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JOINT ASSESSMENT OF THE SAFETY AT WORK AND ENVIRONMENTAL IMPACTS¹

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ABSTRACT

At the height of the new industrial era, the processes of production and storage tend to replace the conventional with automated remote control. The question is: how would the new industrial age affect workers' safety? This research is a brief overview of the general safety criteria, selecting the most appropriate alternative. Also, a short overview is given to the significance of environmental impact issues, which should be approached from the health and safety perspective, in order all together to recognize the importance of all aspects of actions, products and services in the industry.

Key words: industry, safety, TOPSIS (Technique for Order Preference by Similarity to Ideal Solution), environmental impact assessment

INTRODUCTION

The workplace environment is a very crucial factor of the productivity and mental and physical health of employees. New technologies are being developed at an implausible speed, but to raise safety, is to become more

¹ original scientific paper

familiar with the principle of work as well as hazards which have a negative impact on the workers' safety and on the environment. This paper is a joint assessment of the safety at work and environmental impacts, based on a survey and MCDM (Multi- Criteria Decision Making) [4] [5] for selecting the alternative which is the nearest to the best alternative, according to the four criteria which we selected as assessors of a safety.

ANALYSIS OF THE CURRENT SITUATION

The history of the industry has four periods: Industry 1.0., Industry 2.0., Industry 3.0., and Industry 4.0 is present since 2011 [1]. We believe that it is difficult to determine exactly when one industry ends and another one begins, but there are references that can declare that. According to our assumption, industry 3.0. is the one that is currently present [2] [3]. Technologically developed Western countries are taking the first steps in the new industry of wireless, remote, autonomous management. Industry 3.0., computer industry, the CNC machines is what most of the current industry has at its disposal [2]. In our online survey, where the respondents were directly involved - industry employees, employees in other departments and students at the Faculty of Mechanical Engineering in Skopje, when asked if they had heard of Industry 4.0., 77 responders out of 115, (i.e. 67%) stated that they had not heard about Industry 4.0. (Fig.1).

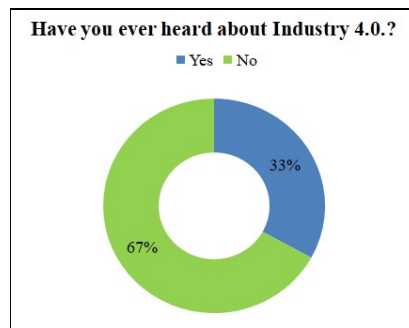


Fig.1. Survey– Industry 4.0.

However, when it comes to occupational safety, 56% of respondents rated the safety of workers in the industry in our country as medium (3). Only 4.3% think security is on an excellent level (Fig.2.).

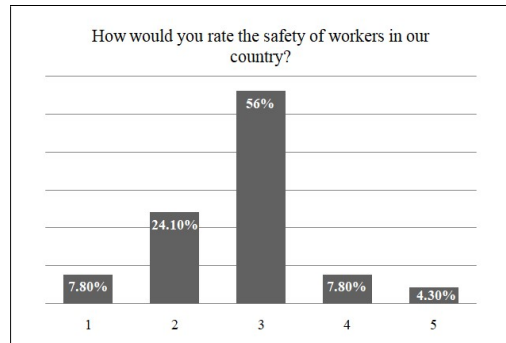


Fig.2. Survey – Workers safety

The results show that most of the respondents rated the safety as: good, poor and very poor. It shows that this issue really needs to be considered and as well as finding alternatives to increase the safety of workers in the industry.

In this paper, the TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) [5] method will be used, based on the results of the survey, to rank the best way to increase safety in the industry [6].

REVIEW OF TOPSIS METHOD MODELING CRITERIA

Depending on the type of industry, the level of used technology varies. The standards, regulations and inspections legally impose the protection of some key elements for the safety of workers.

We will use the MCDM method to rank the performance of security enhancement elements. This method is used to select a variety of decisions [5]. The good side of this method is that you can compare criteria that are not related and still be evaluated with the same values. TOPSIS is the method chosen in this paper for ranking the alternatives [6].

First of all, the results obtained from the survey will be reviewed, so that the assessments for the implementation of the TOPSIS method can be formulated.

The main question of determining the criteria for selecting the most common causes of accidents at work, when asked most respondents (25) consider that the lack of work equipment is the first cause of accidents at work. Other 18 respondents consider the improper mechanization handling.

While only 8 respondents believe that the cause may be outdated mechanization (Fig.3.).

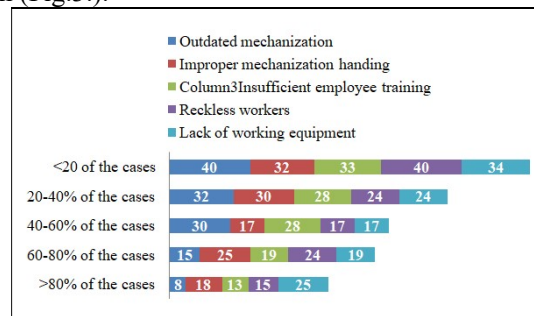


Fig.3. Survey – Causes of accidents at work

Four criteria will be drawn from this question, according to which security will be ranked with the TOPSIS method [5]:

- Criterion 1: Age of machinery;
- Criterion 2: Handling;
- Criterion 3: Employee training;
- Criterion 4: Working equipment.

The decision on the alternatives was made based on the results of the same survey, on the following questions: How much reliance do you have in the remote / wireless / autonomous management of the mechanization? On this question, 44.3%, which is a big part of the respondents, rated it with 4, which is satisfactory given the mechanization of the new era (Fig.4.).

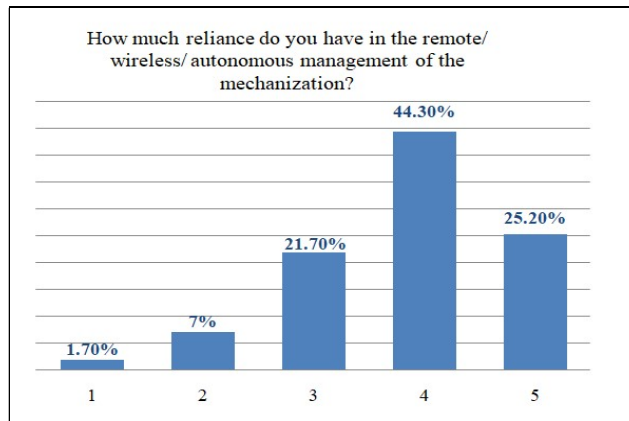


Fig.4. Survey - reliance in remote / autonomous mechanization management

Survey results show that as many as 76.5% of the respondents would opt for autonomous / wireless machinery if they needed to purchase new machinery. The results of these two questions (Fig.4. and Fig.5.) provide a key direction for determining the first alternative: Implementation of Industry 4.0.

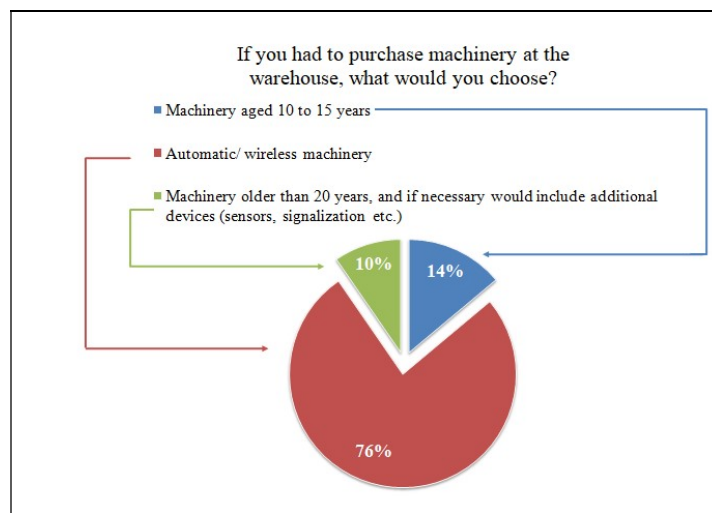


Fig.5. Survey – Purchase of new machinery

To determine the second and third alternative, we reviews the result of the question: What would you choose as the best option to increase safety (Fig.6.) ?

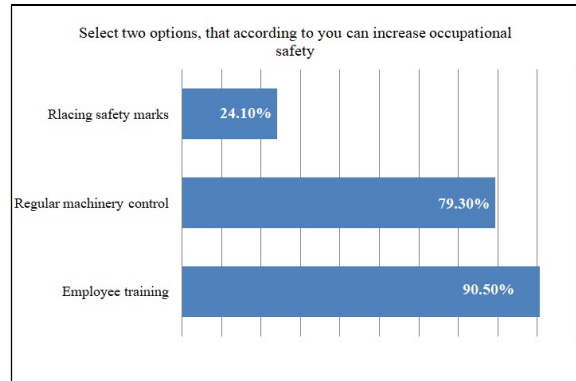


Fig.6. Survey – Increase safety

90.5% of respondents chose employee training and 79.3% chose regular machinery control.

According to this, second alternative would be: regular employee training, whilst as a third alternative: regular machinery control. The next point will show the process of calculating the selection of the best alternative, according to the four criteria and the three alternatives that were selected.

IMPLEMENTATION OF THE TOPSIS METHOD

Table 1 shows the alternatives and criteria, appropriately evaluated (according to the survey).

Alternatives	Age of machinery	Handling	Employee training	Working equipment
	Min	max	max	max
A1: Implementation of the industry: 4.0.	7	7	5	9
A2: Trainings	5	9	9	5
A3: Regular control	5	5	5	5
weightage	0.15	0.25	0.25	0.35

Through expression (1) [5] [6], the matrix is normalized, which shown in the following Table 2. Calculation of weighted normalized matrix is made using the expression (2):

$$\bar{X}_{ij} = \frac{X_{ij}}{\sqrt{\sum_{j=1}^n X_{ij}^2}} \quad (1)$$

$$v_{ij} = \bar{X}_{ij} \times W_j \quad (2)$$

Table 2: Normalized decision matrix

	Age of machinery	Handling	Employee training	Working equipment
	min	max	max	max
A1:	0.703526471	0.56225353	0.436852028	0.786333651
A2:	0.502518908	0.722897396	0.786333651	0.436852028
A3:	0.502518908	0.401609664	0.436852028	0.436852028

After that, follows the calculation of the ideal best (formula (3)) and ideal worst (formula (4)) value.

$$V^+ = (v_1^+, v_2^+, \dots, v_n^+) = \left[\left(\max_{j \in I} v_{ij} \right), \left(\min_{j \in J} v_{ij} \right) \right] \quad (3)$$

$$V^- = (v_1^-, v_2^-, \dots, v_n^-) = \left[\left(\min_{j \in I} v_{ij} \right), \left(\max_{j \in J} v_{ij} \right) \right] \quad (4)$$

Table 3. Calculation of the ideal best (V+) and ideal worst (V-) value

Calculation of the ideal best (V+) and ideal worst (V-) value				
	Age of machinery	Handling	Employee training	Working equipment
	min	max	max	max
A1:	0.105528971	0.140563383	0.109213007	0.275216778
A2:	0.075377836	0.180724349	0.196583413	0.15289821
A3:	0.075377836	0.100402416	0.109213007	0.15289821
V+	0.075377836	0.180724349	0.196583413	0.275216778
V-	0.105528971	0.100402416	0.109213007	0.15289821

Once V + and V- are divided by the expressions the Euclidean distance from the ideal best (Si +), formula (5) and ideal worst (Si-) (6) is determined.

$$S_i^+ = \left[\sum_{j=1}^m (v_{ij} - v_j^+)^2 \right]^{0.5} \quad (5)$$

$$S_i^- = [\sum_{j=1}^m (v_{ij} - v_j^-)^2]^{0.5} \quad (6)$$

Table 4. Euclidean distance from the Ideal best and ideal worst

S+	S-
0.100774907	0.128742904
0.122318568	0.12245118
0.170431901	0.030151134

Ultimately, P_i is defined with the expression (7), and a ranking of the obtained results is made (Table 5).

$$P_i = \frac{S_i^-}{S_i^+ + S_i^-} \quad (7)$$

Table 5. Rank

Pi	Rank
0.439072	3
0.499729	2
0.849683	1

According to the results we have got, the alternative no. 3 (Regular control) is the best solution according to the TOPSIS method and according to the evaluations that we entered in the survey.

HEALTH, SAFETY AND ENVIRONMENTAL IMPACT ASSESSMENT (HSELA)

The health, safety and environmental impact assessment (HSEIA) is a systematic process of identifying the impact of existing, new or substantially altered projects related to health, safety and/or the environment. The main objectives of a HSEIA report are to demonstrate: that all HSE hazards, including major accident hazards and occupational health hazards, have been systematically identified, assessed and mitigated; and that environmental impacts have been identified, assessed and mitigated [6].

An HSE impact assessment should be conducted to demonstrate that [6]:

- a prevention plan for major accidents and HSE management system is in place,
- health and safety hazards and environmental impacts have been identified, recorded and assessed,
- environmental impacts and risks are being managed,
- suitable measures have been identified and the critical equipment and systems are in place,
- onsite and offsite emergency plans have been drawn up,
- a sound overall plan is in place to safeguard life, property and the environment.

REDUCTION/MITIGATION MEASURES FOR HEALTH, SAFETY AND ENVIRONMENTAL RISKS

An unacceptable risk requires the implementation of risk reduction and mitigation measures. Practically, this consists of decreasing the frequency and/or the severity of a hazardous event or concern [7].

Different types of these measures can be applied [7]:

- *Technical measures*: These consist of the implementation of technical modifications such as change in the process design, addition or replacement of some process parts, etc.
- *Process control measures*: These refer to any changes of the control system routine. This may be the addition of new control devices on the process chain with the suitable alarm system. The implementation of these new control devices must include setup of the adequate emergency management system.
- *Organizational measures*: These refer to various activities relative to the organization of the work.

All these measures for health, safety and environmental risks reduction should not be taken as a straightforward process. Additional hazardous events may appear. Also, a re-evaluation of risks for the modified industrial processes may be necessary [7].

CONCLUSION

The results obtained through the TOPSIS method are in some cases relative. In our case, the assessment and the values of the weight factor are determined according to the answers of the survey respondents. It can be stated that regular control is the best alternative out of the three, because in that way the machinery does not have to be the latest, but it must have a high degree of reliance. Regular controls can show any flaws or deficiencies that may have been caused by improper use, and point it out to the operators. Through regular controls, it can also be checked whether the marking is appropriate i.e. If there are safety marks.

Health, safety and environmental impact assessment has to be carried out during the planning phase in order to improve the industry's facilities conceptual design. In existing industrial facilities, this joint kind of assessment allows the reduction of the ongoing risks by continual updating. The possibilities offered by this kind of assessment are multiple [7]:

- timely identification of the possible hazards and their associated occurrence probability;
- identification of the consequences arising from these possible hazards and their severity;
- evaluation of the risks at the expert level;
- effective application of suitable reduction measures;
- review and update of the risk assessment on a regular basis.

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