to prediction accuracy, but training phase is much faster. Additionally, DecisionStump requires the shortest amount of time to be trained, while it exhibits the worst accuracy performance. However, iBk based on k-NN shows slightly better results, but the required training time is longer. Finally, average prediction time for a single prediction for all the methods does not exceed 0.1 s.

4. CONCLUSION

In this paper, the expression for the outage probability (P_{out}) is derived as one of the important measures for the quality of transmission in wireless networks. Numerical results showed that increasing the fading parameters m_1 and interference m_2 leads to a decrease in P_{out} and the system works better. We also concluded that increasing the number of SC diversity branches reduces the level of P_{out} and the performance of the system is better. Additionally, we have proposed the software environment for simulation of P_{out} for the observed Nakagami-*m* fading system, leveraging the calculated value as one of inputs for classification-based method aiming QoS estimation. According to the achieved experimental outcome, the proposed workflow shows both promising accuracies, quite fast training and single prediction execution times.

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ENVIRONMENT AND SUSTAINABLE DEVELOPMENT. MECHATRONICS. OCCUPATIONAL SAFETY AND HEALTH AND FIRE SAFETY. SMART MANAGEMENT SYSTEMS. GRAPHIC ENGINEERING. DESIGN. TRAFFIC ENGINEERING. BIOTECHNOLOGY AND HEALTHCARE. MECHANICAL ENGINEERING. ECOTOURISM AND RURAL DEVELOPMENT.

COMPUTER DEVICES AND THE SERBIAN LANGUAGE - INTERFACE AND APPLICATION

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Abstract: *Computer devices (desktop and portable computers, tablets, mobile phones ...) are used daily for creating documents and for various forms of communication. The user controls the computer (or "communicates with it") through a special set of programs called the operating system, through graphical elements and text in different languages, including Serbian in Cyrillic or Latin script. This paper deals with the level of using the Serbian language usage for communication with computers, as well as the creation of documents in the Serbian language. There is an overview and description of using computer techniques in Serbian on various devices and operating systems, such as Windows, Linux, Android, iOS. The specifics of using the Cyrillic and Latin letters scripts are covered, also as well as combining and converting one letter script to another (transliteration). A pilot study was conducted on users' familiarity with the possibilities of using computers in the Serbian language, the ways in which they use them and their views on the necessity of observing language standards. Measures were proposed to improve the level of language culture when using computer devices, especially in educational institutions.*
Keywords: computer use, Serbian language, Cyrillic script, Latin script

1. INTRODUCTION

In the transition period from the 20th to the 21st century, there was a rapid increase in the use of computer devices in Serbia. In that period, there was no adequate support for the use of computers in the Serbian (operating systems and document creation) This support is mainly related to the lack of hardware and software components, inadequate training of teachers and, consequently, unsatisfactory training of users. The situation is further complicated by the fact that two scripts are used in the Serbian (Cyrillic and Latin), while only Cyrillic is recognized internationally. That is why manufacturers of computer devices and software have taken different positions regarding the use of both the Cyrillic and Latin alphabets. This led to the creation of bad habits among users: excessive use of the English language in communication with computer devices, acceptance of poorly adjusted devices and non-respect of Serbian spelling, etc. Overall, the result is low productivity and low-quality documents in the Serbian language, while the considered support has not been significantly improved so far. The aim of this paper is to point out the currently available possibilities and shortcomings of available computer devices (hardware and software) and to propose measures to complete the support for the use of computers in the Serbian language.

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2. KEYBOARDS

As a rule, text entry is performed using the keyboard. Keyboards can be a separate peripheral device or a dedicated part of the screen. One key is activated by clicking the mouse or touching a finger on touch screens (virtual keyboards). Physical keyboards enable faster and more productive text input and editing. Physical keyboards are mostly used on desktop and laptop computers, and virtual keyboards on mobile devices (tablets and mobile phones). Programs for managing keyboards determine the arrangement of characters on keys and the way to change the keyboard. All keyboards allow the entry of special characters and characters of different world alphabets through the dedicated management programs.
Physical keyboard are separated computer peripherals. A physical keyboard for a language or script means that the keys are arranged according to the appropriate standard and that the corresponding letters of that language or script are visible on the keys. Physical keyboards for the Serbian language on the Serbian market exist mostly only for the Latin alphabet. The authors were able to find only one type of Cyrillic keyboard in three online stores (for example [1]). Regardless of the fact that there are Latin keyboards, Serbian users often use some other keyboards, most often English, to write text in the Serbian language. If there is no suitable Serbian keyboard, users have the following options:

1. Use the keyboard you have, set the Serbian Cyrillic or Latin alphabet in the software, learn by heart where each letter or character is located (and often make mistakes). This kind of thing is mostly practiced when the Serbian Latin keyboard is used to enter text in Cyrillic.
2. Improvise. Write a letter or stick a label on the characteristic keys, Figure 1 [2]
3. Obtain and stick sets of stickers for one or two languages or letters that the user will use the most Figure 1 [3].

Figure 1. Improvised key labelling and Keyboard with a set of stickers
Source: *https://urlis.net/jzjoht8y & https://urlis.net/g1m3m1zp*

Using multiple languages/scripts on one computer also requires an efficient way to change wih. For example, the more efficient Win+Space or Accent Grave (`) can be added to the usual Alt+Shift in Windows.
Virtual keyboards are special programs (tools) built into operating systems and software packages. Virtual keyboards exist for all types of devices and operating systems, but are mainly used for portable devices with a touch screen; they exist for both Cyrillic and Latin. English keyboards for the Latin alphabet have keys for every letter of the English alphabet, and letters containing diacritical marks (for the Serbian alphabet šđčćž) are typed by long pressing the corresponding key to get a menu with all available letters with diacritical marks. This is also the case with the Serbian Latin keyboard for the iOS operating system (Figure 2). This method greatly slows down text input, so users often type only the basic character: c for c, č and ć; s for s and sh; z for z and ž, as well as dj instead of đ – the so-called clipped Latin alphabet. Users who acquire such a harmful habit also often apply it to keyboards, physical and virtual, which have keys for all the necessary letters. Cyrillic keyboards have a corresponding key for each letter of the Serbian alphabet (for example Figure 2, also for iOS), as well as, for example, the GBoard and Swift Key keyboards, which are available for several operating systems.

All keyboards have a lot of techniques that make it easier to type text, including giving suggestions for finishing the started word - these techniques, however, require a lot of adjustment and getting used to, so beginners often don't apply them. Some keyboards, such as Gboard, have the ability to convert speech into text for the Serbian language. For the Android operating system, the functionality is good, but for iOS, our country/region is not supported! Overall, there are good options for converting speech to text for Android, while the iOS Serbian language is not supported at the level of the operating system.

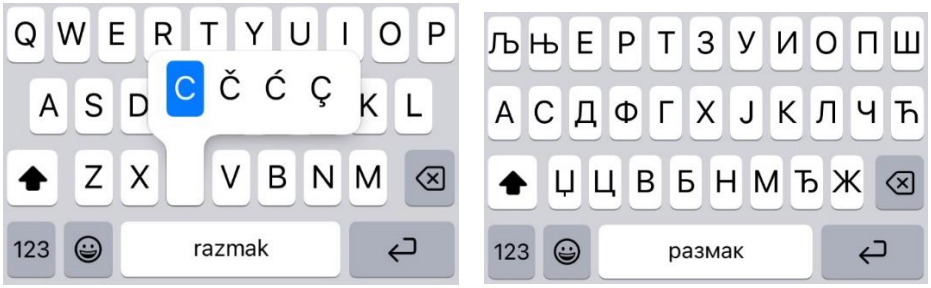

Figure 2. Virtual Keyboard for iOS
***Source**: original copyright*

3. TEXTUAL INTERFACE OF OPERATING SYSTEMS AND APPLICATIONS

Most operating systems have a predominantly graphical interface, but also with a lot of text for command names and messages. It is similar with applications of various types such as office applications, web browsers and open source software. All operating systems except iOS and on all devices support the Serbian Cyrillic and Latin interface, as well as most of the listed applications (except those for iOS). Figure 3 shows an example of the application interface in the Serbian language.

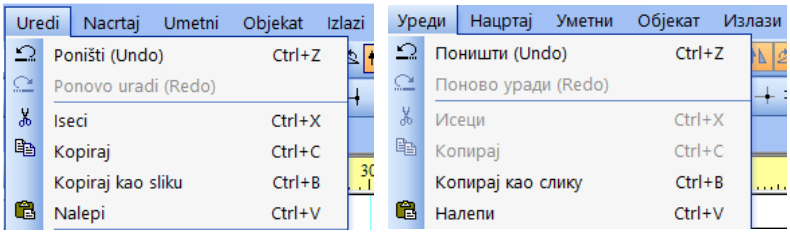

Figure 3. User interface example in Serbian
***Source**: original copyright*

4. LANGUAGE TOOLS FOR SERBIAN LANGUAGE

Spellchecking involves comparing a written word with words in the dictionary. The user is prompted for an error, offers options for replacing or adding a new word to the dictionary. The ability to add a new word is especially important for the Serbian language, since different cases and other words with different suffixes in spellcheckers are treated as separate words. However, in the application, one user quickly refills the list of words and the spelling check is quite functional. The most commonly used word processing programs have built-in spellchecking for Cyrillic and Latin script, with a corresponding adjustment, which is not quite simple so it is often absent. Most e-mail programs have spell checking, often through additional programs and settings. For example, online Gmail has a good spell checker for Cyrillic. Other language tools: hyphenation, thesaurus, automatic word correction, grammar checking - in principle they also exist for the Serbian language, but not with a mostly incomplete word pool, but with the possibility of adding it. Language tools for Serbian language are numerous for web browsers, but mostly are not widely used and sufficiently developed. Interesting is the language tool [4] which allows irregular and unacceptable typing of text in Latin script (Dosli su saptaci. – Figure 4) to be converted into correct text in Cyrillic – Дошли су шаптачи.

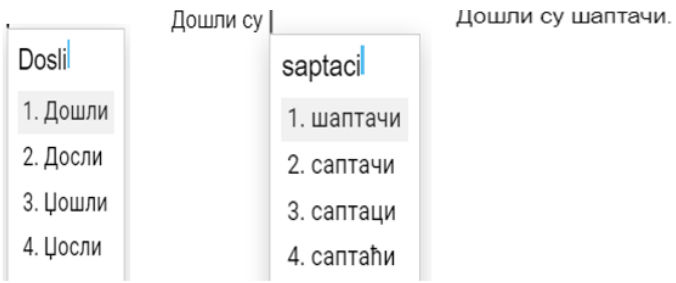

Figure 4. Example of language tools
***Source**: original copyright*

Document templates (DTs) are predefined documents that serve as the basis and starting point for creating new ones. DT is read only file, so an ordinary user can hardly modify them, but can easily create new ones. DTs contain a variety of language (e.g. script language) and national settings (e.g. date and paper format), and may contain parts of the content. There is usually a basic default DT (e.g. called Normal). If DT for Serbian language is not already installed, users should adapt the basic DT to the Serbian language and the usual documents. If, for example, DT for English instead of for Serbian is used, typical errors can occur such as: using Letter paper instead of A4, displaying dates 12/03/2023 incorrectly as 12/03/2023 or, worse, 03/12/2023 and, typically, the conjunction "i" transformed into "I" (English personal pronoun) through autocorrect options.

5. TRANSLITERATION

Transliteration (preslovljavanje in Serbian) is the process of transferring a word from the alphabet of one script to another. Problems in transliteration Cyrillic to Latin and vice versa arise from the fact that in Latin for some letters two characters are used: lj for љ, nj for њ, as well as irregular but often used dj instead of đ for ђ.
Table 1 shows examples of errors in the conversion of Cyrillic to Latin and Latin to Cyrillic. Colour and bold letters indicate converted or misspelled words. The first example refers to the conversion of the letter pair n-j in which the letter nj can also be denoted in the Latin alphabet. The second and third examples refer to the appearance of Latin letters in the dominant Cyrillic text: Roman numerals and units of measurement. The fourth and fifth examples show the correct and incorrect input of the Latin letter đ as dj. All of these irregular conversions should be recognized by the spellchecker, but the conversion is not automatic and requires additional user involvement. Another way would be to extend transilleration programs with vocabulary words that need to be excluded from conversion. From the table it can be seen that the conversion from Cyrillic to Latin alphabet is always correct, while with reverse conversion there are errors. Plugins and web services for transliteration are mostly created by individuals or open source communities, so they are often not maintained or upgraded. The authors do not know that there are such tools created by a state institution or one of the manufacturers of word processors. Thus, transliteration users are reduced to the conversion of smaller wholes of text and careful proofreading, while the transcription of entire documents is generally more complicated. In general, it can be recommended that for texts that should be published in both Latin and Cyrillic, first make a text in Cyrillic, and then convert into Latin. In addition, it is necessary to encourage the organization and state institutions to create appropriate programming tools for transliteration.

Table 1. Transliteration examples
***Source**: original copyright*

	Cyrillic	Cyrillic to Latin	Latin to Cyrillic
1.	Инјекција	Injekcija	**Ињекција**
2.	III i IV vek	III i IV vek	**ИИИ и ИВ век**
3.	Потрошња од 256 kWh	Potrošnja od 256 kWh	Потрошња од **256 кWх**
4.	Ђорђе	Đorđe	Ђорђе
5.		**Djordje**	**Џорџје**

6. SURVEY

In the electronic survey on computer devices and the Serbian language conducted from April to August 2023, 111 respondents participated, of which 90% have higher education and five have secondary education; 32% are 25 to 40 years old and 64% are 40 to 65 years old. So, it is mainly about the active population where 32% work in the public service or public company, 10% are teachers at some of the levels of education, 6% are IT specialists and students 4%. 45% of respondents aged 25 to 40 assessed the level of training they had for the use of computer devices in Serbian as satisfactory at the primary and secondary level of education; and 50% on higher education (offered answers were: satisfactory, unsatisfactory and without training). For a population of 40 to 65, satisfactory training had 20%. It is possible that there was an interesting situation that the second mentioned population trained the first!

92% to 96% of respondents know that the interface of computer devices can be in Serbian (mostly for mobile phones). About 2/3 of the respondents use the English interface, one-third serbian, for all devices except mobile phones, where it is the other way around. For word processing, e-mail, and web browsing, 55% of respondents use the interface in Serbian and 45% in English. For SMS and social networks, this relationship is 77% for Serbian and 23% for English. These results suggest that only mobile phone providers and partly mobile phone vendors sell phones that are already set up for use in Serbia. Setting up for Serbian language with vendors of other devices, as well as setting up in companies and institutions (including those required by law to use the Cyrillic alphabet) – is largely absent. Correct Latin script is mostly used for writing texts in Serbian, except for official correspondence, where Cyrillic script dominates (Figure 5). The mutilated Latin script is mostly used for short messages that are mostly written on a mobile phone.

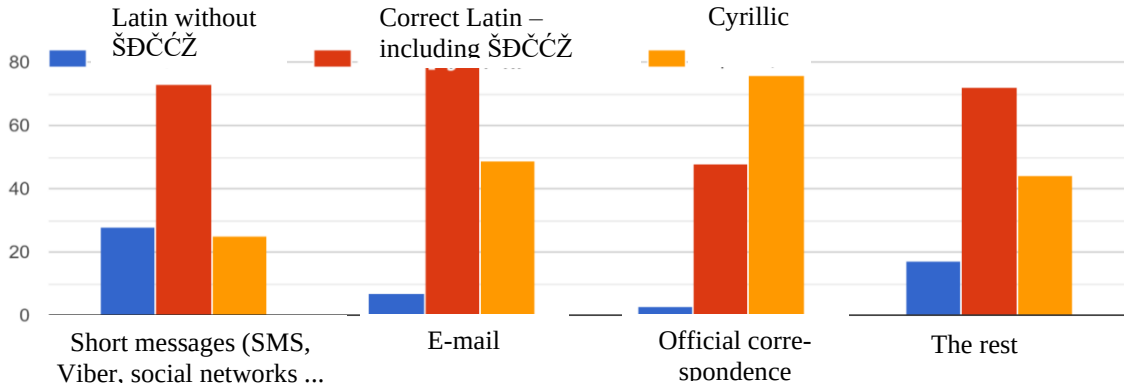

Figure 5. Script used for texts in Serbian language
***Source**: original copyright*

Respondents were able to cite a number of reasons: **A)** Why English is more suitable for communicating with computers – offered answers with the possible addition of new answers. The following answers were obtained (given by more than 10% of respondents): 29% - English is not more suitable; 41% - due to habit; 39% - because most computers are set up for English; 29% - I know computer terms in English very well; 11% - because most keyboards are for English. **B)** Why writing without SĐČĆŽ is more suitable for them to write. The following answers were obtained: 63% - do not approve of such writing; 15% - because computers are often not set up for Serbian; 12% - due to habit; 11% - the letters šđčćž are not visible on mobile devices. **C)** Why Cyrillic is more suitable for writing. The answers are: 20% - I believe that writing in Cyrillic is not suitable (we already have Latin alphabet); 54% - Cyrillic script is primarily Serbian script; 15% - because it always uses only one key to write one letter.

37% of respondents believe that learning to use computer programs would be easier if the interface language was Serbian, 22% believe that this would not be the case, and 41% of respondents are not sure. Respondents were asked to assess the extent to which it is important to properly use the Serbian language on computer devices. Ratings of 1 to 10 are offered, where 10 corresponds to the highest importance. 50% of respondents gave a score of 10, 86% from 6 to 10, and as many as 5% to grade 1.

In short, the survey was conducted on a sample of a population that actively uses computer devices in Serbian. In the relevant group of respondents aged 25 to 40 years, only 50% were satisfied with the training for using computers and writing in Serbian. Although practically all respondents know the interface of computer devices can be in Serbian, only about 2/3 of respondents use the English interface, one-third use Serbian, for all devices except mobile phones, where it is the other way around. The above indicates poor training and setup of devices (hardware and software) for computer use and the production of documents in Serbian. This led to the fact that most computers are set up for use in English, and that texts in Serbian are difficult to write and often misspelled incorrectly.

7. RECOMMENDATIONS

In order to improve the production of documents in the Serbian language, it is necessary that institutions, especially educational and ministries, as well as companies, systematically implement the following steps:
1. **Training for the use of computers** with a Serbian interface and preparation of documents in the Serbian language, as a rule Cyrillic Script. **A)** Train teachers at all levels of education, with appropriate training checks – upon employment and periodically. **B)** Train the IT professionals who configure the computers, with the prior creation of a precise configuration specification. **C)** Pupils and students should be trained exclusively to work on computers with a Serbian interface and for the production of documents in the Serbian language with clear requirements. It is especially important that young children use only devices with an operating system in the Serbian Cyrillic alphabet from the beginning, since literacy also begins in the Cyrillic alphabet.
2. **Hardware.** Oblige computer sellers to have Serbian Latin and Cyrillic keyboards as a basic offer – as two separate devices and as a single device.
3. **Software. A)** Oblige sellers to sell all software in wide use already set for the Serbian language. **B)** Encourage the creation of a program for Transliteration as well as templates for documents in the Serbian language and make them available free of charge to sellers and users. **C)** Encourage the development and improvement of other tools, such as hyphenation, thesaurus, automatic word correction, grammar checking.
4. **Regulation.** Enact appropriate regulations related to the previous points.

8. CONCLUSION

The paper deals with hardware components and software tools for using computer devices in the Serbian language - possibilities and availability on the market. The results of a survey on the use of computers in the Serbian language were presented. It has been shown that the main causes of non-productivity and errors in the preparation of documents and texts in the Serbian language are: inadequate training, poor adjustment of computer devices and inadequate offer on the market, as well as already created bad habits among users. Specific measures that institutions and companies should undertake in order to improve the productivity and quality of writing texts and documents in the Serbian language are proposed. These measures are primarily related to encouraging and obliging, above all, educational institutions to conduct training with correctly selected and adjusted software and to pass appropriate regulations. Also, development and improvement of appropriate software tools should be encouraged and their free use should be enabled for all users.

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[3] Stik, Keyboard sticker, universal keyboard stickers, type as you say, In Serbian,
[4] Google alatke za unos teksta, [Internet] Available on: https://shorturl.at/ioEH8 , Accessed 15.09.2023.)

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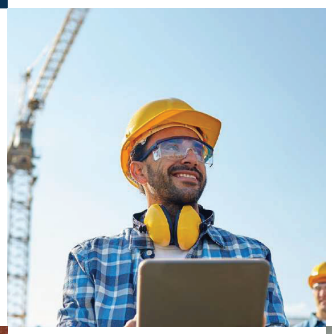

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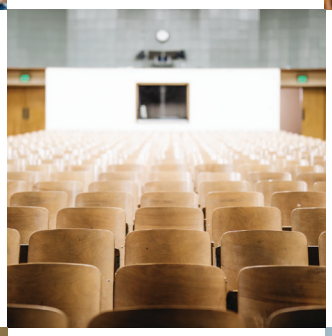

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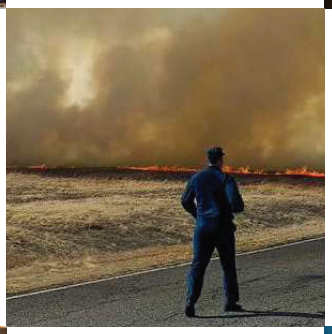

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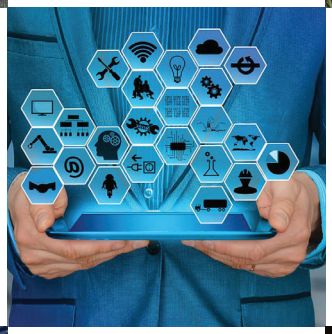

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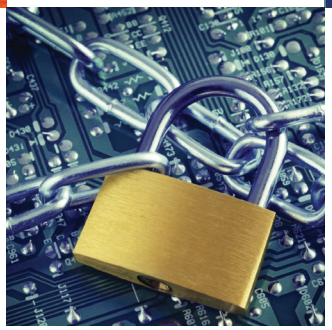

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GRAFIKUM

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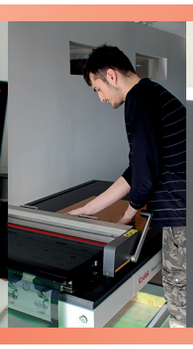
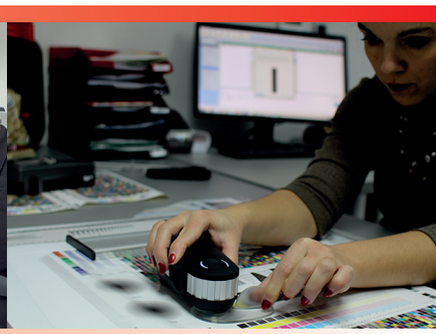
Sa više od 150 klijenata, uglavnom sa tržišta ofset i flekso štampe, Grafikum je dobro poznato ime i simbol za ponudu dobrih proizvoda, vrhunskih tehnologija i softvera.

Prepoznajemo potrebu da podržimo naše klijente i sa servisne strane. Zahvaljujući stručnosti naših servisera imamo veliki broj potpisanih ugovora o servisiranju naših CTP uređaja. Ovakvim pristupom, naši klijenti su sigurni u svojim procesima znajući da će u svakom trenutku imati našu podršku.



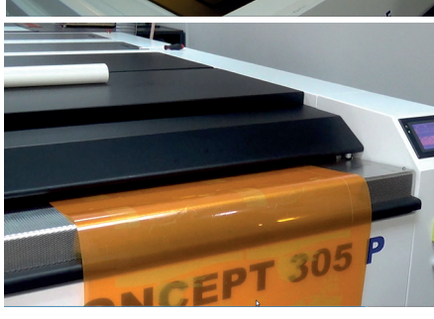


Kodak Flexel NX sistem, lider u procesu izrade flekso ploča, samo je jedan sa liste naših odličnih proizvoda.

Gradeći sopstveni Demo Flexel NX Studio, sa kompletnim procesom izrade ploča, Grafikum nudi tržištu mogućnost korišćenja NX ploča i istraživanja ove sjajne tehnologije sa svim njenim prednostima.

Pokazujući šta NX flekso ploča donosi štampi, stičemo puno poverenja u flekso industriji i uspostavljamo jake veze.

Studio je takođe opremljen workflow softverom (Kodak Prinergy Wokflow), mernim uređajima (Techkon) i sistemom za izradu probnog otiska (CGS ORIS) kako bi kupci, kako stari tako i novi, mogli da vide naše proizvode na delu i upoznaju se sa svim beneficijama koje oni nude.



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