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EDITORIAL - Preface to Volume 6 Issue 2 of the Scientific Journal of Civil Engineering (SJCE)

Todorka Samardzioska EDITOR – IN - CHIEF

Dear Readers,

Scientific Journal of Civil Engineering (SJCE) was established in December 2012. It is published bi-annually and is available online at the web site of the Faculty of Civil Engineering in Skopje (www.gf.ukim.edu.mk).

This Journal welcomes original works within the field of civil engineering, which includes: all the types of engineering structures and materials, water engineering, geo-technics, highway and railroad engineering, survey and geo-spatial engineering, buildings and environmental protection, construction management and many others. The Journal focuses on analysis, experimental work, theory, practice and computational studies in the fields.

The international editorial board encourages all researchers, practitioners and members of the academic community to submit papers and contribute for the development and maintenance of the quality of the SJCE journal. The primary goal continues to be high quality of publications, enhancing objectivity and fairness of the review process.

As an editor of the Scientific Journal of Civil Engineering (SJCE), it is my pleasure to introduce the Second Issue of VOLUME 6.

This year marks the 40th anniversary of the high geodetic education in the Republic of Macedonia. Studies of geodesy lasting five semesters had been open for the first time in our country in 1977. The two departments of geodesy at the Faculty of Civil Engineering in Skopje worthily celebrate this significant jubilee for the geodesy in the Republic of Macedonia.

This issue of our Journal is entirely devoted to topics of geodesy and geomatics.

We are very pleased with the great response of our colleagues and friends from many countries in Europe and from Macedonia that responded to the call for papers. The result is this special Issue with a record number of 18 papers devoted to geodesy, mapping, photogrammetry, cadastre, real estate and related topics. I wish to thank to all authors for all the work and trust on us.

I also very much thank Prof. Zlatko Srbinoski and As. Prof. Zlatko Bogdanovski for the initiative and the great efforts invested in the final form of this edition of the Journal.

To all of our faithful readers, friends and colleagues

Happy New Year and Merry Christmas!

May your home be filled with happiness, your hearts with love, your days with joy for the upcoming holydays and always!

Sincerely Yours,
Prof. Dr. Sc. Todorka Samardzioska
December, 2017

Impressum

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40 YEARS OF HIGHER GEODETIC EDUACATION AT THE UNIVERSITY OF "SS. CYRIL AND METHODIUS" - FACULTY OF CIVIL ENGINEERING - SKOPJE

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In this paper is represented the short historical development of High education in area of geodesy in Republic of Macedonia. Teaching of geodesy like subject on academic level in Republic of Macedonia was started in past 1949. Big step forward in geodetic education was made in 1977, when as part of Faculty of Civil Engineering for the first time were open studies of geodesy with five semesters. In Faculty of Civil Engineering in Skopje after producing of real conditions, in 2001/02 were started studies of geodesy with ten semesters for education of graduate geodetic engineers.

The tendency for geodetic education to become better in Republic of Macedonia go on with reforms in 2006/07. Those reforms were established in accordance with Bologna process and the results were new high educational geodetic profiles. With new reform were open undergraduate and postgraduate studies of geodesy in accordance with ECTS model 3+2.

In this paper is placed the actual curriculum of undergraduate and postgraduate studies of geodesy at Faculty of Civil Engineering from Skopje. Also there are presented publishing activity, scientific activity and professional activity of the members in the Faculty's geodetic chairs.

Keywords: Geodetic education, Faculty of Civil Engineering - Skopje, Bologna process.

1. BASIC INFORMATIONS ABOUTE UNIVERSITY "SS. CYRIL AND METHODIUS" AND FACULTY OF CIVIL ENGINEERING - SKOPJE

The University "Ss. Cyril and Methodius" is the oldest, biggest and most respected university in the Republic of Macedonia. The University was established with Law on the University by Parliament of the Republic of Macedonia on 26.01.1949.

In the year of its establishment, the University had a total number of 77 teaching staff and 989 students.

Today, the structure of the University is comprised of 23 faculties, 5 scientific institutes and 12 associate members. At the University the teaching is organized in 192 first cycle curriculums, 242 second cycle curriculums and 40 third cycle curriculums - doctoral studies.

The total number of students at University is about 60000, and the teaching-scientific staff at the University is comprised of about 1850 teachers.

The permanent changes in organization and integration provide basis for practical functioning of the University as an integrated university, with aim of fostering the tradition as the oldest and biggest university in the country. As same as contribution to the promotion of quality in higher education, researching and implementation of innovations in building process of a common European educational space.

The Faculty of civil engineering - Skopje was founded in the distant 1949 as a part of the Technical faculty, which was consisted of two departments - Civil engineering department and Architectural department. It is a period with scarce educational and scientific potential and working conditions for the teaching processes. From these reasons, except their own eight professors and three associates, also were involved professors from other faculties from Skopje, Belgrade and Zagreb.

Figure 1. Faculty of civil engineering - Skopje

After less than ten years, within the Technical faculty were formed three more departments such Mechanical, Electrotechnical and metallurgical department. In 1965 the Technical faculty was divided into individual faculties. In this organizational reform, from the Civil engineering department and Architectural department was formed the Faculty of Architecture and Civil Engineering. In 1975, another reform was made in which the Faculty of Civil Engineering and the Faculty of Architecture are functioning as two independent faculties.

Good situation with teaching staff, the growth of the economy needs, which contributed to an increase in number of students not only from Macedonia but also from other Yugoslav republics, as well as from abroad, are only part of the motives for establishing an independent Faculty of Civil Engineering with independent management structure. It was a structure of six institutes:

- Institute for materials and structures,
- Institute for hidrotechnics,
- Institute for roads and railways,
- Institute for organization and mechanization,
- Institute for geotechnics,
- Institute for geodesy.

Since 1995, the faculty activities are in 14 chairs.

At the beginning of 2009, with the reform of the University, in accordance with the new Law on Higher Education, a change was made in the organizational scheme of the Faculty, where it became into a unit of the University "St. Cyril and Methodius". The chairs remained basic organizational units, and as a higher degree of organization were formed five departments:

- *Department for constructive mechanics* composed of:
  - Chair of technical mechanics and strength of materials;
  - Chair of theory of structures.
- *Department for theory of structures* composed of:
  - Chair for concrete and wooden structures;
  - Chair for metal structures.
- *Department for hidrotechnics and building organization* composed of:
  - Chair for hydraulics, hydrology and arranging of watercourses;
  - Chair for water supply, sewerage and meliorations;
  - Chair for Hydrotechnical structures;

  - Chair for technology and building organization.
- *Department for geotechnics, roads and railways* composed of:
  - Chair for roads;
  - Chair for railways;
  - Chair for geotechnics.
- *Department for geodesy and mathematics* composed of:
  - Chair for geodesy;
  - Chair for Advanced geodesy;
  - Chair for mathematics.

The teaching and scientific activity of the Faculty of Civil Engineering is currently being performed by 55 teachers and associates.

2. SHORT HISTORY OF THE GEODESY STUDIES AT FACULTY OF CIVIL ENGINEERING - SKOPJE

The study of geodesy as a teaching discipline at the academic level in the Republic of Macedonia began in the distant 1949 - from the very establishment of the Technical Faculty, at that time which was consisting of two departments: Architectural and Civil Engineering.

Big qualitative step forward in the geodetic education was made in 1977 when were opened geodesy studies with $VI/_1$ degree in frame of the Faculty of civil engineering at whom were educated geodetic engineers. That period fits with forming period of the Institute for Geodesy at Faculty of civil engineering - a scientific unit that took care of the higher education of the geodetic personnel in the Republic of Macedonia.

With changes and renewal of the curricula for the studies in all civil engineering courses at the Faculty of Civil Engineering, certain changes were made to the curriculum and studies of the first degree in geodesy, according to which the teaching process started in the academic year 1988/89.

With reorganization of the Faculty of civil engineering in 1995, when the Institutes are separated to chairs, from the Institute for geodesy are separated two geodetic chairs: Chair for geodesy and Chair for Advanced geodesy. The members of the geodetic chairs took care of the teaching processes of several courses at the geodetic studies and studies of civil engineering, while at the same time they were included in teaching process at the Faculty of Mining and Geology from Stip.

There follows a period of active promotion of the teaching of geodesy, which in 2001 resulted in the opening of full (10-semester) undergraduate geodesy studies at the Faculty of Civil Engineering in Skopje.

Following the tendencies of the European high educational level and European Credit Transfer System (ECTS), in school year 2006/07 it was a reform of the academic geodetic education, when new study system was introduced which includes a 6 semesters undergraduate and 4 semester postgraduate education in field of geodesy (system 3+2).

The last organizational change was made in 2008 when in accordance with Statute of the University “Ss. Cyril and Methodius, the both geodetic chairs: Cahir for geodesy and Chair for Advanced geodesy, together with Chair for Mathematics became an integral part of the Department for Geodesy and Mathematics.

3. TEACHING ACTIVITY AT GEODETIC DEPARTMENT IN FRAME OF THE FACULTY OF CIVIL ENGINEERING

As it was already emphasized, the educational activity from field of geodesy began in 1977 - with foundation of geodesy studies with $VI/_1$ degree in frames of the Faculty of civil engineering.

The education of the geodetic personnel in accordance with $VI/_1$ degree at the Faculty of civil engineering in Skopje was established primarily to alleviate the lack of qualified geodetic personnel and was conceived as the beginning of the geodetic studies, which soon should have turned into full studies. The curriculum with who were started geodesy studies with $VI/_1$ degree at the Faculty of civil engineering is shown in Table 1.

The number of enrolled students in the academic year 1977/78 was 102, and since many of them were permanently employed, teaching process was performed mainly in the afternoon. In the next years that number was limited from 40 to 60 students.

From the foundation of the geodesy studies with $VI/_1$ degree at the Faculty of civil engineering until their closure in 2001, these studies were completed by a total of 550 students - geodetic engineers.

Table 1. The curriculum of the VI/1 geodesy studies in time period 1977-1988.

No.	Course	Semester				
		I	II	III	IV	V
1	Mathematics	4+4				
2	Descriptive geometry	2+2				
3	Technical mechanics	3+3				
4	Geodesy 1	2+2				
5	Basics of Marxism	3+2	3+2			
6	General national defense 1	2+0	2+0			
7	General national defense 2			2+0	2+0	
8	Geodesy 2		4+5			
9	Geodetic drawing and plans		2+4			
10	Geodetic practice		1+5			
11	Geodesy 3			4+4		
12	Geodetic calculations with calculation technique			4+4		
13	Basics of hydrotechnics			4+0		
14	Geodesy 4				2+2	
15	Applied geodesy				6+2	
16	Theory of errors with adjustment				4+4	
17	Photogrammetry 1				2+2	
18	Introduction to Advanced geodesy					6+2
19	Photogrammetry 2					6+2
20	Cadaster					2+2
21	Roads and railways					4+0
	Total:	16+13	12+16	14+8	16+10	18+6

After the existing assistant staff managed to acquire the necessary qualifications, from the school year 2001/2002 at the Faculty of Civil Engineering in Skopje started the educational process of full (10 semestral) geodesy studies for the education of graduated geodetic engineers..

The curriculum was rational and consisted of 36 courses, and it is characteristic was that students after the II, III and IV year were performing practical training with which they gained the necessary field experience and the necessary skills in handling the geodetic instruments.

The curriculum of 10 semestral geodesy studies is presented in Table 2.

The number of enrolled students was limited to 50, and the total number of the graduated geodetic engineers at this study program was about 100.

Table 2. The curriculum of the ten semestral geodesy studies

No	Course	Semester									
		I	II	III	IV	V	VI	VII	VIII	IX	X
1	Descriptive geometry	3+4									
2	Mathematics 1	3+3	3+3								
3	Physics	3+2									
4	Defendology	2+1	2+1								

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Table 2. The curriculum of the ten semestral geodesy studies (continue)

No	Course	Semester									
		I	II	III	IV	V	VI	VII	VIII	IX	X
5	Geodesy 1	4+3	4+4								
6	Technical mechanics		3+3								
7	Basics of the electronics		2+2								
8	Technical drawing		1+2								
9	Sociology			2+1	2+1						
10	Mathematics 2			3+3	3+3						
11	Geodesy 2			3+3	3+3						
12	Theory of errors 1			3+2	3+3						
13	Law and legal regulations				1+1						
14	Basics of hydrotechnics				2+2						
15	Basics of traffic roads			2+2							
16	Programing and databases			3+3	2+2						
17	Geodetic metrology					2+2	3+2				
18	Theory of errors 2					2+2	2+3				
19	Photogrammetry 1					2+2	2+2				
20	Cadaster					3+2	2+2				
21	Theoretical geodesy 1					2+2	2+2				
22	Engineering geodesy 1					3+3	3+3				
23	Spatial planning					2+2	2+1				
24	Photogrammetry 2							2+2	2+2		
25	Advanced geodesy							2+2	3+3		
26	Engineering geodesy 2							2+2	2+2		
27	Cartography 1							3+3	2+1		
28	Automatic data processing								2+2		
29	Geodetic astronomy							3+3	2+2		
30	Spatial information systems							3+2	2+4		
31	Management and technology of geodetic works									2+2	
32	Theoretical geodesy 2									2+2	
33	Cartography 2									2+2	
34	Industrial geodesy									2+2	
35	Geophysics									2+2	
36	Diploma work										0+2

3.1 GEODESY STUDIES IN ACCORDANCE WITH THE BOLOGNA PROCESS AND ECTS

The Bologna process and the legal regulation which concerns to high education in the Republic of Macedonia are defining the framework and deadlines for change of the educational process of the studies at the University “Ss. Cyril and Methodius”. The Faculty of civil engineering starts with the reforms in school year2004/2005 and in that moment represents lieder of this process in frames of the University “Ss. Cyril and Methodius”.

3.1.1 First cycle studies

The Bologna process had its own repercussion on the geodesy studies, which in the short period after the opening of the 10 semestral studies had undergone the first reform of the curriculum. In addition, at the whole Faculty of Civil Engineering the ECTS model of study 4 + 1 has been accepted (4 years undergraduate + 1 year postgraduate studies). Shortly after the establishment, the weaknesses of this model were detected. Those weaknesses primarily were related to the defining postgraduate studies, as well as the establishment of the compatibility with the others geodetic studies in the neighborhood and more widely, where the ECTS model 3+2 is mostly used.

After several mounts of analysis on the European tendencies for organizing of the educational process at the geodetic faculties, the teaching council of the Faculty of civil engineering adopted a decision to modernize their existing curriculums of geodesy, which was the second curriculum reform. The current geodesy study model, which was started to applying in school year 2006/07, is in accordance with principles of the Bologna process and European Credit Transfer System, where it contains the 3 + 2 concept (3 years undergraduate + 2 years postgraduate studies).

This reform has provided great benefits that fully justified the engagement over its implementation. Namely, the new type of the studies allows achieving compatibility with geodesy studies which are performing at the European and Balkan universities, increases the interest for studying geodesy, promotes the concept *Life Long Learning* and most important for the first time in Macedonia provides education of personnel at postgraduate geodesy studies.

The curriculum of first cycle geodesy studies has been slightly changed in 2012, since the beginning of the first official accreditation on this curriculum.

The total number of credits is 180 and they are correctly deployed - 60 per each study year. When was defined the curriculum it were taken into account the recommendations of the University “Ss. Cyril and Methodius” for a minimum representation of 15% of elective courses.

The curriculum of the actual undergraduate geodesy studies (first cycle studies) is presented in Table 3. In Table 4 are shown the elective courses.

Table 3. Curriculum of undergraduate geodesy studies according to ECTS

No.	Course	Fund of classes	Semester						credits
			I	II	III	IV	V	VI	
1	Mathematics	60+60	4+4						8
2	Basics of geodesy	45+60	3+4						8
3	*Elective course (general courses)*	30+30	2+2						6
4	*Elective course (general courses)*	30+30	2+2						6
5	*Elective course (university group)*	30+0	2+0						2
			13+12						**30**
6	Geodesy 1	45+60		3+4					8
7	Geodetic plans	30+45		2+3					8
8	Foreign language 1	30+30		2+2					4
9	*Elective course (general courses)*			2+2					6
10	*Elective course (university group)*	30+0		2+0					2
11	*Elective course (university group)*	30+0		2+0					2
				13+11					**30**
12	Theory of errors	45+60			3+4				8
13	Geodetic measuring technology	30+45			2+3				6
14	Foreign language 2	30+30			2+2				4
15	*Elective course from group 1*	30+30			2+2				6

Table 3. Curriculum of undergraduate geodesy studies according to ECTS (continue)

No.	Course	Fund of classes	Semester						credits
			I	II	III	IV	V	VI	
16	*Elective course from group 1*	30+30			2+2				6
					11+13				**30**
17	Geodetic adjustments	45+45				3+3			6
18	Geodetic metrology	45+45				3+3			6
19	Spatial planning	45+45				3+3			6
20	*Elective course from group 2*	30+30				2+2			4
21	*Elective course from group 2*	30+30				2+2			4
22	Geodetic practice 1	0+90				0+6			4
						13+19			**30**
23	Photogrammetry	45+45					3+3		8
24	Cadaster	60+45					4+3		8
25	Ellipsoidal geodesy	30+30					2+2		4
26	Geoinformation systems	45+45					3+3		6
27	*Elective course from group 3*	30+30					2+2		4
							14+13		**30**
28	Advanced geodesy	45+45						3+3	5
29	Global positional systems	30+30						2+2	4
30	Engineering geodesy	45+45						3+3	6
31	Mathematical cartography	45+45						3+3	5
32	*Elective course from group 3*	30+30						2+2	4
33	Geodetic practice 2	0+75						0+5	3
34	Diploma work	0+60						0+4	4
								13+22	**30**

Table 4. List of elective courses at undergraduate level

No.	Course	Fund of classes	lectures	exercises	credits
	Elective general courses				
1	Sociology of enterprises	30+30	2	2	6
2	Spherical trigonometry	30+30	2	2	6
3	Theoretical mechanics	30+30	2	2	6
4	Basics of informatics	30+30	2	2	6
5	WEB design	30+30	2	2	6
6	Basics of the electronics	30+30	2	2	6
7	Physics	30+30	2	2	6
8	Descriptive geometry	30+30	2	2	6
	Elective general courses - group 1				
1	Basics of traffic roads	30+30	2	2	6
2	Basics of hydrotechnics	30+30	2	2	6
3	Basics of construction structures	30+30	2	2	6
4	Basics of geomorphology	30+30	2	2	6

Table 4. List of elective courses at undergraduate level (continue)

No.	Course	Fund of classes	lectures	exercises	credits
	Elective general courses - group 2				
1	Programing	30+30	2	2	4
2	Databases	30+30	2	2	4
3	Geodesy 2	30+30	2	2	4
	Elective general courses - group 3				
1	Software packages in geodesy	30+30	2	2	4
2	Real estate management	30+30	2	2	4
3	General cartography	30+30	2	2	4

The offered schedule execution of individual course programs within the curriculum (table 3) is optimal, but each candidate, depending on his / her possibilities and wishes, can make his or her own path in the curriculum. The basic criterion for advancement is the adopted mutual dependence of individual syllabi.

As can be seen from the curriculum, undergraduate geodesy studies are intended for profiling of classical geodetic engineers who will not have a narrower specialty. Namely, the narrower specialization is envisaged within the postgraduate studies where, with the help of elective courses, students themselves with the help of elective courses are directed to the disciplines that are subject of their special interest.

The introduction of the ECTS also brings change in the financing of the studies, in which co-financing of the studies by students is obligatory. The amount to be allocated to students in the state quota of geodesy studies is 200 Euro/year.

Under the terms of the Contest for enrollment of students at the University "St. Cyril and Methodius", in the new 6 semestral geodesy studies are enrolled 50 students per year.

In past 10 years period, these first cycle studies have completed about 350 students.

3.1.2 Second cycle studies

Implementation of the Bologna process on geodesy studies at Faculty of civil engineering enabled process for opening of second cycle studies - postgraduate studies. In that way has completed one more important degree in higher education in the area of geodesy in the Republic of Macedonia.

At this time, at the Faculty of civil engineering from Skopje are organizing two curriculums of second cycle in frame of the geodesy studies.

- Curriculum of *Geodesy* and
- Curriculum of *Real estate management*.

Curriculum of *Geodesy*

The postgraduate studies of geodesy, organized in accordance with criteria by ECTS were started in school year 2007/2008.

With the opening of the postgraduate studies, Bachelors of the geodesy had the opportunity to deepen their knowledge, and at the same time, these studies stimulated the scientific and research activity. The aim of these postgraduate studies is to create a solid experts base which will contribute to successfully solve the problems that are in front of the geodetic economy. Also with the organization of the postgraduate studies was created the possibility of self-reproduction of teaching and scientific potential which is more than necessary for performing of the educational process of higher geodetic education in our country.

The duration of studies is 2 years (4 semesters), of which, three semesters of lectures and the fourth semester is intended for geodetic practice and preparation of the Master's Thesis. The total number of courses is 17 with included Master Thesis. In addition, many of the courses are elective. With that is providing modularity in studying, and students are able through the elective course to select the narrow direction themselves.

Upon completing the studies, students receive a diploma for completed second cycle geodetic studies and acquire the *Master's degree in technical sciences in the field of geodesy* (m-r, actually M.Sc.).

In the postgraduate geodesy studies is possible to enroll candidates with completed undergraduate geodesy studies. The curriculum is designed according to 3 + 2 model, it is primarily intended for students with completed three-year undergraduate studies.. With a postgraduate diploma, candidates who have completed four-year or five-year undergraduate geodesy studies may be acquired by determining the equivalence of the respective curriculums.

The total number of credits is 120 and they are correctly deployed - 60 per each study year.

Under the terms of the Contest for enrollment of students at the University "St. Cyril and Methodius", in the postgraduate geodesy studies are enrolled 30 students per year. In the Contest is defined the sum of the amount that students should pay for co-financing studies. Currently, that amount is 400 euros/semester.

The curriculum of the postgraduate geodesy studies is presented in Table 5. In Table 6 are shown the elective courses.

With postgraduate geodesy studies is defining the geodetic profile of students who attend this second education cycle.

As can be seen from Tables 5 and 6, postgraduate studies include all classical geodetic courses curriculums that are normally taught in geodetic studies across Europe. In addition to them, the curriculum contains a series of modern disciplines (GIS, Land Management, GNSS, Remote sensing, etc.), which are open new horizons for young geodetic professionals who will complete these postgraduate studies.

In past 9 years period, these second cycle studies have completed about 80 students.

Table 5. Curriculum of postgraduate geodesy studies according to ECTS

No.	**Course**	**Fund of classes**	**S e m e s t e r**				**credits**
			I	**II**	**III**	**IV**	
1	Selected chapters from mathematics	60+60	4+4				8
2	Application of geodesy in the engineering	45+45	3+3				8
3	National geodetic networks	30+30	2+2				4
4	Modern cadaster	45+45	3+3				8
5	*Elective course from university group*	30+0	2+0				2
			14+12				**30**
6	Arranging of real estates	45+45		3+3			8
7	Physical geodesy	45+45		3+3			8
8	*Elective course from group 1*	30+30		2+2			6
9	*Elective course from group 1*	30+30		2+2			6
10	*Elective course from university group*	30+0		2+0			2
				12+10			**30**
11	*Elective course from group 2*	30+30			2+2		6
12	*Elective course from group 2*	30+30			2+2		6
13	*Elective course from group 3*	30+30			2+2		6
14	*Elective course from group 3*	30+30			2+2		6
15	*Elective course from group 3*	30+30			2+2		6
					10+10		**30**
16	Geodetic practice	0+90				0+6	**6**
17	Master thesis	0+360				0+24	**24**
						0+30	**30**

Table 6. Elective courses in second cycle geodesy studies

No.	Course	Fund of classes	lectures	exercises	credits
	Elective courses - group 1				
1	Administrating with real estates	30+30	2	2	6
2	Selected chapters from photogrammetry	30+30	2	2	6
3	Optimization of the geodetic networks	30+30	2	2	6
4	Management of the geodetic works	30+30	2	2	6
	Elective courses - group 2				
1	Parametrical adjustments	30+30	2	2	6
2	Digital photogrammetry	30+30	2	2	6
3	Selected chapters from mathematical cartography	30+30	2	2	6
4	Land information system	30+30	2	2	6
5	Land appraisal	30+30	2	2	6
	Elective courses - group 3				
1	Satellite geodesy	30+30	2	2	6
2	Gravimetry	30+30	2	2	6
3	Geodetic astronomy	30+30	2	2	6
4	Industrial geodesy	30+30	2	2	6
5	WEB oriented Geoinformation systems	30+30	2	2	6
6	Remote sensing	30+30	2	2	6
7	Digital cartography	30+30	2	2	6

Curriculum of *Real estate management*

Postgraduate studies in area of real estate management are the newest curriculum of second cycle studies that are organizing at the Faculty of civil engineering in Skopje. The curriculum of the second cycle studies of real estate management was accredited in 2012, and its concept is related with realization of the TEMPUS project “Development of New Land Governance Studies in Macedonia and Ukraine”.

The main objective of the second cycle of studies in real estate management is to offer advanced multidisciplinary knowledge in the field of real estate administration from spatial, economic and legal aspects. In the context of these guidelines, the studies provide a modern approach in determining basic and advanced knowledge of valuation of real estate, comparability and determining the power of the applied assessment methodology, as well as the structure of the market for determining and verifying the value. The curriculum is conceived in order to allow students to enrich education, with the latest scientific and professional knowledge and skills with a particular emphasis on the development of creative abilities and independence in professional and research work.

The duration of studies is 2 years (4 semesters), of which, three semesters of lectures and the fourth semester is intended for preparation of the Master's Thesis. The total number of courses is 16 with included Master Thesis.

Upon completing the studies, students receive a diploma for completed second cycle geodetic studies and acquire the *Master's degree in sciences in the field of real estate management* (m-r, actually M.Sc.)

Under the terms of the Contest for enrollment of students at the University "St. Cyril and Methodius", in the postgraduate real estate management studies are enrolled 20 students per year. In the Contest is defined the sum of the amount that students should pay for co-financing studies. Currently, that amount is 400 euros/semester.

The curriculum of the postgraduate real estate studies is presented in Table 7. In Table 8 are shown the elective courses.

As can be seen from Tables 7 and 8, postgraduate studies include multidisciplinary study program where are dominating courses from field of geodesy, economics and legal.

Table 7. Curriculum of postgraduate studies in Real estate management

No.	Course	Fund of classes	Semester				credits
			I	II	III	IV	
1	Civil law	60+60	4+4				8
2	Cadaster for real estate	60+60	4+4				8
3	Economics	45+30	3+2				5
4	Rural economics and development	45+30	3+2				5
5	*Elective course from group 1*	30+30	2+2				4
			16+14				**30**
6	Legal and technical aspects of Spatial Planning and Environmental Protection	60+60		4+4			8
7	Real estate appraisal	60+60		4+4			8
8	*Elective course from group 2.1*	30+15		2+1			3
9	*Elective course from group 2.2*	60+45		4+3			7
10	Real estate market	30+30		2+2			4
				16+18			**30**
11	*Elective course from group 3*	60+45			4+3		7
12	Sustainable development of a rural environment	60+60			4+4		9
13	Sustainable development of the urban environment	60+60			4+4		9
14	Theory of science and research methodology	30+15			2+1		3
15	*Elective course from university group*	30+0			2+0		2
					10+10		**30**
16	Master thesis	0+30				**0+30**	**30**

Table 8. Elective courses in second cycle studies of Real estate management

No.	Course	Fund of classes	lectures	exercises	credits
	Elective courses - group 1				
1	Measuring systems in real estate management	30+30	2	2	4
2	Geodetic measuring technology	30+30	2	2	4
	Elective courses - group 2.1				
1	Strategies in rural and urban development	30+15	2	1	3
2	Remote sensing	30+15	2	1	3
	Elective courses - group 2.2				
1	Land Information Systems	60+45	4	3	7
2	Modern Cadastre	60+45	4	3	7
	Elective courses - group 3				
1	Mass appraisal with GeoIS	60+45	4	3	7
2	WEB oriented GeoIS	60+45	4	3	7

In past 5 years period, these second cycle studies have completed 12 students.

3.1.3 Third cycle studies

The performance of doctoral (PhD) studies at the University "Ss. Cyril and Methodius" is regulated by the *Rulebook on the unique basis for postgraduate and PhD studies*.

Until the implementation of the Bologna process, doctoral studies in geodesy at the Faculty of Civil Engineering were performed according to the mentoring system and a strictly defined procedure.

Currently, at the University level, ongoing procedure for defining doctoral studies that will be with duration of 3 years. These studies will have certain joint modules in the first academic yearl, while the second and third year will be dedicated to professional examinations and preparation of the PhD dissertation. The start of doctoral studies is scheduled for the academic year 2019/20. In this way, the completion of the higher education in the field of geodesy according to the European Credit Transfer System will be completed, respecting the model **3+2+3**.

3.1.4 Life Long learning process

The process of Life Long Learning - LLL is one of the main provisions of the Bologna process, which is consistently applied to the geodesy studies at the Faculty of Civil Engineering in Skopje. Namely, in the past few years, the geodesy studies have organized several seminars, workshops and presentations, where the colleagues from the private geodetic practice were able to get acquainted with the latest achievements of the geodetic science and practice.

In this direction, the most important are the possibilities that the Faculty of Civil Engineering offers previous students for completing its education. This primarily refers to geodetic engineers who in the past period completed five-semester geodesy studies. For them are organizing lectures in special terms, with who is possible to upgrade their education and gain the title Bachelor of geodesy.

3.2 PUBLISHING ACTIVITY

The educational activity is supplemented by the issuance of specialized geodetic literature which fully corresponds with the curricula for the individual subjects that are studied in the geodesy studies. In the past 15 years by members of the geodetic department have issued more than 20 books and scripts for the respective course programs, with which students are greatly facilitated in the preparation of exams. In this context we need to mention these issues:

- Vuckov S. (2004): *Applied geodesy, university textbook*, Faculty of civil engineering, Skopje.
- Gjorgjiev V. (2004): *Geoinformation systems, university textbook*, Faculty of civil engineering, Skopje.
- Gjorgjiev V. (2006): *Modern cadaster, university textbook*, Faculty of civil engineering, Skopje.
- Ribarovski R. (1997): *TTheory of errors, university textbook*, Faculty of civil engineering, Skopje.
- Ribarovski R. (1999): *Geodetic calculations, university textbook*, Faculty of civil engineering, Skopje
- Ribarovski R. (2002): *Practical geodesy, university textbook*, Faculty of civil engineering, Skopje.
- Ribarovski R. (2005): *Advanced geodesy, university textbook*, Faculty of civil engineering, Skopje.
- Ribarovski R. (2005): *Management of the geodetic works, university textbook*, Faculty of civil engineering, Skopje.
- Ribarovski R. (2007): *Parametrical adjustments, university textbook*, Faculty of civil engineering, Skopje.
- Srbinoski Z. (2005): *Ellipsoidal geodesy, university textbook*, Faculty of civil engineering, Skopje.
- Srbinoski Z. (2008): *Physical geodesy, university textbook*, Faculty of civil engineering, Skopje.

Figure 2. Cover page of the book from the geodesy studies

- Srbinoski Z. (2012): *General cartography, university textbook*, Faculty of civil engineering, Skopje.
- Srbinoski Z. (2015): *Measuring systems in real estate management, university textbook*, Faculty of civil engineering, Skopje.

3.3 SCIENTIFIC ACTIVITY

Besides educational activities, at the geodetic chairs from Faculty of civil engineering in Skopje are equally present the other activities which are characteristic of an academic institution, among which stands out scientific research.

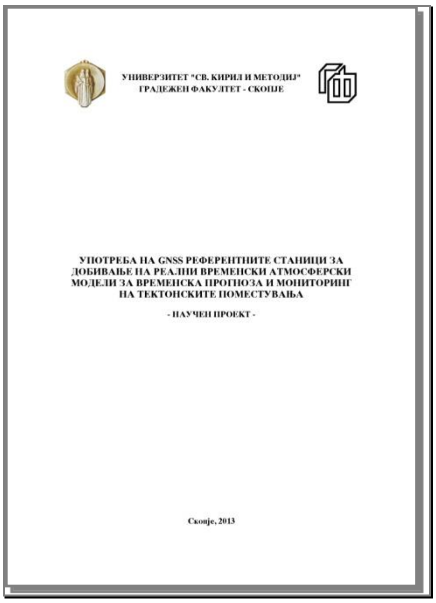
The main accents of the scientific and research activity of the Faculty are:

- Participation in scientific-research projects;
- Preparation and defense of the doctoral dissertations;
- Preparation of the scientific papers and their presentation at the scientific gathering and scientific journals.

From the very beginning of the functioning of the geodetic chairs, their members are actively involved in the preparation of scientific-research projects, as well as preparation of scientific papers published at home and international scientific meetings and relevant professional and scientific journals.

Since the formation of the geodetic chairs in 1995, their members have actively participated in thirteen scientific research projects:

- *Selection of the most suitable cartographic projection for projecting of the territory of the Republic of Macedonia*.
- *GPS and Satel-SPOT platforms in the function of forming the base structure of GIS*.
- *Preparation a topographic map of the Republic of Macedonia in scale 1:50000*.
- *Exploring a new technological procedure for the preparation of a digital topographic map of the Republic of Macedonia.*
- *Usage of the UTM - projection and the geodetic system WGS 84 as main NATO standards in cartographic production in the Republic of Macedonia*.
- *TEMPUS Project, "DEREC"*, University of Florence, University of Bochum, University of Thessaloniki, University of Vienna, University of "St. Cyril and Methodius" - Skopje.
- Scientific Project "*BALGEOS - Balkan Geodetic Observation System"*, Technical University of Vienna, BAS Institute for geodesy, University of Sarajevo, University of "St. Cyril and Methodius" - Skopje.
- Scientific Project "*BALGEOS II" - Balkan Countries into GGOS*", Technical University of Vienna, BAS Institute for geodesy, University of Sarajevo, University of "St. Cyril and Methodius" - Skopje
- TEMPUS Project "*LAGOS - Development of New Land Governance Studies in Macedonia and Ukraine"*.
- *Strengthening and development of Earth Observation activities for the environment in the Balkan area,* project financed from FP7 program;
- *Use of GNSS reference station networks to provide close to real time atmospheric models for weather forecast and monitoring of tectonic movements.* Bilateral Macedonian - Austrian scientific - researching project.
- *Analysis of the accuracy of the new digital topographic maps for the territory of the Republic of Macedonia,* scientific project financed by University of "St. Cyril and Methodius".
- *Western Balkan Academic Education Evolution and Professional's Sustainable Training for Spatial Data Infrastructures - BESTSDI*, ERASMUS+ Ka2 project of EU.


УНИВЕРЗИТЕТ "СВ. КИРИЛ И МЕТОДИЈ"
ГРАДЕЖЕН ФАКУЛТЕТ - СКОПЈЕ

УПОТРЕБА НА GNSS РЕФЕРЕНТНИТЕ СТАНИЦИ ЗА ДОБИВАЊЕ НА РЕАЛНИ ВРЕМЕНСКИ АТМОСФЕРСКИ МОДЕЛИ ЗА ВРЕМЕНСКА ПРОГНОЗА И МОНИТОРИНГ НА ТЕКТОНСКИТЕ ПОМЕСТУВАЊА

- НАУЧЕН ПРОЕКТ -

Скопје, 2013

Figure 3. Front page of scientific project from geodetic department

Within the Faculty of civil engineering in Skopje till now successfully are defended 10 doctoral dissertations in the area of geodesy:

- Lazarov D. (1964): *Attachment to the accuracy of the geodetic plans.*
- Gjorgjiev V. (1996): *Spatial information systems with developing model on geodetic information systems and subsystem of underground installations networks in the Republic of Macedonia.*
- Jovanov J. (2001): *Application of the land consolidation in the Republic of Macedonia and modernization of agricultural production.*
- Srbinoski Z. (2001): *Enclosure to the research for defining a new state cartographic projection*.
- Dimov L. (2001): *Empirical accuracy of digital calculation of the relief.*
- Nasevski M. (2006): *Analysis of state triangulation with a proposal for its remediation.*
- Idrizi B. (2007): *Modern trends for automation on mapping generalization of geospatial regions.*
- Dimova S. (2008): *Methodology and standards for production of digital topographic maps.*
- Bogdanovski Z. (2015): *Determination of the geodynamics of the Skopje Valley based on geodetic measurements.*
- Gjorgjiev Gj. (2015): *Analysis of the situation of illegal buildings and a proposal for a progressive model for their administration in the cadastre systems.*

In addition to research projects, the members of the geodetic department of the Faculty of civil engineering with their works have participated in more than 50 international and national scientific meetings and have published more than 100 scientific papers in proceedings of international conferences and in professional and scientific journals in the geodesy area.

It should be noted that the members of the geodetic department of the Faculty of civil engineering in Skopje participated in a number of scientific and expert projects in the field of cartography, geodynamics, basic geodetic networks, cadastre and the national spatial data infrastructure. Considering the global (state) character of the mentioned projects, the Agency for real estate cadastre was most often responsible for their implementation.

Also, the Faculty of civil engineering participated in a series of projects that popularized the geodetic and cartographic activity in the Republic of Macedonia, such as the *Project for determining the geographical center of the Republic of Macedonia*.

Figure 4. Field materialization of the geographical center

4. PROFESSIONAL - APPLICABLE ACTIVITY

The third very significant activity of the geodetic department of the Faculty of civil engineering in Skopje refers to applicative activity. It is an area where the professional and scientific bases are applied and checked through solving practical problems, and the benefit of such activity is more substantial, as material - improvement of the standard of the scientific workers and of the Faculty of civil Engineering, as well as the professional and scientific upgrading of the teaching staff.

In the past 40 years, the members of the geodetic department participated in the preparation of more than 500 expert-applicative papers. These are mostly papers from the area of:

- Geodetic deformation measurements on important structures (dams, bridges, tunnels, cooling towers, cultural and historical objects, industrial structures and machines and so on).
- Production of the digital terrain models and other products from the digital cartography,
- Surveying and stakeout for the needs of the traffic, hydrotechnical and energy infrastructure (roads, pipelines, transmission lines etc.),
- Geodetic measurements and elaborates from the cadaster area (elaborates for

expropriation, land consolidation and so on),

- Audits of geodetic projects, consulting services, expertise and so on.

Figure 5. Dam Gradce - Kocani, structure on which is performing auscultation more than 40 years from members of geodetic department

For teaching needs or scientific and applicative work, the geodetic department at the Faculty of civil engineering have a modern geodetic laboratory. Besides measuring instruments, the geodetic department at the Faculty of civil engineering possesses also adequate computer equipment and software that enable processing of measured data and their presentation in digital form.

5. GEODETIC LABORATORY

The geodetic laboratory at the Faculty of civil engineering was established in 1949 in same time with start of the educational process at the Technical faculty.

At the beginning, the laboratory had some of the oldest constructions of geodetic instruments (theodolites and leveling instrumentsers), obtained from the state geodetic institutions of post-war Yugoslavia. Geodetic Laboratory gradually grow with new (classical) surveying instruments and measuring equipment, so in the middle 70s of last century, it was valid for one of the best equipped geodetic laboratories on territory of the Balkan peninsula. The greatest merit for equipping the laboratory in that period certainly belongs to prof. d-r. Dime Lazarov, who with selflessly commitment and investment of personal authority, managed to procure many geodetic instruments from renowned European manufacturers: Wild, Carl Zeiss, Kern and many more.

Figure 6. Classical geodetic instruments: Brass theodolite and Koni 007 leveling instrument

With the commencement of the independent geodesy studies with VI/$_1$ degree, the trend of equipping the laboratory continues. Thus, in the 90s of the last century, the first electronic surveying instruments were purchased. The electronic instruments were products of the company Leica, which is one of the world's leading brands in the production of electronic geodetic instruments.

Figure 7. Modern electronic leveling instrument Leica Sprinter

In school year 2001/02, began five-year studies with VII/$_1$ degree, according to that increased the need of new modern geodetic (surveying) instruments. For this purpose, in 2005, the Faculty of Civil Engineering acquired more modern electronic geodetic instruments, among which, for the first time, a one set of GPS instrument.

The Faculty of civil engineering, within its capabilities continues with efforts to modernize the geodetic laboratory, which is one of the basic prerequisites for ensuring high quality of educational process of geodesy. In that direction, must be highlighted the cooperation with the SAGW - State Authority for Geodetic Works (now the Agency for Real estate cadastre). The SAGW in 2007, within the framework of an international project funded by the SIDA - Swedish International

Development Agency, in part of the geodetic laboratory established a Trimble equipment of permanent GPS station. The data from the permanent GPS station are available to the teaching staff and students from the Faculty of civil engineering. With that are opened new opportunities in the process of education of the geodetic personnel in the Republic of Macedonia.

The trend of the modernization of the geodetic laboratory was continuing in 2008 when in frame of the *Project for strengthening the capacities of the geodetic activity in the Republic of Macedonia*, financed from World Bank, several modern electronic surveying instruments and computer equipment were purchased, as well as a modern high precision global positioning system Trimble R6.

Figure 8. Modern GNSS instrument Trimble R6

At the moment, the geodetic laboratory is equipped with several modern geodetic instruments used in the practical teaching and in the application activity of the faculty, from which can be distinguished:

- GNSS system *Trimble R6*;
- GNSS system *Leica GS08 plus*;
- GPS system *Leica SR20*;
- Total stations *Leica TS 02, Leica TCR 407, Nikon 332 DTM* and *Trimble S6*;
- Hand held GPS systems (*Garmin* and *Magellan*);
- Electronic leveling instrument *Leica NA 3003*;
- Electronic leveling instrument *Trimble DiNi 07*;
- Electronic leveling instrument *Leica Sprinter 100m*;
- More than 30 classical surveying instruments (theodolites and leveling instruments) with complete equipment.

Besides measuring instruments, geodetic department at the Faculty of civil engineering possess adequate computer equipment and software that is used for processing of measured data and their presentation in digital form. The software used for the stated purposes can be distinguished:

- Leica Geo Office,
- Trimble Business Center,
- Vertical mapper,
- AutoCAD Civil 3D;
- MicroSurvey STARNET
- MicroSurvey CAD and many more.

The geodetic laboratory is one of the most important links in the geodetic education, which is realized within the Faculty of civil engineering. Numerous instruments and modern geodetic equipment enable the qualitative realization of the practical geodetic education in which students are introduced to the basic characteristics of the modern geodetic measuring technology. In addition, the laboratory instruments are regularly used in the scientific and research work that is performed by the geodetic chairs. This primarily refers to the preparation of master's theses and doctoral dissertations, as well as to the participations in scientific-research projects that include field geodetic measurements.

Finally (but not leastimportant), it is necessary to emphasize the importance of the geodetic laboratory for the application activity realized by the members of the geodetic chairs. The instruments are mostly used for performing geodetic deformation measurements that determine the deformations of capital construction objects (dams, bridges, towers, etc.). Geodetic instruments are also used for terrain surveying, which result in the production of digital cartographic products and the production of spatial data bases for needs of the geoinformation systems. The application activity is a valuable source of financial resources and at the same time enables affirmation of the experts from the geodetic department and the geodetic profession in general.

From all of the aforementioned, it can be concluded that the geodetic laboratory is an extremely important segment of the Faculty of civil engineering and it should be maintained and permanently enriched with the latest geodetic instruments that will enable development and quality in geodetic education in the Republic of Macedonia.

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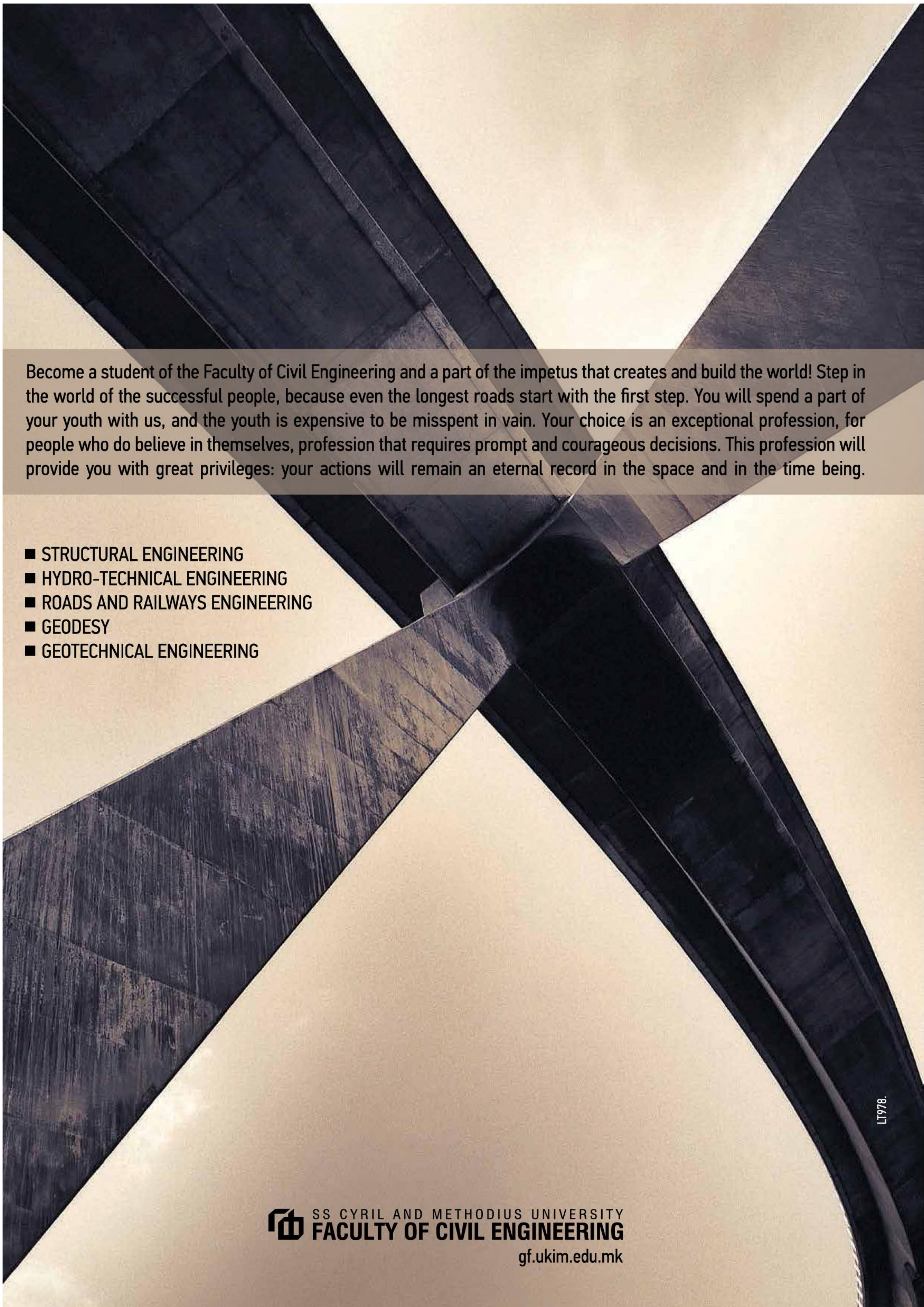
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GNSS FOR CLIMATE-RELATED STUDIES

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In recent years the space geodetic technique GNSS (Global Navigation Satellite Systems) has been used for climate-related investigations. Based on permanent station networks operated, for example by the International GNSS Service (IGS) since more than two decades, GNSS provides nowadays a data-base for investigation of climate variations on a global scale. The aim of this paper is to present recent studies on climatological signals in GNSS-based coordinate and tropospheric delay time series performed at the German Research Center for Geosciences (GFZ). Based on the station coordinates, the elastic reaction of the Earth's crust on mass re-distribution caused by possible climatological variations is studied. In this paper, we show results for a regional-scale GNSS network in Greenland. In addition to the post-glacial rebound signal, increased vertical motion rates are found for nearly all stations. The analysis of GNSS-based atmospheric water vapor time series or zenith total delay (ZTD) shows the change in the amount of water vapor in the troposphere and hence gives an indication about climate change on regional scales. For further investigations GFZ participates in the GRUAN project, which aims at providing an international reference network of co-located GNSS and various meteorological sensors for observing climate variables.

Keywords: GNSS, climate, coordinate time series, troposphere, water vapor

1. INTRODUCTION

Besides positioning and navigation, GNSS (Global Navigation Satellite Systems) allow detailed insight into the various processes within the Earth system. For more than two decades GNSS have been recognized as an accurate sensor for estimating the atmospheric water vapor content. Water vapor is the most abundant greenhouse gas that has a significant influence on the change of the Earth's climate [1]. GNSS-based water vapor estimates derived as vertical Integrated Water Vapor (IWV) was firstly studied at GFZ in 2000 in the framework of the "GPS Atmosphere Sounding Project" (GASP, [2], [3]). Today, data from more than 700 globally distributed GNSS stations are processed at GFZ with a latency of 1.5 h and an accuracy better than 2 mm (1 mm standard deviation). The derived products are operationally assimilated into numerical weather forecasts by DWD, the German Meteorological Service.

In addition to the operational weather prediction, GNSS-based water vapor time series with lengths exceeding two decades, have proven to be useful for first climate studies (e.g. [4]). According to the World Meteorological Organization (WMO) a time series length of 30 years is recommend to derive climatic trends in order to filter out interannual signals and anomalies. With the long-term maintained GNSS station network provided by the International GNSS Service (IGS, [5]) with continuous observations since 1994, GNSS-based climate-related studies are becoming feasible.

Besides the direct assessment of climate variations by analyzing long time series of atmospheric water vapor, indirect measurements are also possible. Mass re-distributions caused for example by climatological variations will result in elastic crustal deformations. Therefore, GNSS-based coordinate time series, especially the height component, can also reflect climatological signals. However, this approach has to be used very carefully as it is challenging to distinguish between crust's elastic response triggered by climatic and non-climate effects as well as long-term visco-elastic crustal deformations due to large-scale loadings (e.g. post-glacial uplift).

This paper provides an overview on GNSS-based climate-related studies at GFZ including examples of the first outcomes. Within the first part initial investigations of coordinate time series are described for a set of stations in Greenland (Section 2). Section 3 describes climate-related investigations regarding water vapor time series based on GFZ GNSS reprocessing activities. In addition, initial results derived in the framework of the GRUAN project for co-located sensor stations are presented. Section 4 complements the paper by providing a summary and an outlook towards the next steps.

2. ANALYSIS OF COORDINATE TIME SERIES

Within the IGS's Tide Gauge Benchmark Monitoring project (TIGA), GFZ analyzed and reprocessed GNSS data of nearly 400 globally distributed IGS stations and around 500 additional stations located near tide gauges ([6]). TIGA aims at monitoring tide gauges for vertical land deformations, e.g. due to postglacial uplift. In addition, TIGA products are also used to calibrate satellite altimeters and to unify national height systems. Based on daily solutions, coordinate time series were formed. The following model was applied:

$$C_t = A sin\left(\frac{2\pi}{P}(t-t_0)+\phi\right)+b_0+b_1(t-t_0)$$

where b_1 corresponds to the station velocity. In addition to the linear velocity, the offset b_0 as well as an annual signal with amplitude A and phase ϕ are estimated. Taking hardware changes, earthquakes and time series reasonably long (i.e., more than two years) into account, nearly 1300 velocity sets were determined for the time period between 1994 and 2016. For the vertical component a median of 0.09 mm/year was found. In the following, vertical station velocities for all stations in Greenland are assessed. Twenty stations located in Greenland are part of the GFZ's TIGA solution. Driven by the postglacial uplift all twenty stations show positive vertical motion rates. In a more detailed study, we computed motion rates in sliding two-year intervals (Figure 1). An increase in the uplift rates is visible. Comparing the mean value in each period's an increasing rate of 0.4 mm/year can be found. This speed-up caused by the Earth crust's elastic response is most probably a result of the increased melting rates ([7]). Between 2010 and 2012, however, a further speed-up occurred which will be discussed within the next paragraph based on the coordinate time series of the IGS station KELY (Kangerlussuaq, West Greenland, 66.99° N, 50.94° W).

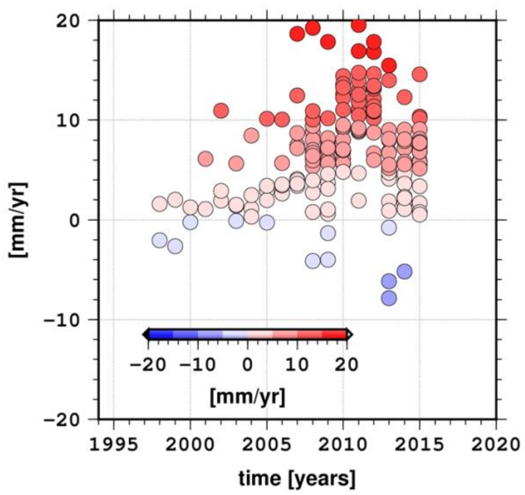

Figure 1. Greenland stations: Velocities estimated over two-year periods

Figure 2 shows in grey the height coordinate for KELY derived from the daily TIGA solutions with the first offset subtracted (a smoothed line is added in black). The orange dots represent the remaining signal ("residuals") after subtracting the estimated station velocities (a smoothed line is added in red). Consequently, any trends in the residuals reflect a mismodeled velocity.

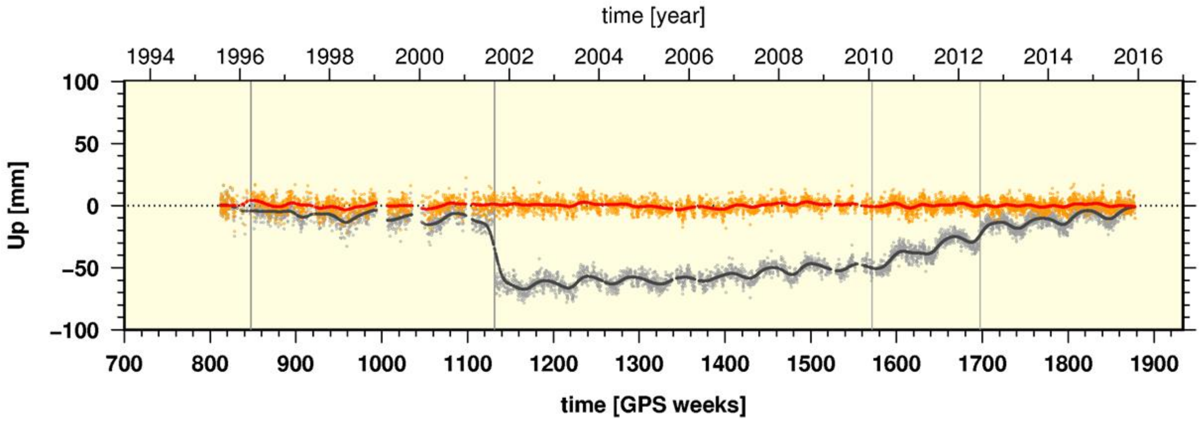

Figure 2. Coordinate time series for KELY (Kangerlussuaq, Greenland, 66.99° N, 50.94° W). Offset-removed height coordinates are shown in grey (smoothed curve in black). De-trended time series in orange (smoothed in red) based on solution 3; antenna replacements occurred in April 1996 and September 2001

Already from the coordinates itself a non-linear uplift rate between 2009 and 2013 is visible. By estimating different velocities for the time periods:

- before February 2010,
- between February 2010 and July 2012,
- after 2012

the variations in the uplift rate become visible (Table 1).

Table 1. Velocity estimates for Kangerlussuaq (IGS: KELY). Three different solutions were obtained by applying the considered intervals. Velocity rates are given in mm/year

	interval periods	sol 1	sol 2	sol 3
A	2001.68-2010.13	4.79	1.98	1.98
B	2010.13-2012.55		7.38	9.79
C	2012.55- 2016.0			3.89

While finding rates of 1.2 mm/year and 3.9 mm/year for intervals (A) and (C), respectively, the rate increases to 9.8 mm/year for interval (B). For KELY this event was also recognized by [7] who called this phenomena the "2010 melting day anomaly" as an unusual large number of melting days was observed in 2010. In addition, [8] found that KELY's vertical acceleration raised from 2 mm/year² to 5 mm/year² between 2010 and early 2013. Moreover, they mentioned already the change in the mass balance resulting in an uplift while former studies (e.g. [9]) and also ice history models like ICE5G ([10]) reveal land subsidence at Kangerlussuaq. Taking Figure 1 into consideration this uplift anomaly appears to have affected nearly all considered stations during 2010 and 2012

3. ANALYSIS OF TROPOSPHERIC TIME SERIES

As mentioned in the introduction, GNSS-derived IWV time series, some spanning over more than 20 years, start to be adequately long for a reliable determination of climatological trends, which can provide further insight into atmospheric processes and can be exploited for climate-related studies ([11], [4]). Figure 3 shows as an example the 18-years time series of the zenith total delay (ZTD) for the site KELY, the smoothed ZTD by moving average filter of one year window and the estimated linear trend. The time series shows a negative trend of -1.42 mm/decade, which is mainly caused by the variations of water vapor. In addition, we computed the trend using data at eight GNSS sites with time series longer than ten years as shown in Figure 4. We observed positive and negative trends, however, detecting a spatial pattern is not possible since the time series have different lengths. As mentioned before, water vapor is the most abundant greenhouse gas and accounts for approximately 60% of the natural greenhouse effect during periods of clear skies ([1], [12]). In general, the content of water vapor in the atmosphere tends to increase with increasing temperature at a rate lower than the Clausius-Clapeyron relation ([4]). This contributes to a positive feedback that accelerates atmospheric warming. Under climate warming, atmospheric cloud cover, and quantity and intensity of precipitation are expected to increase due to the general increase in moisture content. This might accelerate hydrological processes and greenhouse-related effects that lead to natural hazards.

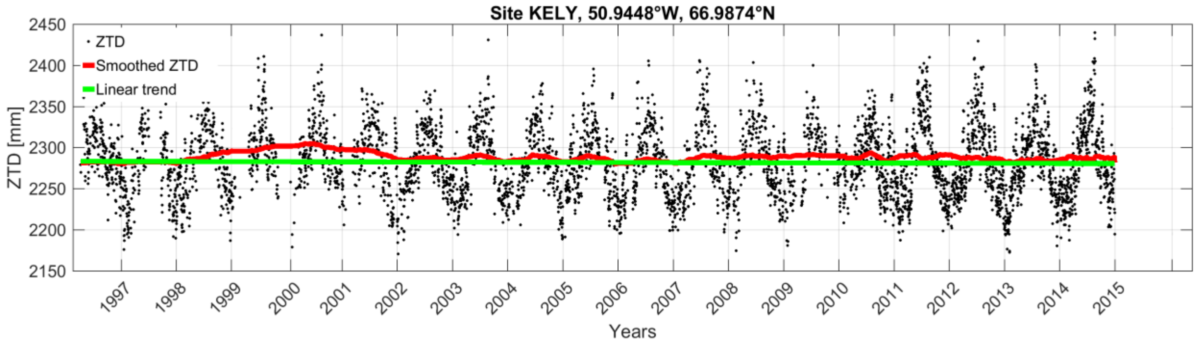

Figure 3. Zenith total delay at site KELY (Greenland, 66.99° N, 50.94° W). A trend of -1.42 mm per decade was derived; this figure is based on the re-processed data set of TIGA stations

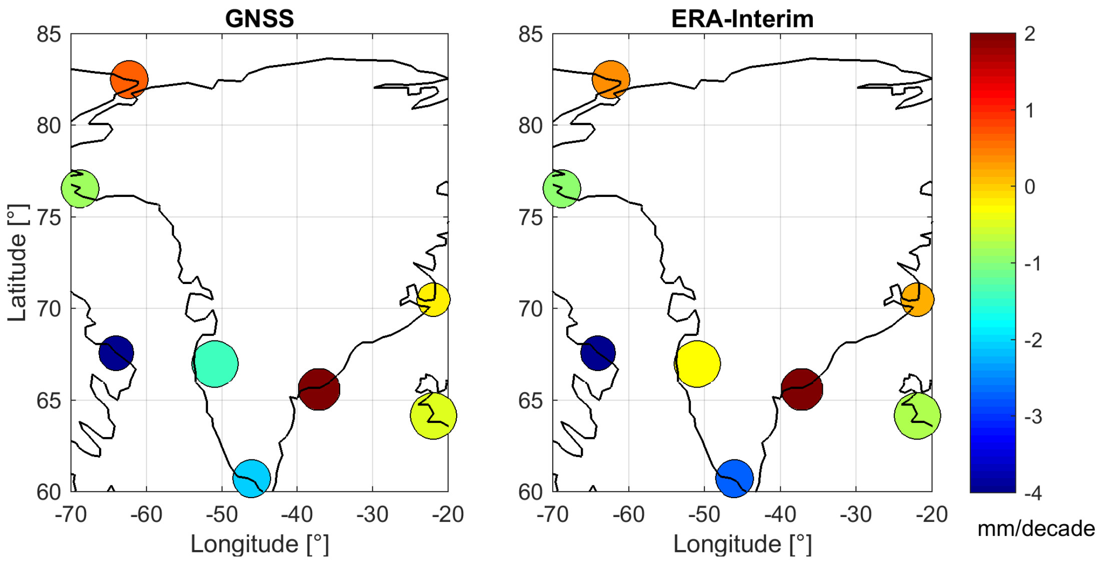

Figure 4. Zenith total delay trends from re-processed GNSS data of TIGA stations and ERA-Interim data (> 10 years); the size of the circles is proportional to the length of the time series

GNSS data are consistently re-processed for climatological investigations in the framework of the Global Climate Observing System (GCOS) of the World Meteorological Organization. Within GCOS the Reference Upper Air Network (GRUAN), an international observing network, was designed to meet climate requirements. Upper air observations within the GRUAN network are providing long-term high-quality climate records. GNSS receivers are an integrative part of the GRUAN station equipment with highest priority for estimating the atmospheric water vapor. Precise GNSS data analysis is a key to obtain IWV on the highest accuracy level. Due to its long-term experience in GNSS data processing, GFZ was selected by WMO as a central GRUAN GNSS data processing center. In addition, GFZ operates the GNSS stations at the GRUAN sites in Ny-Ålesund (Norway), Lindenberg (Germany), Boulder and Utqiagvik (USA), Sodankyla (Finland), and Lauder (New Zealand). An example for the validation is shown in Figure 5 for GRUAN station Ny-Ålesund (Spitsbergen, 78.55° N, 11.51° O). An overall good agreement between GNSS and radiosonde data is visible. The best agreement is present during the winter months while the site is exposed to the dryest air condition. Larger deviations between GNSS and radiosonde results are visible especially during summer with an increased amount of water vapor. In addition, Ny-Ålesund is often affected by strong winds which disturbs the ideal concept of co-located measurements by drifting the radiosonde significantly.

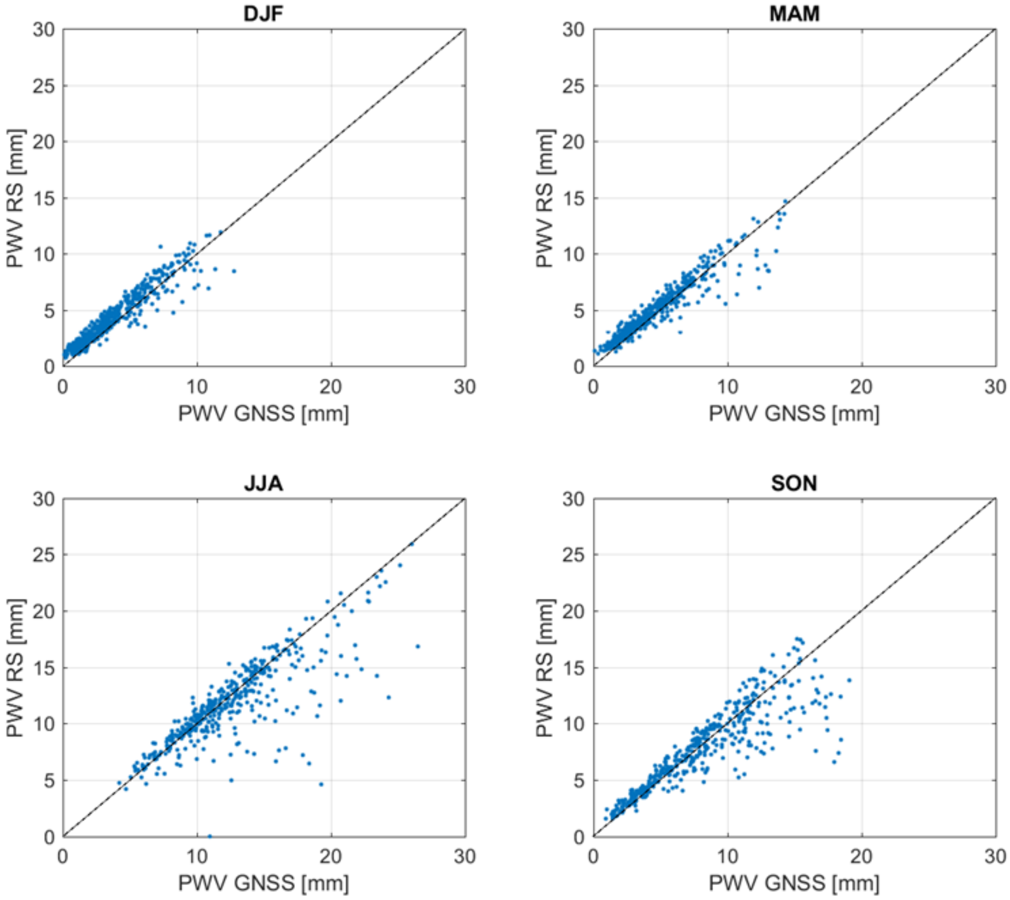

Figure 5. Integrated water vapor at GRUAN station Ny-Ålesund (Spitsbergen, 78.55° N, 11.51° O). GNSS-derived water vapor from re-processed data for 2011–2016 have been compared seasonally with radiosonde data

3. SUMMARY AND CONCLUSIONS

GNSS-based climate-orientated research can be based on investigating long time series of atmospheric water vapor or by assessing the climate-related signals incorporated in coordinate time series. This paper gives an introduction to the usage of both approaches at GFZ. Station vertical motions derived within the TIGA reprocessing reveal the increased vertical uplift rates in Greenland especially for the time period 2010–2012. For the IGS station KELY a significantly increased uplift rate of nearly 1 cm/year was determined for this period. GNSS-based estimates of the important greenhouse gas water vapor agree well with radiosonde data, meteorological data and models and show also significant increases. In order to strengthen investigations regarding the determination of integrated water vapor within GRUAN dedicated monitoring sites co-locating various sensors are established. For the GNSS-based climatological research at GFZ the next steps are the continuation of reprocessing activities as well as combined investigations in regions strongly affected by climate change.

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BASIC GRAVIMETRIC NETWORK OF REPUBLIC OF MACEDONIA - A NEW REALITY

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In the paper is presented a realization of the Basic Gravimetric Network of the Republic of Macedonia. The project and the realization are made in 2012 and 2013. This new basic gravimetric network is the first prime order gravimetric network in Macedonia. The gravity datum is defined by the absolute gravity network in Macedonia. The absolute gravity network in Macedonia consists of three points that was established in 2010. The definition and the realization of the basic gravimetric network of Macedonia, as a part of the new geodetic reference systems, was made under the authority of the Agency for Real Estate Cadastre of Macedonia. The project was supported by the World Bank project. In the project are presented network design plan, point monumentation plan, network observation schedule, and the required resources for its realization.

The main stages of the establishment of the network are presented. The measurements and processing of the data are realized in cooperation of specialists and equipments from Bulgaria, Macedonia and Serbia. In details are given the basic parameters, the method of measurements, the processing and the achieved results.

Keywords: gravimetric network, datum.

1. INTRODUCTION

The definition and the realization of the State Reference System in Republic of Macedonia (RM) is under the authority of the Agency for Real Estate Cadastre, in compliance to the provisions from the Law on Real Estate Cadastre. The State Reference System as a one unit is comprised of the following reference systems: Spatial (three-dimensional) reference system; Horizontal (two-dimensional) reference system; Vertical (one-dimensional) reference system; Gravimetric reference system and Astronomic reference system.

The Basic Gravimetric Network of RM (is a network which) has objective to establish a modern and functional Gravimetric reference

system on the territory of Macedonia. Basic Gravimetric Network is developed according to European standards will be basis for a quality geo-positioning throughout the territory of Macedonia and will also serve for different scientific and geo-physical researches.
Detailed Project for realization of the Gravimetric Works in the Republic of Macedonia was prepared from Agency for Real Estate Cadastre supported by WB Project (Bidding Document for procurement of Basic Gravimetric Network of Republic of Macedonia – Establishment, Measurement and Delivering of Data ICBNo: MK-RECRP-7928MK-ICB-C5.4-14). The Gravimetric Works under this procurement include: Gravimetric Works for establishment and determination of Basic Gravimetric Network in the Republic of Macedonia, establishment of horizontal gravimetric calibration base and establishment of Microgravity Networks Points around of the each Absolute gravimetric points.

The Gravimetric Works under this project are realized by Joint Venture between “Geotechengineering” Ltd. (Bulgaria) and “Geofoto Zenit Engineering” Ltd (Macedonia) - JV Geotechengineering & Zenit. In realization of the project take part Macedonian, Bulgarian and Serbian (Republic of Serbia Geodetic Authority) specialists.

Absolute Gravimetric Network (Zero order gravity network) is part of the Basic Gravimetric Network in the Republic of Macedonia. Absolute Gravimetric Network is defining Gravimetric datum. The absolute gravity network in Macedonia was established by means of absolute gravimetric campaign that was performed in year 2010 and it consists of three points in Skopje (AGT01) (set up in the basement of the geoseismic laboratory in Skopje), Ohrid (AGT02) (set up in the vicinity of the location of IGS/EPN point) and Valandovo (AGT03) (stabilized in the geoseismic observatory).

For absolute gravimetric survey, the absolute gravimeter Micro-g-LaCoste FG5 No. 233 is used. At the locations of absolute gravimetric points, there are also made relative gravimetric measurements for the purpose of determining the vertical gradient value at each location of the absolute gravimetric point. The accuracy of gravity accelerations for three absolute points is 2.10^{-8} m/s^2 for height 1.2 m above point and 4.10^{-8} m/s^2 for point level (Engfeldt A., Odolinski R., Agren A., 2010).

For the purpose of securing the absolute gravimetric points, i.e. of measured absolute values of gravity acceleration on them, are established three Microgravity Networks (each consists from three eccentric points) in the environment of each of the absolute gravimetric points.

All of the eccentric points are newly constructed. The distance of the eccentric points from the absolute gravimetric points is from 0.5 km to 5 km.

2. BASIC GRAVIMETRIC NETWORK

2.1 MAIN CHARACTERISTICS OF FIRST ORDER GRAVIMETRIC NETWORK, NET DESIGN, MEASUREMENTS

The First Order Gravity Network of the Republic of Macedonia is defined by 25 points (Fig. 1). Eleven points of the First Order Gravity Network are chosen to be the same with points from GNSS Network (Passive GNSS Network of Macedonia). Ten points of the First Order Gravity Network are chosen to be the same with nodal points from Leveling Network of Macedonia. There are four new stabilized points - GT 103, GT 111, GT 113 and GT114. The positional coordinates are given in the datum ETRS89, epoch 1989.0 and the heights are orthometric.

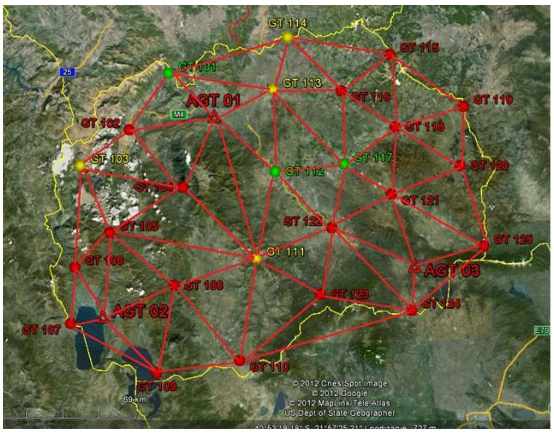

Figure 1. First Order Gravity Network of RM

The points from First Order Network are regularly covering the territory of Macedonia. The density of the set up points in the First Order Network is approximately 1 point per 1070 km2. Gravity differences (connections) between points are 68 lines, which are closing 41 triangles. The average distance between points is 39 km.

The positions and heights of each First Order gravimetric point is determined by applying GNSS measurements with dual frequency GNSS receivers, using MAKPOS system, with 3D accuracy of 2-4 cm. The ellipsoid coordinates are determined in global and local geodetic datum, and plane Gauss-Krüger coordinates and orthometric heights should be calculated by applying the transformation parameters (supplied by AREC).

Gravimetric measurements are realized with two gravimeters models Scinterx CG3+ (Ser.No. 120140052) and Scintrex CG-5 (Ser. No. 73). Measurements are made simultaneously with both gravimeters according to Measurement plan in Technical documentation. In time of gravimetric measurements are registered air pressure and temperature with two instruments (barometers) of type PHB-318.

2.2 CALIBRATION BASE MEASUREMENTS

Horizontal calibration base of the Republic of Macedonia is defined within two absolute gravimetric points – AGT01 (Skopje) and AGT02 (Ohrid). Calibration measurements are made three times over period of gravimetric campaign – before, in the middle and at the end of measurements. For each calibration measurements are calculated gravity differences with real and normal vertical gradient for both instruments. Calibration coefficients are calculated for each gravimeter from the three calibration measurements. Mean linear calibration coefficients calculated with real vertical gradient are used for calibration of gravity differences from each gravimeter.

2.3 GRAVIMETRIC MEASUREMENTS

Gravimetric measurements in **First Order Gravity Network** are carried for 23 gravimetric days. Measurements are made simultaneously with both gravimeters. The used scheme of measurements is by Star method or known as Difference method (Fig. 2). Connection between every two points is measured in scheme 1-2-1. The main closing figures of measurements are triangles.

On absolute points instruments are stationing side by side at the surface of point (Fig. 4). On points from **First Order Gravity Network** was adopted gravimeter CG-5 to be set on the point, and CG-3 to be set at the base of the point (Fig. 5). Height of the instruments was measured very carefully with accuracy of 1 mm. In order to achieve correct instrument height according to surface, height is measured at 3 different sides of instrument. End instrument height is formed from mean arithmetical values from 3 measurements. Atmospheric pressure and temperature are measured too in time of measurement.

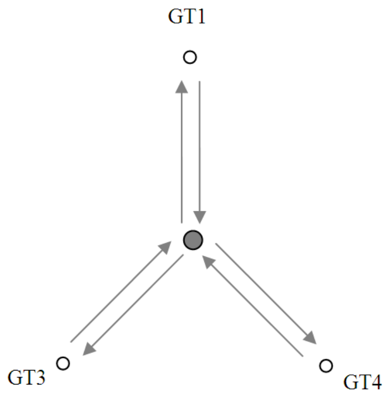

Figure 2. Difference method (star method) for First Order Gravity Network

Figure 3. a) Stationing at absolute gravimetric point; b) stationing at points from First Order Gravity Network

In every station are presented 6 cycle measurements in order to have at least 5 reliable cycle measurements if there are disturbances in period of measurement. Duration of measurement each cycle measurement is 60 seconds with applied Tide correction, Seismic filter, Continuous tilt correction and Auto-rejection of bad measurements.

Gravimetric measurements in each gravity station are processed separately to achieve the reading in and SD of reading in each station. Gravity readings with their SD from raw files with measurements are processed in MS Excel worksheet. All records are analyzed together with information from Field books. Two criteria are used for estimation of data: 1) standard deviation of arithmetical mean from 6 readings to be less than 0.005 mgal and 2) difference from maximal and minimal reading to be more than 10 microgal (0.010 mgal).

From all measurements with CG-3+ and CG-5 are excluded 4 readings.

2.4 CORRECTIONS TO GRAVIMETRIC MEASUREMENTS

Tidal corrections – earth tide correction is introduced automatically in the time of measurement (CG-5 Scintrex Operational Manual, 2006). The corection is is calculated in the Scintrex software via the Longman formula (Longman I.M., 1959) by entering of the latitude, longitude and UTC time. The time used in the tidal computation is the midpoint between the start and the end of a reading session. The accuracy of introduced correction is ± 3 microgal, because of accepted mean gravimetric factor 1.16 in Longman formula and existents of variations in it. Ocean loading effect is not taken into account.

Atmospheric corrections - atmospheric pressure correction is introducing error from pressure variations in period of measurement. Pressure is measured in each gravity station in *hPa* units. For computation of correction is used empirical formula:

$$\delta O_{pressure} = 0.3(p - p_n), \quad (microgal) \qquad (1)$$

where

$$p = measured\ \ pressure\ at\ station\ in\ hPa; \qquad (2)$$
$$p_n = normal\ \ pressure\ at\ station\ in\ hPa;$$

Normal atmospheric pressure (p_n) for station is calculated upon orthometric height of point for International Standard Atmosphere (ISA). After IAG (International Association of Geodesy) resolutions is used formula for Normal Atmosphere DIN 5450 (Schuler, 2000).

$$p_n = 1013.25\left(1 - \frac{0.065\,H^{ort}}{288.15}\right)^{5.2559} \qquad (3)$$

Seismic effects – possible seismic processes are filtered in time of measurement with seismic filter options in time of measurements.

Tilt effect – introduced in time of measurement with automatic readings of x-level and y-level. Preliminary set criteria are inclination of x- and y-levels to be less than 10 arcseconds.

Temperature effects – variations in air temperature are calculated and introduced automatically in time of measurement.

Magnetic field – possible influences of Earth's magnetic field to gravity measurements are eliminated with same orientation of instrument in each station. To assure same orientation in all measurements in each gravity stations legs of instrument are marked in first measurement.

Drift - After introduction of the corrections in measurements linear drift correction for every connection (gravity difference) is calculated. The value of linear drift is calculated from double measurements in every gravity connection.

Calibration - Measured gravity differences are calibrated according to calculated calibration coefficient for each instrument.

All these computations are made in one MS Excel worksheet for each gravimetric day, where every gravity difference is calculated separately.

2.5 DATA MODELS FOR ESTIMATION AND ADJUSTMENT

Two data models are formed: (1) arithmetical mean of six readings and arithmetical mean SD of readings ("s" model) and (2) mean proportional of six readings and mean proportional SD of readings ("t" model).

For each data model are applied three stochastic models: (1) equal weights (p1=1); (2) weights proportional to the duration of measurement (Δt) of gravity connection (p2 = 1/Δt); (3) weights calculated upon standard deviations for each gravity connection (p3 = c/mΔg2, c=constant).

Combined models for measurements with two gravimeters CG3 and CG5 are formed for arithmetical ("s" models – 35sp1, 35sp2 and 35sp3) and mean proportional ("t" models – 35tp1, 35tp2 and 35tp3) models for each gravimeter, according to weight model (p1, p2 or p3). For mean proportional models are formed and "scaled models" calculated with scaled weight with value for posteriori RMS after free network adjustment of each gravimeter data (35_mtp1, 35_mtp2 and 35_mtp3). For model with good quality after analysis is chosen mean proportional scaled model "35_mtp2". For this model is applied an active robust estimation method - Danish method (Krarup, 1967; Krarup T., J. Jul, K. Kubik, 1980). Danish method is performed as a variant of application with modifying function given by Caspary (2000). Result model after Danish method is assigned as "35_dtp2".

Used models are performed in Figure 4.

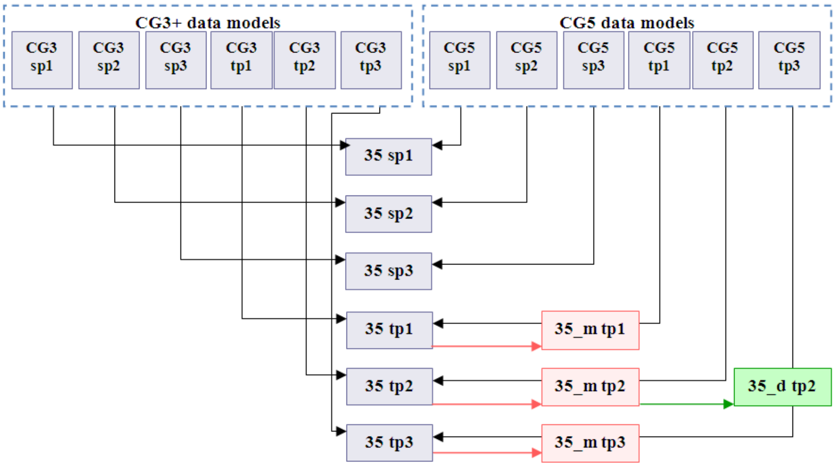

Figure 4. Data models for CG3+, CG5 and combined models

2.6 PRELIMINARY ACCURACY ESTIMATION

According to realized gravimetric measurements simultaneously with two gravimeters CG3 and CG5 could be performed two type preliminary accuracy estimations.

- **Preliminary accuracy estimation of network upon closures of triangles in gravity network;**
- **Preliminary accuracy estimation of network upon to differences in accele-ration between gravity connections achieved with each gravity meter CG3 and CG5.**

For statistical rows with values for closers of triangles and differences between two gravimeters are performed statistical tests for:

- **availability of gross errors** with confidence level of probability 0.997;
- **availability of systematical errors** – applied for non-calibrated and calibrated data. Calibrated data gives insignificant values for systematical errors;
- **hypothesis for normal distribution** - applied for non-calibrated and calibrated data. Results for calibrated data show that hypothesis is not rejected, so data are not in contradiction with hypothesis for normal distribution.

2.6 LEAST SQUARES ADJUSTMENTS AND LEAST SQUARES ADJUSTMENTS ANALYSIS

Adjustments of gravity measurements and data analysis are made with program GRAVI_P. This applied program is written on Visual Studio C++ language and is especially made for precise gravity measurements least squares adjustment and least squares adjustment analysis. Program is made by Prof. Penio Penev from Geodetic Faculty of University of Architecture, Civil Engeneering and Geodesy UACEG (Sofia, Bulgaria).

With program GRAVI_P are made free and constrained adjustments for the different composed models. Free adjustments are used for estimation of accuracy of observations, beside preliminary made estimations of observations. Results from preliminary estimations and from free network adjustment show very good agreement. In free adjustments with program GRAVI_P are made statistical tests - Tau test and Chi square test. Tau test is applied after Pope's techniques (Pope, 1976) to detect outliers in observations. Chi square test is a global test on residuals (variance factor test) (Walpole R.E. and R.H. Myers, 1989). The two tests are applied with global significance level 5%.

2.7.1 CG3 models

For CG3 models (Figure 4) better results are achieved for mean proportional observation data. Free networks RMS of weight unit are for p1 – 9.59 microgal, p2 – 5.62 microgal, p3 – 10.64 microgal. Connections with biggest residuals are 117-122 and 114-101. Chi square test is satisfied – a-priori RMS of unit weight is in agreement with achieved posteriori value. Connections with bigger residuals are the same as connections find as outliers in applied robust estimation with Danish method.

But when the same models are adjusted as constrained networks to three absolute points their RMSs are increased with ~ 50% - RMS of weight unit are for p1 – 18.61 microgal, p2 – 11.36 microgal, p3 – 23.70 microgal. Connections with biggest residuals are changed to connections with point AGT01 – 113-1 and AGT01-111. This shows that after fixing of networks behavior of networks is changed.

2.7.2 CG5 models

For CG5 models (Figure 4) better results are achieved for mean proportional observation data. Free networks RMS of weight unit are for p1 – 11.98 microgal, p2 – 7.60 microgal, p3 – 14.66 microgal. Connections with biggest residuals are 120-118 and 120-125. Chi square test is satisfied – a-priori RMS of unit weight is in agreement with achieved posteriori value. Connections with bigger residuals are the same as connections find as outliers in applied robust estimation with Danish method.

But when the same models are adjusted as constrained networks to three absolute points their RMSs are increased with ~ 60% - RMS of weight unit are for p1 – 31.54 microgal, p2 – 18.87 microgal, p3 – 41.10 microgal. Connections with the biggest residuals are changed to connections with point AGT01 – 1-111 and 1-104. This shows that after fixing of networks behavior of networks is changed.

2.7.3 Combined models

After free networks adjustment and preliminary estimations, mean proportional data models shows much better representation results, that is the reason for free and constrained adjustment of combined models to be used only combined formed from mean proportional separate models for CG3 and CG5. First are combined proportional mean models and second are combined proportional mean scaled models (“m” models). These models are used for free and constrained adjustments. Free adjustments are made to estimate accuracy of networks for combined models. Better results are achieved for Combined proportional mean scaled models (“m” models) - RMS of weight unit are for p1 – 9.68 microgal, p2 – 5.68 microgal, p3 – 11.15 microgal. Connection with the biggest residuals for three weight models is 120-125. Chi square test is satisfied – a-priori RMS of unit weight is in agreement with achieved posteriori value. Connections with bigger residuals are same as connections find as outliers in applied robust estimation with Danish method.

When the same models are adjusted as constrained networks to the three absolute points their RMSs are increased with ~ 60% - RMS of weight unit are for p1 – 28.64 microgal, p2 – 16.41 microgal, p3 – 34.73 microgal. Connections with biggest residuals are changed to connection with point AGT01 – 1-111 for three weight models. This shows that after fixing of networks behavior of networks is changed.

For better combined models - combined proportional mean scaled models (“m” models) are performed robust estimations in order to find and minimize eventual availability of gross errors. Found outliers in iterations processes of application of Danish method are with reduced weights. They are compared with results for combined proportional mean scaled models (“m” models). Accuracy of RMS for free network after last iteration in Danish method is getting better with 30-44% - for p1 – 5.50 microgal, p2 – 3.60 microgal, p3 – 7.88 microgal. Besides that when same models are used for constrained adjustment RMS of unit weights are almost the same. Connection with the biggest residual for three weight models for free adjustment is 120-125, and connection with the biggest residual for three weight models for constrained adjustment is 1-111.

Indicated outliers in application of Danish method for all models in iterations are corresponding with registered disturbances in time of measurements. The outlier with maximal value for all 3 models is found to be measurement between points **120-125**. Observation is made in 16.09.2013 and in field book for that day is written remark that weather is rainy, muddy, with big humidity. The next maximal value of outlier is **for model 1** – **120-118** (15.09.2013 – point 118 – strong wind) (this connection is found as outlier for model 2 and model 3), **for model 2** – **123-110** (11.09.2013 – rainy weather, muddy) (found as outlier in model 1 and model 3); **for model 3** – **124-110** (13.09.2013 – strong wind and vibrations) (this connection is found as outlier for model 1). Connection between points **124-125** is found as outlier in three models it is measured on 13.09.2013 – strong wind and vibrations. Connection between points **111-112** is found as outlier in three models, and in model 3 is third maximal value – it is measured on 01.09.2013 (autobus vibrations) and remeasured on 19.09.2013.

After fixing of networks from last iteration in Danish method the behavior of network is changed. Registered outliers in all estimations of observations and free adjustments are changed with bigger residuals for connections to absolute points.

After processing of observations, estimations and adjustments of Fundamental network we could say that relation between weights is not equal. Weights models p1 and p2 after applied Danish method for robust estimation are giving similar results and are with same behavior. As final data are suggested to be used results from constrained adjustment of proportional mean scaled "m" model for weight p2 (35_2mv), after application of Danish method for robust estimation (35_2dv).

For combined models with weight p2 (proportional to time of measurement) are given main characteristic results from free (Table 1) and constrained adjustment (Table 2). Characteristics are: **RMS a-priory**, calculated upon closure of triangles; **RMS posteriory**; **$m_{max}g$** – maximal value of RMS for gravity acceleration; **Nr. of point** - number of point in which is found this maximal value; **$M_{ar.mean}g$** – average of RMS's for gravity accelerations; **$M_{geom.mean}g$** – generalized variance of RMS's for gravity accelerations and **[pv]** – sum of product of residuals and weights.

Table 1. Results from free adjustment of combined models with weight p2

FREE ADJUSTMENT	**Combined models with weight (p2) proportional to time of measurement**		
	Combined model	**Scaled combined model**	**Scaled combined model after Danish method**
Model name	**35_p2**	**35_mp2**	**35_dp2**
RMS a-priory [μGal]	6.42	5.41	3.95
RMS posteriori [μGal]	**6.75**	**5.68**	**3.60**
$m_{max}g$ [μGal]	5.57	5.32	4.17
Nr. of point	GT119	GT119	GT115
$M_{ar.mean}g$ [μGal]	**4.39**	**4.19**	**3.03**
$M_{geom.mean}g$ [μGal]	**4.33**	**4.14**	**2.98**
[pv]	**37.8**	**21.4**	**2.8**

Table 2. Results from constrained adjustment of combined models with weight p2

CONSTRAINED ADJUSTMENT	**Combined models with weight (p2) proportional to time of measurement**		
	Combined model	**Scaled combined model**	**Scaled combined model after Danish method**
Model name	**35_v2**	**35_mv2**	**35_dv2**
RMS posteriori [μGal]	**20.19**	**16.41**	**15.12**
$m_{max}g$ [μGal]	18.66	17.24	19.62
Nr. of point	119	119	115
$M_{ar.mean}g$ [μGal]	**13.59**	**12.56**	**13.05**
$M_{geom.mean}g$ [μGal]	**13.43**	**12.41**	**12.81**
[pv]	**203.5**	**141.9**	**113.3**

3. CONCLUSION

Presented Basic Gravimetric Network of republic Macedonia is a contemporary gravimetric network satisfying present-day standards for accuracy and realization. The network is realized with use of modern instruments and technologies. In processing of data are introduced all necessary corrections for precise relative gravimetric measurements. In main stages of processing are made all tests and analyses. The key points in processing are: control of data in time of measurement; applying of appropriate scheme of gravimetric measurements, which is leading to identical calculation of drift in all loops and securing of direct independence between measurements. The appropriate net design and scheme for gravimetric loops are giving availability to realize good preliminary estimation of accuracy. Forming of two type data models with three type weights is a base for detailed analysis of results and localization of possible mistakes in measurements or calculations. The verification for completeness and propriety of formed models is made with analyses of residuals with application of Tau-test and Chi-square test. Successfully is applied an active robust estimation method – Danish method. With use of Danish method are localized possible estimates for measurements and for them are set appropriate weights. The good qualities of network are verified with many tests, analyses, using of precise instruments and applying of suitable methods.

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GEODETIC PROJECTS AS PART OF MAIN PROJECT FOR NEW BASIC LEVELING NETWORK

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The basic leveling network is a part of geodetic networks, with which is defining altimetric base for performing of the geodetic activities within a state.

In time period 2011-2013, an extensive preparations and specific field activities were carried out for realization of a new basic level network. With new leveling network the state it's trying to deflect the short comings of the existing leveling network, as well as to realize its intentions to connect its geodetic networks in frame of the European geodetic networks.

In this paper are shown the short history of leveling networks in Republic of Macedonia, the concept and main characteristics of new leveling network, as well as results of the leveling measurements.

Keywords: basic leveling networks, geodetic networks, leveling network.

1. INTRODUCTION

The leveling network is an altimetric base which is used to determine the heights of discrete points that are defining the vertical terrain representation and the engineering objects.

The first geodetic works related with establishment of referent leveling network for the territory of the Republic of Macedonia are realized by Military geodetic institute from Begrade in time period 1911-1931, as a part of the activities for establishment of first leveling network with high accuracy (NVT1) on territories of countries from Kingdom of Yugoslavia. The fundamental benchmark for these leveling measurements is set in Trieste. On territory of the Republic of Macedonia were developed three closed leveling traverses and the connections with the neighboring countries (Bulgaria and Greece) were accomplished with three traverses (Bitola, Gevgelija and Strumica).

Figure 1. First leveling network in Kingdom of Yugoslavia

The network of the second leveling with high accuracy (NVT2) was designed in 1967. The leveleing and gravimetric measurements for NVT2 are performed in time period 1968 - 1973. The vertical datum was defined with mean level of the Adriatic Sea, which was measured with mareographs at Kopar, Rovinj, Bakar, Split, Dubrovnik and Bar, with obser-vations in 18.6 years period (epoch 1971.5).

On territory of the Republic of Macedonia were developed only two closed leveling poligons with length of 545 and 625 km.

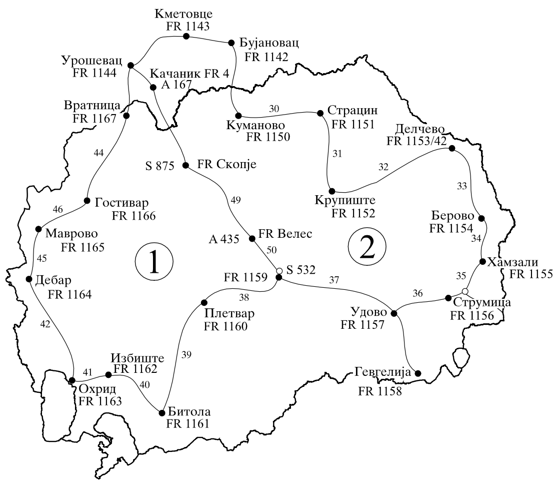


Figure 2. Second leveling with high accuracy of the Republic of Macedonia

The network of NVT2 was adjusted as a whole network, following a strict method and its characteristic is extremely high relative accuracy. Thereby, for all benchmarks are determined geo-potential heights, dynamic, orthometric, normal and spheroid height.

In the Republic of Macedonia as an referent height base still is using network of NVT1, and network of NVT2 despite its homogeneity and high quality of determination, has never been into official use.

2. THE NEW LEVELING NETWORK OF THE REPUBLIC OF MACEDONIA

Taking into account the fact that the NVT1and NVT2 networks have been established and determeneted before many decades ago, according to their design, datum and accuracy they are no longer suited to the modern needs of the geodetic profession. The main disadvantages of the old leveling network can be sublimated through the following:

- Inhomogeneity of the network - old network includes measurements with significant differences in accuracy;
- Insufficient coverage of the state territory - only two leveling traverses are developed on the whole territory of the Republic of Macedonia;
- Lack of gravimetric measurements - with aim for qualitative defining on systems of orthometric and normal heights;
- Weak conection of leveling network with networks of neighboring countries;
- The nead of preparation for the adoption of a new state vertical datum EVRS (European Vertikal Reference System).

From these reasons, the Agency of real estate cadastre of the Republic of Macedonia, took concrete steps for establishing new leveling network with high accuracy on state territory according to international standards.

In 2009, a Study for development of leveling and gravimetric network in the Republic of Macedonia was prepared, and in 2011 a detailed Project for realization of the leveling network in the Republic of Macedonia, which further were used as the basis for the establishment of the new leveling network of high accuracy (NVT3). In the Study and in the Project were defined:

- accuracy of the network,
- datum of the network (MSL and connection with EULN),
- heights systems (geo-potential heights, normal and orthometric heights),
- the design of the network (5 variants were made),

- reconnaissance and stabilization of the benchmarks,
- criteria for accuracy of the measurements and
- connections with neighboring countries.

The new leveling network with high accuracy (NVT3) is consisting of 1098 leveling points (benchmarks) connected with 49 leveling lines and 19 polygons, plus 12 lines for connection with neighboring countries. The total length of leveling traverses is 2189 km, with an average distance of 1800 m between benchmarks and average perimeter of the polygons with 166 km.

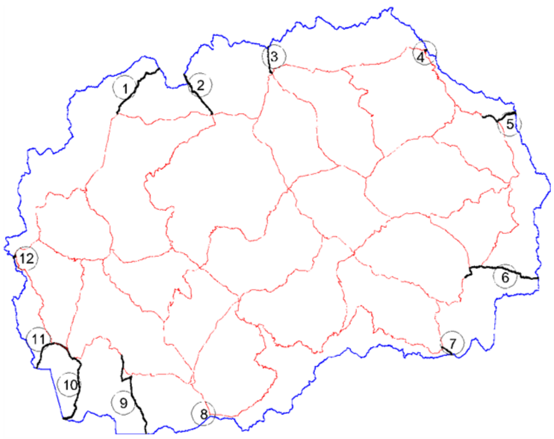


Figure 3. The new leveling network of the Republic of Macedonia and conections with neighboring countries

The new leveling network is consisting 28 fundamental benchmarks and 31 nodal points.

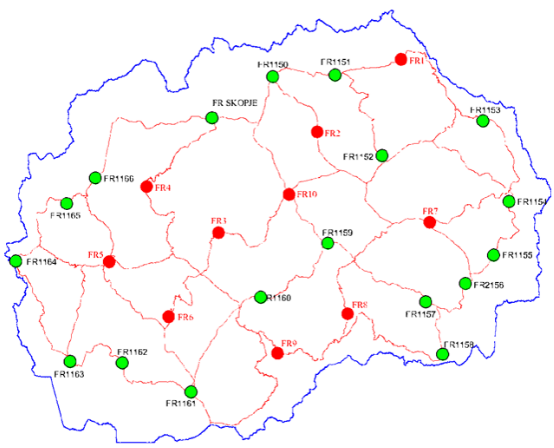


Figure 4. Schedule of the fundamental benchmarks from new leveling network

The development of the new leveling network has been realized in four parts which are covering the entire territory of the Republic of Macedonia. The field works connected with determination of the network NVT3 (reconnaissance, stabilization, leveling measurements and GNSS measurements) are performed in time period August 2012 - December 2013.

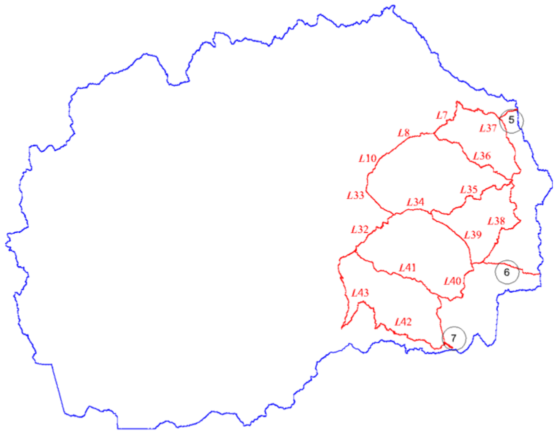


Figure 5. First part of the new leveling network realisation

For all parts of new leveling network are made:

- Project of reconnaissance;
- Project of stabilization and
- Project for measuring height differences.

In ***Project of reconnaissance*** were defined locations of the leveling network benchmarks. That Project contains:

- Technical report;
- Overview map of polygons;
- Map of the leveling lines in scale 1:25000;
- Table with basic data for the polygons;
- Description of the reconnassanced location
- Overview geological map;
- A detailed project for the fundamental benchmarks (if exist).

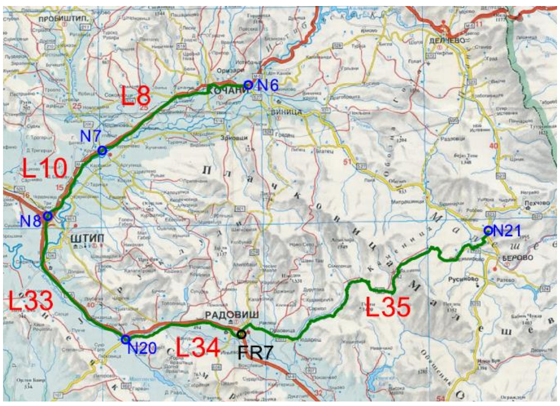
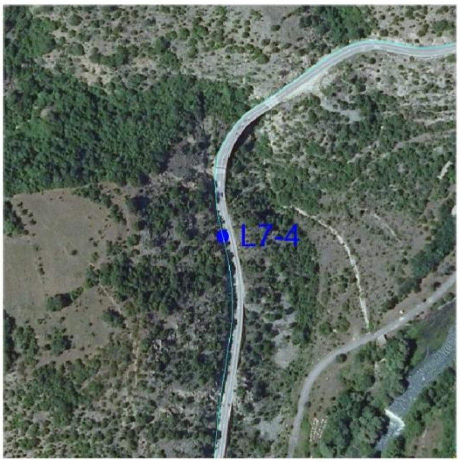


Figure 6. Overview map of polygons

Leveling network of Macedonia	Line: L7	Benchmark: L7-4

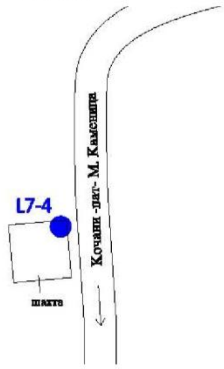
Ortophoto scale 1:5000



Topographic map scale 1:25000

Photography

Sketch



Approximate coordinates	Y	630999	X	4648618	H	446

Planned monumentation		
	☐	Fundamental benchmark
	☐	Nodal benchmark
	☐	Passive point
	☐	Geodetic mark
	☐	Ordinary vertically placed
	X	Ordinary horizontally placed

Remark:

Reconnoiter			Company
Name	Kiril	Pance	Geofoto Zenit Inzenering DOO Skopje
Surname	Seckov	Mitev	
Date	3.10.2012		

Figure 7. Description of the predicted locations for the benchmarks

After preparation of the *Project of reconnaissance*, was made a ***Project on stabilization*** of new leveling network benchmarks. That Project was followed with massive field works in frame of performed field stabilization of the benchmarks.

The basic contents of this project are:

- Types of field markers for field stabilization;
- Map of the polygons;
- List of ETRS89 coordinates;
- Description of the stabilized benchmarks and
- Field sheets of GNSS measurements.

For all types of benchmarks were made sketches according to which they are materialized.

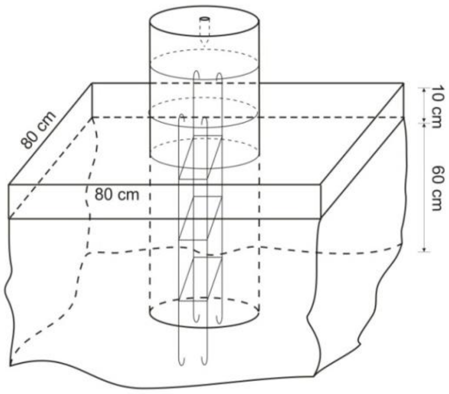


Figure 8. Draft for stabilization of nodal point

In frame of the leveling network there are five types of different markers with which are stabilized the benchmarks:

- Stabilization of the fundamental benchmarks - for all new fundamental benchmarks in leveling network were made special designs for stabilization. In those designs are defined: the dimensions of the excavation, the reinforcement plan and the type of the benchmark which is sets in foundation.

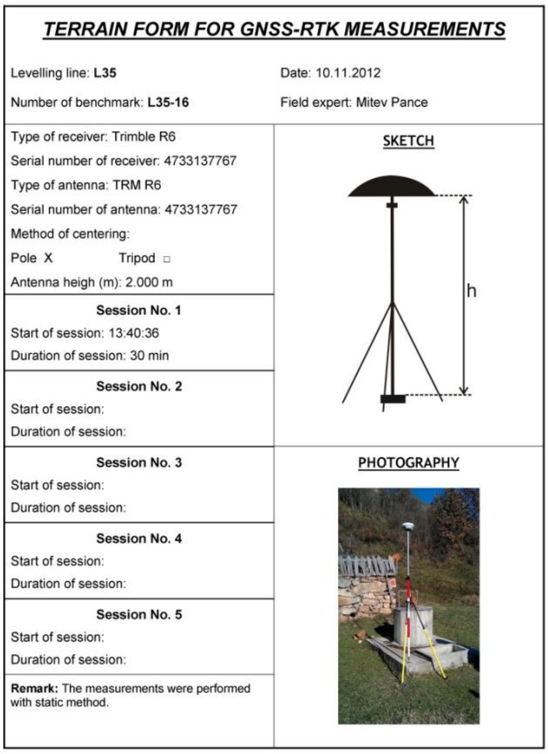
Figure 9. Stabilization of the fundamental benchmark

- Stabilization of the nodal points - the nodal points in which are connecting three or more leveling traverses are stabilized with special tube.

Figure 10. Stabilization of the nodal points

- Stabilization with a short tube - type of stabilization which is used at locations where there are no stable objects for setting the benchmarks.
- Stabilization with horizontal benchmark - in stabile objekt.
- Stabilization with vertical benchmark - in stabile objekt.

For all benchmarks are prepared Terrain forms in which are described benchmarks location, the way of stabilization and coordinates in ETRS 89 system. The coordinates are determined by three series of RTK measurements in relation with MAKPOS or with static method with time period of 30'. In the frame of the Project of stabilization are shown the Field sheets for GNSS measurerments for new benchmarks.



TERRAIN FORM FOR GNSS-RTK MEASUREMENTS

Levelling line: **L35** Date: 10.11.2012
Number of benchmark: **L35-16** Field expert: Mitev Pance

Type of receiver: Trimble R6
Serial number of receiver: 4733137767
Type of antenna: TRM R6
Serial number of antenna: 4733137767
Method of centering:
Pole X Tripod □
Antenna heigh (m): 2.000 m

SKETCH

h

Session No. 1
Start of session: 13:40:36
Duration of session: 30 min

Session No. 2
Start of session:
Duration of session:

Session No. 3
Start of session:
Duration of session:

PHOTOGRAPHY

Session No. 4
Start of session:
Duration of session:

Session No. 5
Start of session:
Duration of session:

Remark: The measurements were performed with static method.

Figure 11. Field sheet for GNSS measurements

The last in series of projects for new leveling network is *Project for measuring height differences*. In that project are defined types of the instruments that can be used in process of measuring of the height differences, also was discrabed the procedure of measuring and were defined criterias of measuring accuracy. The basic contents of this project are:

- Certificates of the instruments and equipment.
- Map of the polygons.
- Leveling sheet.
- List of coordinates in system ETRS 89.
- Average values of the height differences and discrepancies.
- Determination of the angle "i".

Under the terms of the Project, was allowed to use leveling instruments that are characterized by an accuracy of ± 0.3 mm/km.

Figure 12. Instrument for measuring of height differences

The basic criterias of the accuracy for performing the measurements are defined through:

- Allowed deviation of the dual height difference (forward-backward):

$$\Delta_{\Delta H}(mm) = 2\sqrt{s} \qquad (1)$$

s - length of the leveling line in km.

- Allowed deviation of closing of the polygon

$$\Delta_{P}(mm) = 4\sqrt{s} \qquad (2)$$

s - length of closed polygon in km.

By using appropriate instruments and observation procedures, the required accuracy was fully met.

Before putting into official usage the data of NVT3 network, it is providing connections with cites leveling networks, datum transformation of present leveling data, changing the legislative framework and stakeholders education about proper application of new data in practice. Also, it is planned to connect NVT3 with the corresponding leveling networks of neighbouring countries, as well as connection with United European Leveling Network - UELN.

3. CONCLUSION

The leveling network as an altimetry system represents a part of the basic geodetic networks which are having fundamental meaning in frame of one country.

In the Republic of Macedonia the old leveling network was developed as a part of the former Yugoslav community and as such is not adequately tailored to our state territory, both in shape and density, and according to the characteristics of its accuracy.

The Project of the new leveling network is one of the biggest geodetic projects in Republic of Macedonia since its independence. Within the project, first of all was performed detailed elaborating of theoretical aspects related to the establishment of the leveling network, then were realized all field activities related to the reconnaissance and stabilization of the benchmarks and were performed the measurements of the height differences.

With respect to all actual standards about development of this type basic geodetic network, the Republic of Macedonia gained a modern and precise geodetic height system.

The activities in this field are related to the introduction of a new state geodetic height datum - compatible with the contemporary European tendencies realized through the EVRS system and United European Leveling Network - UELN.

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A STUDY ON THE IMPACT OF THE VERTICAL REFRACTION ON THE RESULTS OF PRECISE LEVELING MEASUREMENTS

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The purpose of this article is to review a subject, which has always been contemporary in the execution of precise geodetic measurements, namely the impact of celestial bodies like the Sun and the Moon and the vertical refraction. The latter has an influence not only on the highly-accurate angle – linear measurements, but on the highly-accurate leveling ones, which are analyzed in this article, as well.

Key words: celestial bodies, highly-accurate measurements, leveling.

1. INTRODUCTION

The most suitable formula for the bringing out of the correction of the height differences, arising from the vertical refraction, is the one by Kukamyaki. It is the most broadly applicable in the practice. We should take into an account the fact that the refraction is different for every single region and a common coefficient, that reflects an accurate impact of this phenomenon everywhere, cannot be derived.

The respective masses and the location of both the Sun and the Moon also have an impact on the precise geometric measurements of the excesses. The deviation of the vertical line under the influence of the mass of the Sun and the Moon will also be reviewed, as well as the influence of the Solar-Lunar tide on the leveling measurements.

A precise geometric leveling of a part of the geodetic network of "Verinsko" base was made. It was conducted according to the present "Instruction for leveling 1st and 2nd class", Head office of geodesy, mapping and cadastre.

2. PRACTICAL MEASUREMENTS

The line between benchmarks is selected so that the phenomenon vertical refraction to be shown to a maximum extent, namely a diversified terrain with a large difference in the height between the first and the last benchmarks. Additionaly the steep terrain make the measurements difficult – short sights, compliance with the requirements for minimum and maximum measurements on the invar staff.

The leveling line between benchmarks 152 and 155 is with a length of 1221.155 m (Figure 1).

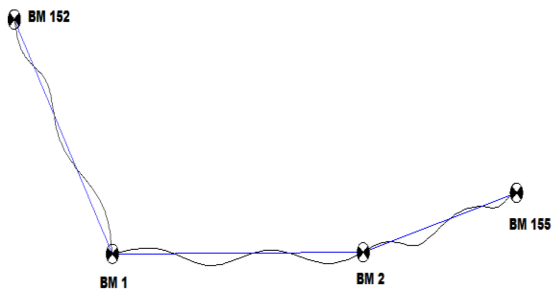

Figure 1. Scheme of the leveling line

The leveling line is divided and measured in sections BM_{152} – BM_1; BM_1 – BM_2; BM_2 – BM_{155}, and every section is characterized by different terrain:

- BM_{152} - BM_1 is slightly crooked, almost flat;

- BM_1 - BM_2 is extremely flat terrain;

- BM_2 - BM_{155} is steep and with clearly indicated big height difference.

Table 1. All height differences of the measured leveling line

№ BM	In between BM, S,km	Height difference, m		d=II - I mm	Average value of height differences
		I	II		
152 1	0,320	-8,9545	+8,9542	-0,30	-8,95435
1 2	0,445	-2,3295	+2,3300	+0,50	-2,32975
2 155	0,456	+30,5877	-30,5878	+0,10	+30,58775
152 155	1,221	+19,3037	-19,3036	-0,10	+19,30365

When a precise geometric leveling is conducted, it is quite complicated to reach a possible theoretical accuracy, because the measurements are influenced by different in character and value errors, associated with external disturbing factors. Those disturbing factors are divided into several groups, according to the object of their influence.

- Factors that affect the instruments directly. Those are the direct sun rays, changes in temperature of the air, artificial electromagnetic fields, changes in gravity field and geomagnetic fields, tidal fluctuations.
- Factors that affect the endurance of the leveling benchmarks. Those are the fluctuations of the temperature in the upper layers of the earth, changes in the level of subterranean waters, freezing of the soil, changes in the slope of ground layers with tidal and non-tidal character.
- Factors that change the direction of the sights beam in the section from the level to the invar staff. That is actually the vertical refraction.

The vertical refraction and the Sun – Moon tides are of greatest importance in conducting a highly – accurate leveling.

One of the sources of mistakes with systematical character is the influence of the mass of the Sun and the Moon on the results of the highly-accurate leveling.

The impact of the Moon and the Sun is most clearly expressed in the slope of the vertical line of angle ε, which is determined by the following formula [2]:

$$tg\varepsilon \approx \varepsilon = \frac{1}{g}\frac{\partial W}{\partial Z} = \frac{3}{2}m\frac{r^3}{R^3}\sin 2Z \qquad (1)$$

Where:

g – the acceleration of the gravity force;

W - disturbing potential of the celestial body;

r - the distance from the place of measurement to the centre of the Earth;

Z – zenith distance;

m - ratio between the mass of the Earth and the celestial body;

R – distance from the centre of the Earth to the centre of the celestial body.

After a convertion of the formula (1) a mathematical expression is derived and it defines the impact of the mass of the disturbing body on the results of the leveling.

$$\psi = Sk\sin 2Z\cos(A-a) \qquad (2)$$

Where:

S - the length of the leveling;

κ - coefficient, dependant on the ratio of the mass of the disturbing body and the Earth;

A – azimuth of the disturbing celestial body;

a - azimuth of the leveling.

It is a proven that the disturbing bodies have the greatest impact on the leveling in the direction of the meridian and the least impact in the direction of the 1st vertical.
The final mathematical expression, that is derived is the following:

$$\psi = -Sk\begin{pmatrix} \frac{1}{2}\sin 2\varphi - \frac{3}{2}\sin^2\delta\sin 2\varphi - \sin 2\delta \\ .\cos\varphi\cos\tau + \frac{1}{2}\sin 2\varphi\cos^2\delta\cos 2\tau \end{pmatrix} \quad (3)$$

$$\psi^I = Sk(\sin 2\delta\sin\varphi\sin\tau + \cos\varphi\cos^2\delta\sin 2\tau)$$

Where:

φ и λ are the geographical coordinates of BM_2;

δ – declination and α – rectascence of the Sun and the Moon are recorded by an astronomical almanac for 2015 for a particular date and hour [1];

τ - the hour angle is also calculated according to the date and the hour.

When an analysis of this equation is made, it can be seen that the influence of ψ in a meridional direction has a systematic character. The first part of the equation in the brackets characterizes the sustained slope of the vertical line, depending on the latitude of the place of observation; the second – long-period one, depending on the slope of the disturbing body.

When (ψ) is being studied for the Sun, its annual period is taken in account, while for the Moon, the computations are more complicated, because it has two periods – short one, 28 days and long one, which is 18 years.

The third and the forth particles of the equation define the dependence of (ψ) from the hour angle of the luminary. The impact of the constituent on the first vertical ψ, composed of two short – periodical particles, bears random character, because the leveling procedures are executed daily and in different mutual positions of the celestial bodies.

A numerical example is presented for the applied corrections on the respective height differences.

By using the formula (3), the corrections of height differences $\Delta h_{152,1}$, $\Delta h_{1,2}$, $\Delta h_{2,155}$ и $\Delta h_{152,155}$ are calculated, according to the Sun and the Moon.

Note of the author: The calculations are made for the two days, in which the measurements have been conducted (06.06.15 and 07.06.15) and are averaged.

Table 2. Correction in relation to the Sun and the Moon

Height difference	Correction in relation to the Sun - Ψ, mm	Correction in relation to the Moon - Ψ', mm
$\Delta h_{152,1}$	+0,050	+0,003
$\Delta h_{1,2}$	+0,069	+0,004
$\Delta h_{2,155}$	+0,071	+0,004
$\Delta h_{152,155}$	+0,190	+0,012

It is well – known that all geodetic measurements are subjected to a certain extend on the influence of the atmospheric refraction, and a defining factor for this are the fluctuations in temperature. The bigger the values of the vertical gradients of the temperature on the way of the sight beam are, the bigger is the impact of the refraction in, relatively equal, other conditions. Under the influence of the vertical refraction, the sight beam is curved.

The vertical temperature gradient in the ground aerial layer determines the degree of influence of the refraction on the results of the geometric leveling. Even if the requirement for the sights, “back” and “front” to be equal is met, the influence of the leveling refraction is not eliminated. Applicable formulas for the calculation of the corrections to the results for the respective region are being used. The most suitable one is the one by Kukamyaki:

$$\delta h_p = 10^{-5}.\delta h_o(S/S_o)^2.(t_3 - t_{\Pi}).h \quad (4)$$

$$\delta h_o = \frac{ctg^2\tau}{Z_3^c - Z_{\Pi}^c}.[\frac{1}{c+1}.(Z_{\Pi}^{c+1} - Z_3^{c+1}) - Z_o^c.(Z_{\Pi} - Z_3)] \quad (5)$$

$$\tau = arcctg\,\frac{S_o}{Z_o - Z_{\Pi}} \qquad (6)$$

Where:

S - length of the particular sight beam;

S_o - length of the sight beam, with which the calculations in the last two formulas have been made;

Z_{Π} – the height of the sight beam in the benchmark, where the “front” invar staff is positioned;

Z_3 – the height of the sight beam in the benchmark, where the “back” invar staff is positioned;

Z_0 - the height of the instrument;

h – measured height difference in the station; $(t_3 - t_{\Pi})$ – measured temperature difference between the Z_3 and Z_{Π} altitudes.

The coefficient c, which is used in formula (5) is determined after a system of three equations is solved:

$$t_1 = a + b.Z_1^c$$
$$t_2 = a + b.Z_2^c$$
$$t_3 = a + b.Z_3^c \qquad (7)$$

The formula (4) is to some extent approximate, that is why it is generally accepted to use the derived by Kukamyaki accurate formula, to calculate the correction because of the refraction towards the measured in a certain station height difference [2].

$$\delta h_p = ctg^2\tau.\frac{\theta}{Z_3^c - Z_{\Pi}^c}.d.[\frac{1}{c+1}.(Z_{\Pi}^{c+1} - Z_3^{c+1}) - Z_o^c.(Z_{\Pi} - Z_3)] \qquad (8)$$

$$d = -10^{-6}.[0,933 - 0,0064(t_{cp} - t_o)].\frac{B}{B_o} \qquad (9)$$

$$\theta = b.(Z_2^c - Z_1^c) \qquad (10)$$

Where:

τ – hour angle;

t_o – 20°C;

t_{cp} – average temperature of the station, in °C;

B – atmospheric pressure, 761 mm Hg (1015 hPa);

B_o = 760 mm Hg (1013,25 hPa);

Z_1, Z_2 – participating in (7) values;

b, c – calculated from (7) unknown coefficients.

The impact of the refraction has a character of clearly expressed systematic errors, not random ones. A numerical example of the made corrections is presented.

Formula (8) has been used to calculate the corrections for every single station of the leveling. They were being summed to derive the total correction for this particular height difference (Table 3).

Table 3. Correction for particular height difference

$\Delta h_{152,1}$	+0.310	mm
$\Delta h_{1,2}$	+0.547	mm
$\Delta h_{2,155}$	+1.201	mm
$\Delta h_{152,155}$	+2.058	mm

The impact of the tides on the earth crust is expressed in tree fundamental ways:

- A change in the gravity force, caused by moving of earth masses;
- A change of the level of Earth’s surface;
- A change in the slope of Earth’s surface.

The results of the precise leveling are mainly affected by the change of the slope of Earth’s surface.
Tidal correction is calculated on the basis of:

$$\delta h_{ij} = 2.q.S_{ij}[(\frac{1}{2}.\sin 2\varphi - \frac{3}{2}.\sin 2\varphi.\sin^2\delta - \cos 2\varphi.\sin 2\delta.\cos t + \frac{1}{2}.\sin 2\varphi.\cos^2\delta.\cos 2t).\cos A_{ij} + (\sin\varphi.\sin 2\delta.\text{int} + \cos\varphi.\cos\varphi.\cos^2\delta.\sin 2t).\sin A_{ij}] \qquad (11)$$

Where:

q – is the coefficient, which, respectively for the Moon and The Sun, takes the values of q= 0.0593 mm/km и q_c = 0.0272 mm/km.

Numerical example of the third correction, which is applied in the precise leveling is calculated by using the formula (11). Calculations referent to the Sun are shown in Table 4 and referent to the Moon in Table 5.

Table 4. Correction referent to the Sun

$\delta h_{152,1}$ =	+0.003	mm
$\delta h_{1,2}$ =	+0.003	mm
$\delta h_{2,155}$ =	+0.002	mm
$\delta h_{152,155}$ =	+0.007	mm

Table 5. Correction referent to the Moon

$\delta h_{152,1}$ =	-0.014	mm
$\delta h_{1,2}$ =	-0.031	mm
$\delta h_{2,155}$ =	-0.018	mm
$\delta h_{152,155}$ =	-0.063	mm

Table 6. Corrected height differences

№	$\Delta h_{i,j}$ (m)	Corrected $\Delta h_{i,j}$ (m)
$\Delta h_{152,1}$	-8,95435	-8,95470
$\Delta h_{1,2}$	-2,32975	-2,33034
$\Delta h_{2,155}$	+30,58775	+30,58901
$\Delta h_{152,155}$	+19,30365	+19,30585

Summarized in Table 6 are compared the values of calculated and corrected height differences.

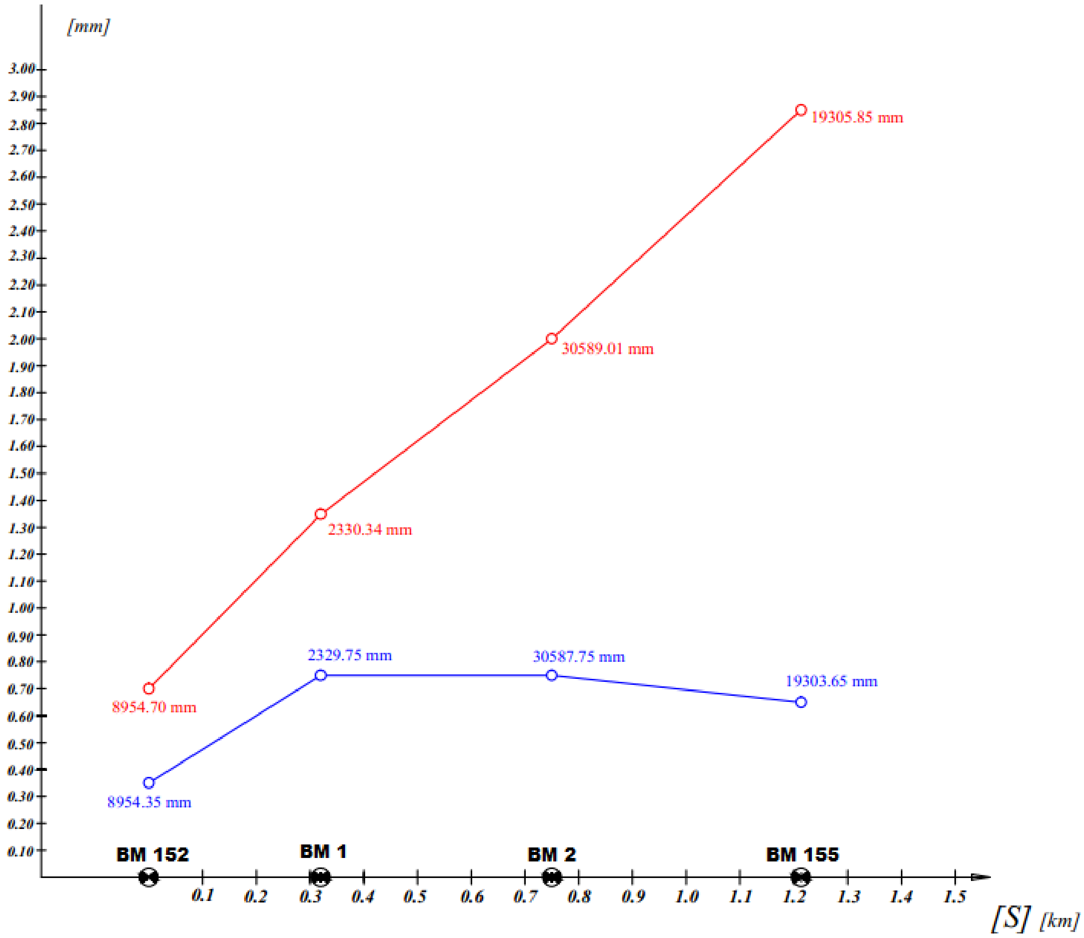

Figure 2.The graphics depicts the difference in the values between measured and corrected height differences

3. CONCLUSIONS

This current article shows, not for the first time, the influence that the vertical refraction has on precise geodetic measurements and here in particular – its impact on geometric leveling. After processing the data from the measurements and applying the necessary corrections, it can be clearly seen that the ending results are in fact changing.

From the graph (Figure 2), which illustrates the derived geometrical height differences and eventually the corrected final ones Δhij, is evident, that the vertical refraction is manifested most strongly in the part of the leveling with the greatest slope (BM_2 – BM_{155}).

The height difference between the two benchmarks is 30.58775 m. In the flat part of the leveling BM_1 – BM_2 with a denivelation of 2.32975 m it is clear, that the influence of the refraction is almost twice less.

The results of the completed measurements and calculations uniquely show the need of applying the already mentioned corrections.

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MAKPOS – NETWORK OF PERMANENT GNSS STATIONS IN THE REPUBLIC OF MACEDONIA

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The Macedonian Positioning System (MAKPOS) is a network of permanent GNSS stations in the Republic of Macedonia, fully established and in efective use since 2009. The system is developed by the Agency for Real Estate Cadastre (AREC), according to the international standards, using the latest GNSS technology. MAKPOS is consisted of 15 permanent GNSS stations evenly distributed across the entire territory of the country, at an average distance of around 50 km, with a control center located in the AREC head office in Skopje. At the moment, the system offers three standard services to the registered users: MAKPOS RTK, MAKPOS PP and MAKPOS DGPS, all of them available 24/7/365. This paper describes the process of the MAKPOS establishment, its technical components, services, pricing policy and plans for some future activities.

Keywords: MAKPOS; GNSS; network; positioning; services.

1. INTRODUCTION

The establishment of a network of permanent GNSS stations, as a terrestrial GNSS infrastructure, is a solution that will definitely allow the users of GNSS technology a fast and reliable way of obtaining geospatial data of high accuracy, at any place of the territory of a country, in real time, or with post processing.

AREC has recognized the importance of establishment of a network of permanent GNSS stations on the territory of the Republic of Macedonia and, as a responsible authority, took all necessary steps for its implementation.

The network of permanent GNSS stations on the territory of Republic of Macedonia is called MAKPOS as an acronym for Macedonian Positioning System.

The MAKPOS system is based on modern scientific achievements and it is developed in accordance with the EU recommendations and standards. It will speed up the application of the GNSS technology in Republic of Macedonia and support a wide spectrum of

GNSS based applications connected with geo-positioning and navigation.

The MAKPOS should provide permanent services for geo-positioning and navigation, determination of spatial coordinates in real time, with accuracy of few centimeters at any place of the territory of the Republic of Macedonia.

2. MAKPOS DESIGN

The implementation of the MAKPOS system was part of the AREC Strategic business plan for the period 2007–2010.

Accordingly, in 2008 in cooperation with the Department of Geodesy at the Faculty for Civil Engineering in Skopje, “The Study for Development of Reference GNSS Basis in the Republic of Macedonia” was prepared. Authors of the Study are Prof. Dr. Stojanco Vuckov and Ass. Gjorgji Gjorgjiev. This Study was basis for further implementation of the MAKPOS system.

3. MAKPOS IMPLEMENTATION

The MAKPOS system is consisted of 15 permanent GNSS stations which are evenly distributed on the entire territory of R. Macedonia, at an average distance of around 50 km, with a control center located in the AREC head office in Skopje.

The permanent GNSS station located in Ohrid, besides being part of the MAKPOS system, serves as a point of the EPN/IGS networks. It is stabilized by BKG – Germany with a specialy funded concrete pillar on a havy rock being operational as a single permanent station since 1998. The other 14 permanent GNSS stations are stabilized on top of the buildings of the AREC cadastre local offices and they are setup by special steel constructions.

The MAKPOS system, according to the original design, is fully implemented in three phases, during 2008 and 2009. In 2016, in order to increase the performances of the system, one additional permanent GNSS station is included in the network.

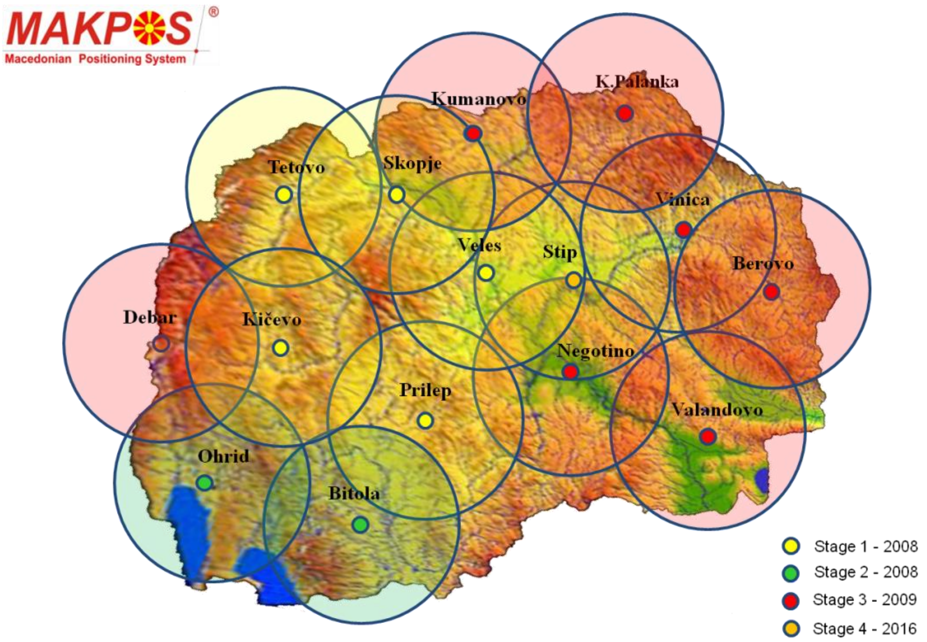

Figure 1. Distribution of the MAKPOS permanent stations

4. MAKPOS TECHNICAL CHARACTERISTICS

The MAKPOS permanent stations are equipped with GNSS receivers and GNSS antennas from the manufacturer Leica, all of them with possibility to track the GPS and GLONASS signals.

The receivers are of the type: Leica GR10 (4), Leica GRX1200+ (9), Leica GRX 1200GG Pro (1) and Leica GX 1230 (1), accompanied with antennas: Leica AR25 3D (13), Leica AT504 GG chock ring (1) and Leica AT 502 (1).

Figure 2. MAKPOS reference stations

For control and management of the MAKPOS system, data processing from the permanent GNSS stations, creating network products, data distribution to the users and user management, the Leica GNSS Spider software is used (Spider NET, Spider Web and Spider QC).

The data transfer from the permanent GNSS stations to the control center in AREC is done through hired VPN and ADSL lines. The products created by the Leica GNSS Spider software, are distributed to the end users via GPRS or Internet, through the WEB server or the RTK proxy server.

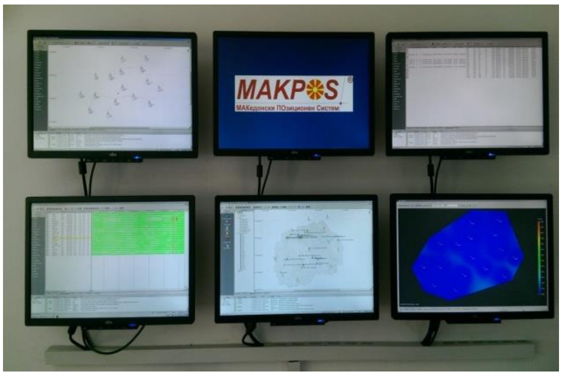

Figure 3. MAKPOS control centre

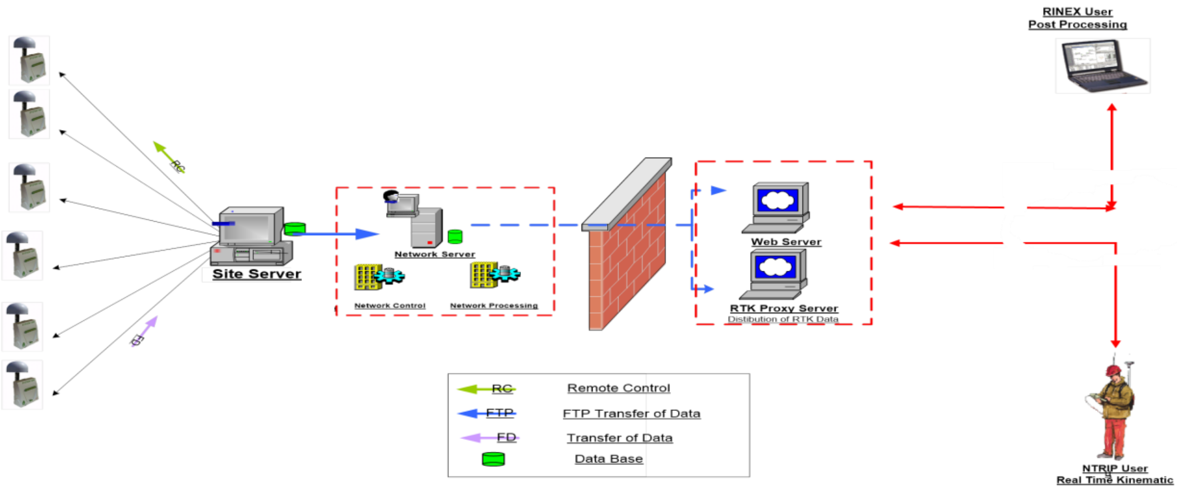

Figure 4. MAKPOS architecture

5. MAKPOS SERVICES

Before the start of the official use of the MAKPOS system, AREC tested its functionality, accuracy and reliability on the entire territory of the country. The test results confirmed that the accuracy of geo-positioning provided by MAKPOS is in compliance with the standards for such a type of systems.

Based on the user needs, the MAKPOS services are divided in three groups:

- **MAKPOS DGNSS** - positioning with applying a differential methods;
- **MAKPOS RTK** - positioning with applying real time kinematics;
- **MAKPOS PP** - positioning with applying static methods.

The availability of the MAKPOS services are 24 hours a day, 7 days a week, 365 days a year.

Table 1. MAKPOS services

No.	Description	Service	3D Accuracy	Data format	Data transfer
1.	Positioning through applying differential methods (DGNS)	MAKPOS DGNSS	0.30 – 0.50 m	RTCM 2.x	Wireless Internet (GPRS) NTRIP protocol
2.	Positioning through applying real time kinematic (RTK) methods	MAKPOS RTK	0.02 – 0.04 m	RTCM 2.x and RTCM 3.x	Wireless Internet (GPRS) NTRIP protocol
3.	Positioning through applying static methods (DGNS)	MAKPOS PP (RINEX)	≤ 0.01 m	RINEX	Internet (FTP, e-mail)

6. MAKPOS USERS

The MAKPOS services are available only to registered users. The registration of the users is free of charge, by submitting an application to AREC and signing a contract. The registered users receive a User Name and a Password for accessing the service for which they have applied.

So far, the number of companies registered as MAKPOS users is 186 with 258 rovers.

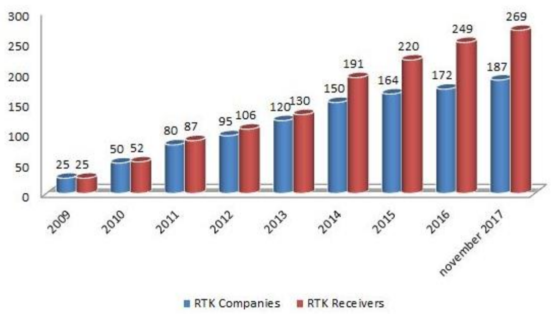

Figure 5. Number of MAKPOS RTK users

The MAKPOS system has its own web site (http://makpos.katastar.gov.mk) through which the users can register, see the status of the system and each individual permanent station in real time and download data for additional processing.

7. MAKPOS PRICES

From the beginning of 2012, the MAKPOS system was launch in commercial use. Since this launch, all MAKPOS users need to pay for use of the MAKPOS services. The fees list was drafted on the bases of cost recovery, which means that the fees are covering only the operational costs.

Table 2. MAKPOS prices

No.	Service	Unit	Price
1.	MAKPOS DGNSS	per year	399 €
2.	MAKPOS RTK	per minute 1 month 3 months 6 months 1 year	0.24 € 114 € 309 € 569 € 980 €
3.	MAKPOS PP (RINEX)	per minute	0.16 €

* The prices for MAKPOS RTK and MAKPOS DGNSS services refer to one receiver.

8. CALCULATION OF THE MAKPOS COORDINATES

Since 2010, MAKPOS permanent GNSS stations are part of the realization of the ETRS89 coordinate system for the territory of the Republic of Macedonia (EUREF MAK 2010 GNSS campaign).

The coordinates of MAKPOS permanent GNSS stations are determined using Bernese 5.0 software based on the 35 daily survey data. In the process of calculation of data the final IGS orbits and pole movements were used. Data processing was performed in the ITRF2005 referential framework, epoch 2010.631, and after that the coordinates were transformed into the ETRF00 (R05). The calculations are done in cooperation with Lantmateriet, Sweden.

The coordinates of MAKPOS permanent stations at the moment are setup in the ETRS89 coordinate system, epoch 1989.0.

9. MAKPOS BENEFITS

The MAKPOS system is used by wide range of users, especially from the field of: geodesy, civil engineering, infrastructure, transportation, mining, agriculture, ecology, crisis management, for creation of GIS systems, scientific researches related to the determination and monitoring of the Earth dimension and shape etc.

There are many expected benefits from the establishment of the MAKPOS system, but as most important for the country and the users are:

- It enables a fast and reliable way of obtaining geospatial data on any position on the territory of the R. of Macedonia;
- It enables an efficient project implementation in the filed of land management, spatial planning and protection of the environment;
- It provides the prerequisites for a more efficient and cost effective work of the private geodetic companies;
- It is a unique and homogenous geodetic network covering the entire territory of the Republic of Macedonia;
- It provides the prerequisites for introducing the European coordinate system ETRS 89, in accordance with the EU recommendations.

10. INTERNATIONAL COOPERATION

Since 2002, Republic of Macedonia is a member of the EUPOS initiative that has the objective of establishing a networks of permanent GNSS stations in the countries of the region from Central and South-Eastern Europe following unique standards. During the establishment of the MAKPOS system, the technical standards were taken into account, as well as other recommendations provided by EUPOS.

Figure 6. EUPOS member countries

At regional level, AREC has signed Data sharing agreements with the Republic geodetic authority of Serbia for sharing GNSS data between MAKPOS and AGROS systems and with the Immovable property registration office of Albania for sharing GNSS data between MAKPOS and ALBPOS systems. In near future AREC plans to connect the MAKPOS network with the other neighboring GNSS networks.

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IMPROVING THE ACCURACY OF A GLOBAL GRID CORRECTION MODEL FOR SPECIFIC AREAS OF INTEREST WHERE EXISTING NETWORK IS MORE ACCURATE THAN THE GRID MODEL

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This study gives a review of the possibility for using modern surveying measuring techniques and also the ways of solving the practical problems which arise from their use.

Due to different reasons, and foremost because of the technical possibilities of the surveying equipment that was used in the past, and because of the different measuring and computation techniques, for many years a lot of errors were present and therefore the state networks are only seemingly homogenous.

By using modern surveying methods all of these errors can be easily recognized, but the problem how to neutralize these errors and find a procedure which will guarantee the usage of the modern measuring equipment with acceptable accuracy is still remaining.

As it is known GNSS systems are relatively new technology and their goal is to provide unique positioning of all objects on the planet in single global coordinate system - WGS'84. [1]

One of the adopted methods for transformation of "Global" measurements in the State coordinate system that provides uniform accuracy all over the territory on a state level is a single classical 3D transformation with a 2D grid model for positional corrections. [2]

The model is widely adopted and provides sufficient accuracy for cadastral works in the areas where the so called "old" trigonometric networks have relatively big residuals.

As the time progressed in the newer history a new type of trigonometric networks were developed especially in the urban areas. These so called city trigonometric networks have higher accuracy than the output accuracy of the global grid model which leads to output results with lower quality than the ones that can be achieved. [3]

By applying the method described in this paper the end results allows smooth transition between the areas with different accuracies and the end results are always closest to the expected.

Keywords: Geodesy, GNSS, Transformation Parameters, Trigonometric Network, Homogenization, Accuracy, Grid Shifts.

1. INTRODUCTION

The Agency for Real-estate Cadaster (AREC) has adopted the above explained model and based on measurements on 3088 commonly known points in both coordinate systems has produced a global transformation and a grid model for the whole territory of R.Macedonia.

This was done in 2012 by a Swedesurvey AB founded project where the bid winner was the faculty for geodesy from Belgrade, author Dragan Blagojevic, PhD.

The goal was to determine the simplest way to transform GNSS data in the "local" coordinate system. For this purpose the following pre-conditions are established: The transformation model should be: simple, single for the whole territory, bidirectional, to absorb the deformations, to be applied on the horizontal component of the coordinates and to provide adequate accuracy. [2]

The output accuracy of the global 3D transformation for the position component of the coordinates is $\sigma_p = \pm 0.45m$.

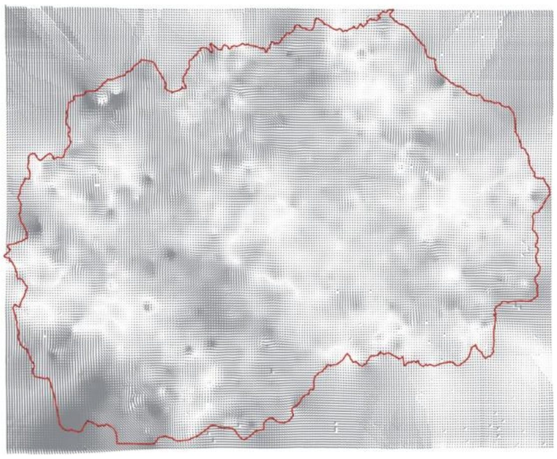

Figure 1. Global Grid Model for R. Macedonia

The adopted global grid model shown on Figure 1 has the following definition:

SW point (E,N min.) = 455000 m, 4523000 m

NE point (E,N max.) = 670000 m, 4694000 m

Grid resolution = 1000 m x 1000 m

Total number of nodes = 37152.

The global grid model covers the whole territory of R.Macedonia and during it's calculation it is adopted that there will be no extrapolation of correction values out of the country borders. This was done by applying a value of 99.99 for the nodal points out of the border which the interpolation software recognizes as a blank node.

The following accuracies are achieved:

Position accuracy in nodal point $= \pm 0.054m$ while maximum position deviation in random interpolated point $= \pm 0.1m$.

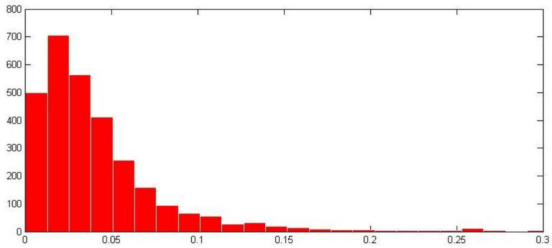

Figure 2. Histogram for interpolated position deviations

Similar results are achieved in a separate research done in the author's PhD thesis from 2013. [4]

Based on their analyses it is determined that there is a possibility for improving and upgrading the existing transformation model with a new one that will provide even more accurate results while keeping the simplicity of using the already established one

1.1 EXPERIMENT

As a final testing procedure before the official publishing of the usage of the new transformation method additional 288 points were measured. These points were for testing purposes and they were not included in the process for creating the global grid model.

This experiment elaborates one practical problem which is present in the areas where a "mix" of data with different accuracy levels exists. In our case this is a mix of points from old trigonometric network points and points from the relatively newer city trigonometric networks that are established higher accuracy than the old ones and also higher accuracy than the grid model itself.

It has been concluded that by applying the transformation model shown on Figure 3. the output results are with lower quality than the ones that can be achieved only by using classical 3D transformation.

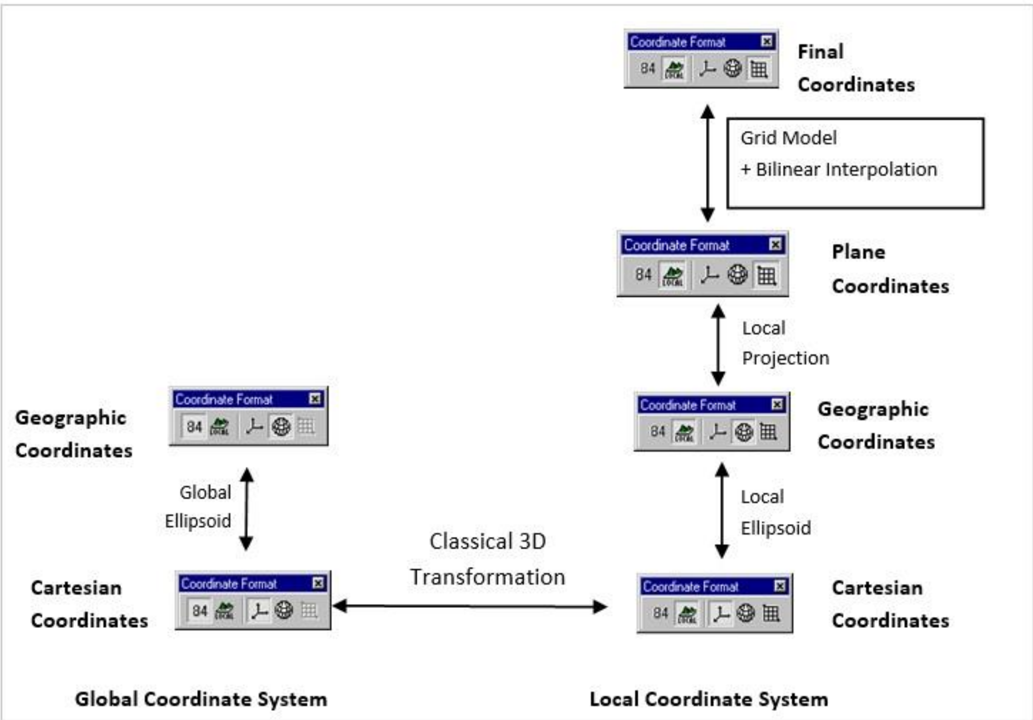

Figure 3. Transformation algorithm

For practical reasons in this paper we will analyze only one city area around city of Makedonski Brod.

1.2 ANALYSES

Table 1. Shows the residuals between the measured/transformed coordinates and the real ones for the Makedonski Brod city area.

Table 1. Residuals for coordinates of Makedonski Brod control points transformed with grid model

Pt.ID	dE [m]	dN [m]	dP [m]
MAB30	-0.27	0.05	0.27
MAB31	-0.23	0.04	0.23
MAB32	-0.21	0.03	0.22
MAB33	-0.22	0.02	0.22
MAB54	-0.27	-0.07	0.28
MAB74	-0.23	0.01	0.23
MAB75	-0.26	-0.02	0.26
MAB77	-0.30	-0.07	0.30

These results compared with the results achieved only by using classical 3D transformation for the same area shown in Table 2, clearly indicate that by applying the grid corrections output accuracy deteriorates and it is 2-3 times lower than the one that can/should be achieved in practice.

Table 2. Residuals for coordinates of Makedonski Brod control points transformed with classical 3D transformation for the area only

Pt.ID	dE [m]	dN [m]	dP [m]
MAB30	-0.07	0.09	0.11
MAB31	-0.04	0.07	0.08
MAB32	-0.04	0.06	0.07
MAB33	-0.06	0.05	0.08
MAB54	-0.10	0.03	0.11
MAB74	-0.04	0.06	0.08
MAB75	-0.08	0.04	0.09
MAB77	-0.09	0.03	0.09

1.3 PROPOSED SOLUTION

In order to produce the sub-grid we first need to analyse the residuals for the points used in creating the initial 3D transformation and the global grid model.

Figure 4. Gives the graphical representation of the residual position vectors. In red colour the position residual vectors from the city trigonometric network are shown and in white positional residual vectors from the old trigonometric network points. Their values are numerically given in Table 3.

Table 3. Position residual vector values

Pt.ID	dE [m]	dN [m]	dP [m]
MB1002	0.61	0.39	0.73
MB1003	0.70	0.61	0.93
MB1004	0.79	0.36	0.87
MB1005	0.96	0.51	1.09
MB1006	0.86	0.68	1.10
MBPOL8	0.78	0.49	0.92

The red polygon on Figure 4 shows the area of interest where results with higher quality are expected.

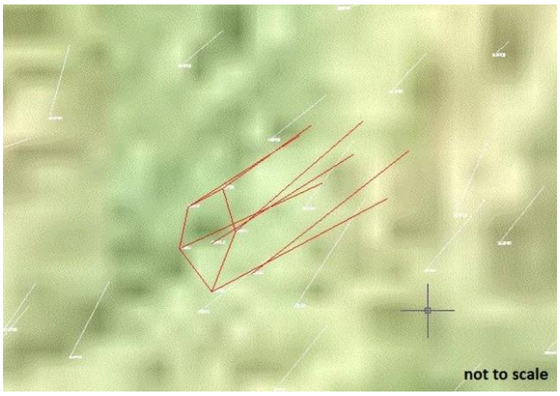

Figure 4. Position residual vectors

The proposed solution addresses two important matters. First one is that the sub grid should apply corrections only inside the area of interest (the red polygon on Figure 4) and the second one is that the extrapolated values outside the polygon must be substituted with the real values from the global grid model. In this manner the results outside the area of interest will be transformed with the correct grid shift.

For this purpose a special software solution was developed that automatically calculates the grid shifts inside the polygon and automatically replaces the extrapolated values outside of the polygon with the real ones form the global grid model.

The output result is graphically shown on Figure 5. Positional residual vectors in grey color are the ones from the global grid model, and the red ones represent the newly created sub grid.

As it can be seen the newly created sub-grid is with bigger resolution than the global one. This allows for better interpolation of grid shifts.

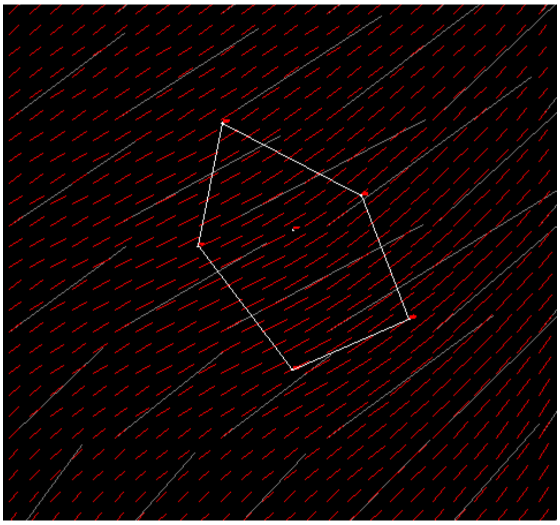

Figure 5. Global and sub-grid

This method allows also the possibility to exclude the points from the classical 3D transformation and the creation of the global grid model hence improving their accuracy and quality.

The results of the transformation after applying the proposed new transformation model are given in Table 4.

Table 4. Residuals for coordinates of Makedonski Brod trigonometric network transformed with sub grid model

Pt.ID	dE [m]	dN [m]	dP [m]
MAB30	-0.04	0.03	0.05
MAB31	-0.01	0.02	0.02
MAB32	-0.01	0.01	0.01
MAB33	-0.02	0.00	0.02
MAB54	-0.08	-0.02	0.08
MAB74	-0.01	0.01	0.01
MAB75	-0.04	-0.01	0.04
MAB77	-0.04	0.03	0.05

The results show that the residuals are now in the limits of the accuracy level of the initial 3D transformation for the area only and are more accurate than the results achieved if the global grid model is applied.

2. CONCLUSION

Output results show that if we want to use modern surveying equipment in this areas based on GNSS instruments and we want results compatible e.g. with existing cadastral plans or data produced with measurements form the existing control points regardless of the achieved accuracy in WGS84 we are forced to disrupt the measurement accuracy. Second problem is that during work on the field it is hard to know exactly in which transformation area we are in and apply the correct transformation set. Therefore we need a solution which will solve these two problems: (produce coordinates with the adequate accuracy and give one transformation set for the whole area of interest).

The output results show that the proposal for using double grid or sub-grid method fulfils the given preconditions in total. If produced accurately this transformation method keeps the simplicity in its usage and improves the accuracy of the output results.

The method is not limited to one area since the produced software for interpolation of the grid corrections can easily manage more than one sub-grid which allows the end used to improve the position accuracy of the transformation in every area of interest where this is required.

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INVESTIGATION OF IONOSPHERIC VARIATIONS AND SUDDEN DISTURBANCES, AS A SOURCE OF GNSS ERRORS AND EARTHQUAKE PRECURSOR

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Ionosphere has significant impact on signals' propagation, which come from Global navigation satellite systems (GNSS). Consequently, it introduces the major part of errors in GNSS applications, such as positioning and navigation. One of the main parameters to describe state in ionosphere is Total Electron Content (TEC). Ionosphere is spatially and temporally highly variable. Sun is the primary source of its ionization. Activities on the Sun, such as solar flares, can cause abnormally high ionization in ionospheric D layer, known as sudden ionospheric disturbances. Geomagnetic storms can additionally disturbed conditions in ionosphere. Some studies, during last decades, showed that variations in ionosphere can also be seen in weeks before and after the earthquake´s occurrence, proposing the model of lithosphere-atmosphere-ionosphere (LAI) coupling. This paper briefly represents results of ionospheric investigation in Bosnia and Herzegovina (BiH). It was conducted using GNSS dual-frequency measurements for estimation of TEC values. Observations of SuperSID monitor were applied for detecting sudden ionospheric disturbances (SID). Some results of lithosphere-ionosphere investigation in 2015 were briefly mentioned as well. Study of TEC variations covered period from 2014 (year of solar maximum) to 2016. We discussed temporal ionospheric TEC variations, sudden ionospheric disturbances and their origin. Results show seasonal variability and solar cycle dependence of TEC values, as expected. Moderate to strong correlation between TEC variations and solar activities was observed. SuperSID monitor successfully detected sudden ionization in ionospheric D layer, due to solar flares from C 1.4 class to X 2.1 class. Geomagnetic disturbances produced the most of ionospheric anomalies observed prior and after moderate seismic activity.

Keywords: GNSS, Ionosphere, Total electron content (TEC), Sudden ionospheric disturbances, Solar activity, Litosphere-atmosphere-ionosphere coupling (LAI).

1. INTRODUCTION

The major errors in GNSS positioning and navigation are introduced by the upper part of atmosphere - ionosphere. This region contains free electrons in amount sufficient to influence propagation of radio signals [1], which consequently cause signal's delay or advance. Amount of free electrons along the GNSS signal's path in ionosphere, on this way from satellite to receiver on the Earth, can be presented by total electron contents (TEC).

High solar activity and space weather can produce significant variations in space environment between Sun and Earth, known as phenomena space weather. Consequently, it can severely disturb Earth's magnetic field (causing geomagnetic storms) and the state of ionosphere as well. The level of solar activity is usually presented by solar indices such as the sunspot Number (SSN) [2] and the solar radio flux at 10.7 cm (F10.7) [3].

Researches during the last decades [4-7] have reported a correlation between the state of the ionosphere and seismic activity of the lithosphere several days before devastating earthquakes. A model that combines different types of precursor is called the LAIC (Litosphere-Atmosphere-Ionosphere Coupling) model. This model combines changes from the Earth's interior to the magnetosphere [8]. The basic components of this model are: the earthquake preparation zone (EPZ), the radon emissions from the Earth and the air ionization caused by the anomalous electric field.

The concept is based on the assumption that changes in the ionosphere, associated with seismic activity, can be observed over the earthquake preparation zone, defined by the formula 1 [9]:

$$\rho = 10^{0.43M}\,km \qquad (1)$$

Where ρ is the radius of earthquake preparation zone in km (kilometers) and M is the earthquake magnitude on the Richter scale.

The LAIC model assumes that radon ionization from Earth increases in earthquake preparation zone, measured experimentally before earthquakes [10] and used as short-term precursor [11]. The ionization effects have electromagnetic and thermodynamic activity. Electromagnetic activity is reflected in creation of an anomalous electric field in the lower layers of the atmosphere, its penetration into the ionosphere and the formation of irregularities in the electrons' concentrations. Thermodynamic activity is reflected in changes in air temperature and relative humidity, through the process of condensation of water vapor, which may also lead to the modification of the ionosphere [8].

Previous research of ionosphere in Bosnia and Herzegovina (BiH) included study of GNSS-derived TEC variations at middle latitude [12-13], investigation of lithosphere-ionosphere coupling process before and after moderate seismic activity in BiH in 2015 [13-15], including few cases of stronger earthquakes in the world [16] and also in relation to severe space weather events [15]. Other studies of ionospheric state in BiH were carried out by investigation of sudden ionospheric disturbances (SID) by very low frequency (VLF) measurements as they bounce off the ionosphere [17-18].

The aim of this paper was to investigate regular and sudden variations in midlatitude ionosphere over Bosnia and Herzegovina, together with their sources. Variations were analyzed regarding solar activities, geomagnetic conditions and lithosphere-atmosphere-ionosphere coupling process. Investigation was carried out by studying GNSS-derived TEC, estimated from GNSS measurements of European Permanent Network (EPN) station SRJV (Sarajevo) at middle latitude (+43º52'04''). It covered the period from 2014 (period of intensive Sun's activity i.e. solar maximum) to 2016 (period of lower Sun's activity, i.e. decline phase of solar cycle 24). Monthly VTEC values were presented and discussed regarding their monthly, seasonal and solar cycle variations. They were compared to solar and their correlations were estimated. Next part of our study was conducted to detect sudden ionospheric disturbances in ionosphere, using observations from SuperSID monitor in Sarajevo and x-ray data flux data from Geostationary Operational Environmental Satellites (GEOS) from March to April 2015. In last part we presented some results from lithosphere-ionosphere coupling investigation before medium earthquakes (M > 4 Richters), in BiH, in April 2015 [14]. The aim of that study was to analyze total electron contents variations before and after seismic shock and determine whether they were caused by geomagnetic or solar activity, or were the consequence of earthquake.

2. MATERIALS AND METHODS

2.1 ESTIMATION OF TEC FROM GNSS – PRINCIPLES

TEC obtained from dual-frequency measurements is actually slant TEC (STEC), Value of STEC represents the total number of free electrons in the cylinder along the path of the electromagnetic wave from the satellite to the receiver. STEC value for a GNSS signal can be obtained from formula 2:

$$STEC = \int_{receiver}^{satellite} N ds \qquad (2)$$

TEC obtained from dual-frequency measurements is actually slant TEC (STEC), Value of STEC represents the total number of free electrons in the cylinder along the path of the electromagnetic wave from the satellite to the receiver. STEC value for a GNSS signal can be obtained from formula 2:

Where *N* represents the density of electrons along the line of sight *ds.*

The value of TEC depends on the frequency, so it can be estimated using two frequencies between receiver and satellite communication (formula 3), from [19]:

$$STEC = \frac{f_{l1}^2 \cdot f_{l2}^2}{40.3 \cdot (f_{l1}^2 - f_{l2}^2)} \cdot (\rho_{l2} - \rho_{l1}) + TEC_{CAL} \qquad (3)$$

Where f_1 is frequency on L1, f_2 is frequency on L2, ρ_1 is pseudo range on L1, ρ_2 is pseudo range on L2 and TEC_{CAL} is the bias error correction (receiver differential delay).

For full TEC modeling, using terrestrial GNSS data is necessary to use vertical TEC (VTEC). Thus it is needed to introduce a mapping function, which depends on elevation and describes the relationship between STEC and VTEC (formula 4):

$$F(z) = \frac{STEC}{VTEC} \qquad (4)$$

VTEC was estimated from dual-frequency measurements using approximations of single layer ionosphere model (SLM) [20], at height of 400 km. VTECs were calibrated by Ciraolo methodology [21], using program VShell GNSS 2017. Carrier phase GNSS measurements of GPS and GLONASS satellite systems were applied.

Correlation coefficient R between VTEC and solar indices (F10,7 and SN) were calculated by equation (formula 5):

$$R = \frac{\sum_{i=1}^{n} (x_i - \bar{x}) \cdot (y_i - \bar{y})}{\sqrt{\sum_{i=1}^{n} (x_i - \bar{x})^2 \cdot \sum_{1=1}^{n} (y_i - \bar{y})^2}} \qquad (5)$$

Where x_i is VTEC value for specific day and y_i is solar index value (F10.7 or SN) for specific day. $\bar{x}$ and y represent average values for the entire study period (2014 - 2016) for VTEC and solar index, respectively.

2.2 OBSERVATION OF SUDDEN IONOSPHERIC DISTURBANCES (SID)

SuperSID monitor uses VLF (very low frequency) signals emitted from remote transmitters. Signal strength of VLF waves change as the Sun affects Earth's ionosphere and adds ionization. Such monitor is set up and currently active at the Faculty of Civil Engineering, Department for Geodesy (University in Sarajevo). Since July 2014, the monitor is officially registered in the database of University in Stanford under the name SRJV_ION 0436 [17-18]. It collects data from chosen VLF transmitters: DHO (Rhauderfehn, Germany), GBZ (Anthorn, UK) and NSC (Niscemi, Italy).

Data were registered every 5 seconds and for every new day at 00:00h in UTC time, in the SuperSID folder on the local computer daily excel files, which contains measured signal strength for each VLF transmitter separately. After collecting data of SuperSID monitor for period March-April 2014, the stored files were plotted in order to analyze the signal signatures. It is important to note that only the day time hours of the graphs can be analyzed since during the night time only cosmic radiation is affecting the Earth.

Larger spikes in graph could be caused by solar flare. Solar flares can be classified into 4 classes, from the weakest to the strongest: B, C, M and X, respectively. On the other hand, noise (interference from sources other than Sun) can appear in the data and look like a flare. Thus detected solar flare events were compared to data from GOES satellites, in order to determine if the peak came from solar flare or interference. Information about solar events was obtained from the catalogues.

2.3 DATA ACQUISITION

GNSS data from European Permanent Network were downloaded from: ftp://igs.bkg.bund.de/EUREF/.
GOES graphs and catalogues of solar events where found under the link: ftp://ftp.swpc.noaa.gov/pub/warehouse/.
Solar index F10.7cm solar radio flux was obtained from Canada, Department of Natural Resources. Space Weather Prediction Center: ftp://ftp.geolab.nrcan.gc.ca/data/solar_flux/daily_flux_values/fluxtable.txt.
Data of Sunspot numbers have been collected from Solar Influences Data Analysis Center (SILSO), of Royal Observatory of Belgium at: http://sidc.oma.be/silso/datafiles/.

3. ANALYSIS AND RESULTS

3.1 VTEC VARIATIONS

Variability of monthly VTEC values for the period 2014-2016 is shown on Fig. 1. The biggest VTEC values were observed in 2014, followed by VTEC decline, from 2015 to 2016.

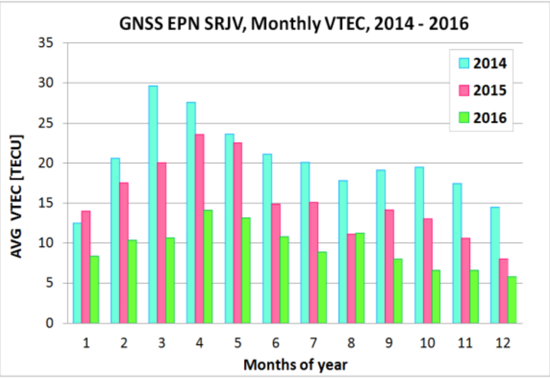


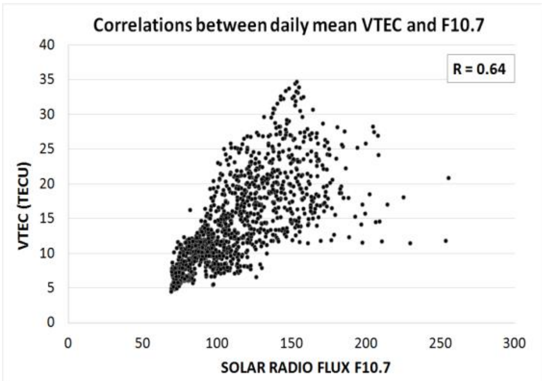
Figure 1: Variations of monthly VTEC at EPN station SRJV from 2014 to 2017, demonstrate seasonal and solar cycle variations. Highest TEC observed in the year of solar maximum (2014) and during spring equinoxes.

During one year the highest monthly values were usually during spring months (March-May). Afterwards, TEC gradually declined until the next peak, noticed in autumn months in 2014 and 2015 (September-October), while in 2016 it was in August. However, TEC values in autumn equinox were lower, than those observed in spring. The lowest TECs were recorded during winter (November-January).

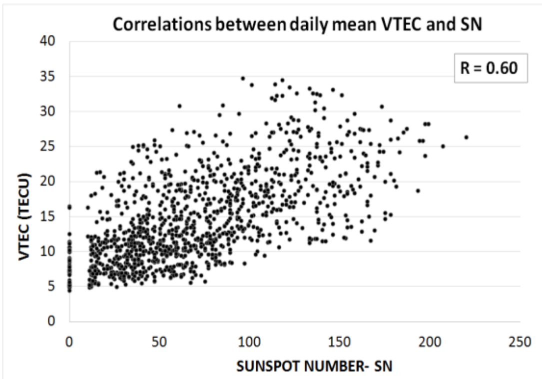
Concerning the entire period, the highest VTEC values and variations were seen in 2014, especially during months of spring equinoxes (March-April). It is period when Sun has reached its maximum activity level (in April 2014). With moving away from solar maximum, TEC variations become smaller and less expressive (especially in 2016). These results indicate seasonal TEC variability and solar cycle dependence

3.2 VTEC AND SOLAR ACTIVITY CORRELATION

Relationship between solar activity and VTEC variations was analyzed. Correlation coefficients between VTEC and solar indices: solar radio flux F10.7 and sunspot number (SN) were calculated for period 2014-2016 (fig. 2). Correlations between VTEC and solar indices from 2014 to 2016 can be described as moderate to strong positive relationship, with coefficient of 0.60 (VTEC and SN) and 0.64 (VTEC and F10.7). Correlation was slightly better between VTEC and solar flux F10.7.



a)



b)

Figure 2: Correlation between daily mean VTEC values and daily mean solar indices: a) solar radio flux F10.7, b) sunspot number (SN).

3.3 SID DETECTION

Figure 3 shows comparison between graph from SuperSID monitor for 11 March 2015 and x-ray flux data from GEOS. Axis on the right hand side of the GOES graph is referring to the strength of a solar flare. Both graphs show similar signal signatures, so we can be sure that our monitor detected solar events. By analyzing DHO data, 4 visible spikes were observed, at around 7 AM, 8 AM, 11:30 AM and 4 PM (UT time). The first solar flare (M1.8) began at 7:10 and ended at 7:43, followed by the M2.6 flare which began at 7:51 and ended at 8:03. The third flare that we detected happened between 11:21 and 12:01 which was a C5.8 flare. Finally, an X-flare, X2.1 happened at 16:21 and was active until 16:29. The source of all flares was the sunspot region 2297, which is responsible for the coronal mass ejection that caused the strongest geomagnetic storm of Solar Cycle 24 (known as St. Patrick's Day geomagnetic storm) on 17.03.2015.

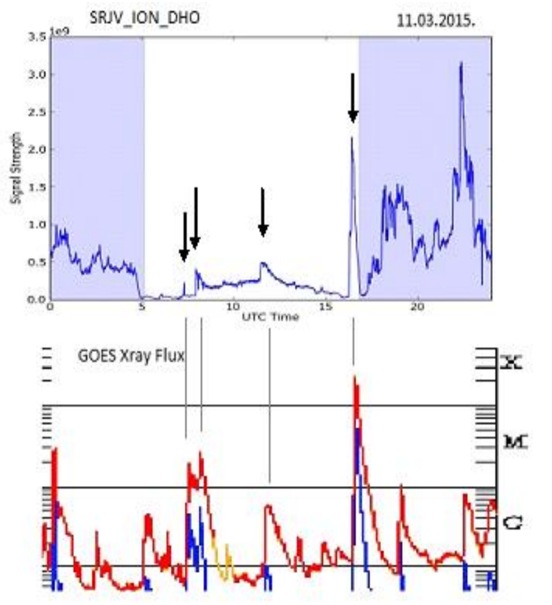


Figure 3: Direct comparison between the upper graph from SuperSID monitor with the lower graph representing x-ray data flux from GEOS. 4 spikes were detected originated from solar flare.

Information of solar event, such as exact time of occurrence, solar flare strength (Frq) and sunspot region (Reg#) that caused a particular solar event, was collected from catalogue of solar events (Tab. 1), for period March-April 2015. During March, stronger disturbances in the ionosphere were visible in the SuperSID graphs until the 16.03.2015. Afterwards, no significant spikes appeared in the graphs, nor a higher solar flare class happened in that time. Solar flares were B and C classes, which usually occur almost every day and have not indicated that solar radiation affected the ionosphere. April, opposite to March, showed in general less solar events, and also a less disturbed ionosphere. During the analyzed period in April, there were just two solar flares of class M detected, on 12.04.2015.

Table 1: List of events, detected by SuperSID monitor SRJV_ION 0436 in 2015. The first half of March showed significant ionospheric disturbances. On the other hand, April was more quiet, but still under influence of solar radiation.

Date	Begin	Max	End	Loc/ Frq	Reg#
11.3.	0710	0718	0743	M1.8	2297
11.3.	0751	0757	0803	M2.6	2297
11.3.	1121	1134	1201	C5.8	2297
11.3.	1611	1622	1629	X2.1	2297
12.3.	1350	1408	1413	M4.2	2297
13.3.	0549	0607	0612	M1.8	2297
13.3.	1107	1123	1147	C1.9	2297
15.3.	0936	0940	0946	M1.0	2297
15.3.	1131	1203	1220	C6.8	2297
16.3.	1039	1058	1117	M1.6	2297
8.4.	1437	1443	1447	M1.4	2320
9.4.	1713	1729	1738	C5.9	2320
10.4.	0757	0803	806	C7.9	2320
10.4.	0933	0952	1000	C2.8	2320
12.4.	0811	0816	0827	C2.9	2321
12.4.	0851	0950	1044	M1.1	2321
13.4.	0821	0826	0828	C4.7	2322
13.4.	1314	1318	1321	C1.4	2320
16.4.	0900	0907	0914	C5.7	2324
16.4.	1117	1122	1130	C2.3	2321
16.4.	1616	1625	1637	C1.8	2321
18.4.	1403	1419	1439	C5.2	2321

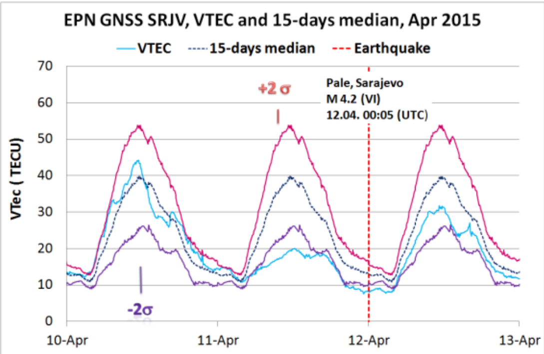
3.4 LITOSPHERE-IONOSPHERE COUPLING

In April 2015, earthquake of magnitude greater than 4 Richter occurred near Sarajevo, followed by the earthquake of magnitude of 3 Richter, five days after. Epicenter of the both earthquakes was in Pale (12 April M=4.2 Richter, 16 April M=3.4 Richter), about 14 km far from Sarajevo [14].

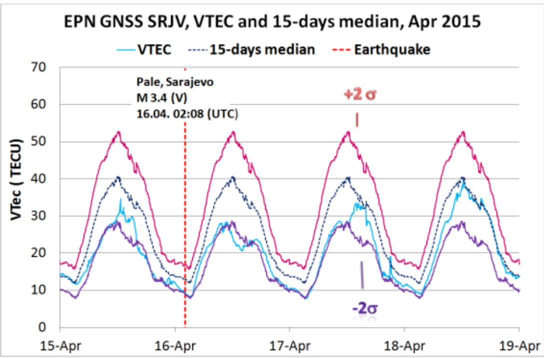
GNSS observation data of EPN station SRJV (station inside earthquake preparation zone - EPZ) were used for TEC values estimation. In addition, data of EPN station ZADA in Zadar

(Croatia, +44^{0}06' 47.42" N, 15^0 13' 39.31" E) were introduced in statistical analysis, as the station outside EPZ [14]. Differences of observed VTEC from monthly median for station SJRV showed significant VTEC decreases shortly prior and after earthquakes' occurance [14].

VTEC variations were analyzed with 15-day median (which preceded the day of consideration) ± 2 * σ (standard deviations), in order to detect anomalies and determine if they were caused by seismic activity or space weather effect. Few significant anomalies in TEC variation were recorded, on 11-12 April and 15-17 April, when they reached lower bound or exceeded it (fig. 4).



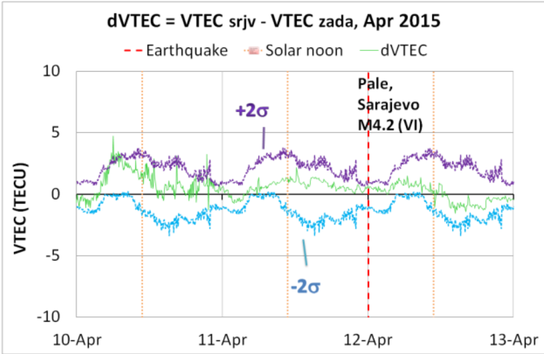
a)



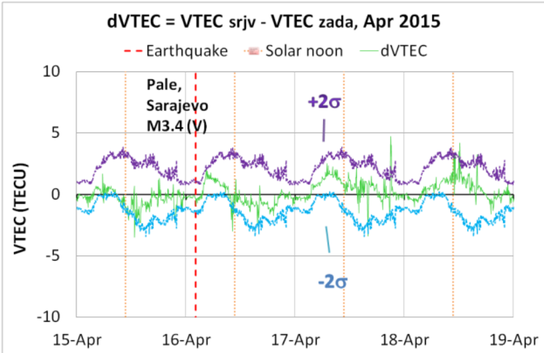
b)

Figure 4: Statistical analysis of VTEC variations at station SRJV, with 15-day median ± 2*σ. a) 10-12 Apr. b) 15-18 Apr. VTEC anomalies reached lower bound or exceeded it [14].

Comparison with data of station ZADA (Fig. 5) showed that the most of VTEC anomalies were also detected in VTEC signature of ZADA station. That implies that the most of anomalies were not produced from seismic activity, but probably from geomagnetic conditions, which was very active during that period, according to Kp and Ap geomagnetic indices [14].



a)



b)

Figure 5: VTEC difference between data of SRJV station (inside EPZ) and ZADA stations (otside (EPZ). a) 10-12 Apr b) 15-18 Apr. Similar variations at the both stations and most of the anomalies detected at the both stations [14].

4. CONCLUSION

Paper briefly showed investigation of the upper part of ionized atmosphere (ionosphere), that is responsible for the biggest errors in applications, which depend on Global Navigation Satellite Systems. Study was conducted for area of Bosnia and Herzegovina and wider region. State of ionosphere was presented with total electron contents along the satellite signal´s path in ionosphere, that comes from satellite (20 200 km above Earth) to receiver (located on the Earth´s surface).

Monthly TEC variability, solar cycle TEC dependence and seasonal TEC variation in mid-latitude ionosphere were studied for the period from 2014 to 2016. Increasing trend of VTEC as well as higher VTEC variations were observed during the months of equinoxes, while the decreasing trend of VTEC and lower variations were mostly seen during solstices. The most expressive TEC values and standard deviations occurred for the period of spring equinox, while the winter solstice caused the lowest. This implies strong influence of the period of a year on ionization in ionosphere. Variations of TEC followed the solar cycle's phases from solar maximum to descending phase of solar cycle 24. The highest values of TEC as well as the greatest standard deviations were recorded in the year of solar maximum (2014). Afterwards values and deviations decreased gradually through 2015, while significant decline was observed in 2016. To sum up, level of solar activity directly influenced the state in ionosphere over Bosnia and Herzegovina, as expected.

Correlation between VTEC values and solar indices solar radio flux F10.7 and sunspot number was medium to strong, during period 2014 to 2016. Correlation coefficients was slighlty better between VTEC and F10.7.

By monitoring the signal strength emitted by distant transmitters of very low frequency (VLF) waves, we detected sudden ionospheric disturbances during March – April 2015. SuperSID monitor successfully detected sudden ionization caused by solar flares, from C 1.4 class to X 2.1 class.

Study of lithosphere-ionosphere coupling process for few medium earthquakes in Bosnia and Herzegovina [14], showed that the most of the ionospheric anomalies, before and after seismic activity, were produced from geomagnetic disturbances.

In further work we are planning to investigate effects of severe solar events and space weather on the accuracy of coordinate estimation in Bosnia and Herzegovina.

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SPECIAL PURPOSE 2-D GEODETIC NETWORK FOR STRUCTURE "KULA VODNO"

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The paper presents the procedure for optimal design of the special purpose 2D network for the needs of the construction and control of the building of the structure "Kula Vodno". In the optimization procedure, the models of a priori accuracy assessment, were used, which are based on the Gauss-Markov's model of indirect adjustment of the geodetic networks.

Key words: Local geodetic network, quality, accuracy, precision, reliability

1. INTRODUCTION

The geodetic works related to the construction of complex construction projects include several phases: providing a geodetic basis (basis for planning), transferring the object on the site (marking project), monitoring the building in the construction phase and in the phase of its exploitation, survey of the performed condition for the needs of the cadastre and so on. For the successful realization of the geodetic works in all phases it is necessary to develop geodetic network for special purpose.

The required position accuracy of the special purpose network arises from the construction standards in relation to the verticality of the structure contained in the main project. The allowed deviation of the axis of the object from the vertical position is the starting parameter for determining the necessary accuracy of the marking, that is, the accuracy of the geodetic network.

The modern approach to projecting geodetic networks, in addition to accuracy, also takes into account their reliability. The accuracy and reliability of the geodetic networks gives a complete picture of their quality. Information on the accuracy of the geodetic network is contained in the covariance matrix of the unknown parameters, while the information on the reliability of the network is found in the cofactor matrix of the corrections of the measured values. The reliability of the geodetic networks indicates the ability of the model for detecting rough errors in the measured values as well as the influence of the possible undetected rough errors on the unknown parameters.

The accuracy and reliability of the geodetic networks can be internal and external accuracy, i.e. reliability, are divided into local and global. Local criteria refer to individual measurements, i.e. points from the network, while global criteria refer to the network as whole.

Figure 1. Kula Vodno (in construction)

2. PROJECT FOR SPECIAL PURPOSE 2D GEODETIC NETWORK

The project of any special purpose geodetic network is prepared on the basis of a project task. The design of the special purpose networks is conditioned by the type and characteristics of the object, the configuration of the terrain and the required accuracy.

The project defines the position of the points, the plan of measurements and its realization (reconnaissance, stabilization and signaling of points, field measurements and adjustment of the network). In addition, the project should provide optimality of the network in terms of geometry, accuracy and reliability. The above parameters are checked through the simulation model for adjustment of the network.

The following elements are taken as the basis for preparation of the project on the network for special purpose:

- The basic project for the construction of the structure;
- Required accuracy for marking and control of the structure;
- Organization of the construction site and the dynamics of the building;
- The available geodetic basis in the area of the construction site;
- The existing geodetic bases for the location of the construction site;
- On-site insights and getting familiar with the configuration of the terrain and micro-locations for setting the points of the network.

Recognizing the requirements of the investor, the criteria defined in the basic project, as well as the factors that limit the accuracy of the geodetic measurements, is made a general concept for the design of the special purpose network.

The general settings on which the geodetic network project is based are as follows:

- The network consists of an optimal number of points;
- The network should be included in the state coordinate system through the necessary (minimum) number of measurements;
- The object and points of the basic network should be in a single coordinate system;
- To ensure such a geometric shape of the network that will guarantee its determination with a predefined accuracy;
- To make an optimal measurement plan and to determine the required accuracy of the measured values;
- To define the allowed deviations for the selection of the results of the measurements that are below the required accuracy;
- With the mathematical processing of the results of the measurements, a proper analysis is carried out for verification of the achieved quality of the network;
- To perform a strict adjustment of the network;
- The projected network should satisfy the conditions of homogeneity and isotropy;

In addition to the general settings, the preparation of the project also takes into account the special factors that arise from the specifics of the structure itself.

- The geometric shape of the network should be such as to ensure satisfaction of all requirements set out in the basic design, i.e. markings of the falsework, control of the geometry of the performed works, control of the verticality of the object as well as monitoring of the deformations of the object in the construction phase and in the phase of exploitation;
- The quality of the network should correspond to the required accuracy of all geodetic activities in the construction stage and in the phase of exploitation of the object;
- Points from the network should be placed at an appropriate (optimal) distance from the structure to allow for the marking and monitoring of the building at all levels of the structure;
- The points of the network should be placed in places that will enable the performing of the measurements without obstacles and they will not be damaged or destroyed during the construction and exploitation of the building;
- From each point of the network to ensure the coverage of as many discrete points of the object as possible;
- Each discrete point of the object is covered by a minimum of two points from the basic network;
- The access to network points is easy and secure;

2.1 THE REQUIRED ACCURACY OF SPECIAL PURPOSE GEODETIC NETWORK

The starting element for the design of the special purpose geodetic networks is the so-called construction tolerance resulting from the geodetic tolerance and the building tolerance of the structure.

$$T^2 = T_G^2 + T_{IO}^2 \quad (1)$$

Where:

T – total (construction) tolerance

T_G – geodetic tolerance

T_{IO} – building tolerance of the structure

The project manager in the main project has not projected value for construction tolerance. In agreement with the contractor of the building, the construction tolerance was agreed to be 10mm.

According to the principle of equal influence of the overall tolerance, the geodetic tolerance is determined, in the expert public known as allowed deviation Δ,

$$\Delta = \frac{T}{\sqrt{2}} = 7.1\,mm \quad (2)$$

From the allowed deviation, for the probability of 95% (99%), a standard error of marking σ_{obl}, that is, a standard position accuracy σ_p of the points of the network is determined.

$$\sigma_{obl} = \frac{\Delta}{2(3)} = 3.6\ (2.4)mm \quad (3a)$$

$$\sigma_p = \frac{\sigma_{obl}}{2(3)} = 1.8\ (0.8)mm \quad (3b)$$

2.2 CHOOSING DATUM FOR THE SPECIAL PURPOSE GEODETIC NETWORK

The datum of the geodetic networks represents a minimum set of parameters that define the spatial position of the network. If these parameters are missing, it is a datum defect. The defect of the network depends on the type of measurements in the network.

According to the way of defining the elements of the datum, the networks can be free and non-free. On free networks, the elements of the datum are defined in arbitrary way, whereas in the non-free networks the elements of the datum are obtained by measurements.

The special purpose geodetic network for the structure "Kula Vodno" is adjusted as a free network with datum parameters defined with a minimum trace for all points on the network. This creates minimal estimates of standard deviations for unknown parameters. In this case, besides the requirement for a minimum norm for the vector of corrections, an additional requirement for a minimum norm for the vector of unknowns is introduced.

$$trag\boldsymbol{K}_{\hat{x}} = \sigma^2 trag\boldsymbol{Q}_{\hat{x}} = min \quad (4)$$

$$trag\boldsymbol{Q}_{\hat{x}} = min \iff \hat{\boldsymbol{x}}^T\hat{\boldsymbol{x}} = min \quad (5)$$

3. ANALYSIS OF THE QUALITY OF THE SPECIAL PURPOSE GEODETIC NETWORKS

The quality of geodetic networks is quantitatively expressed through the elements of accuracy, precision and reliability. Accuracy covers all kinds of errors, precision affects only random errors, while reliability affects only rough errors.

The quality of the geodetic networks is generally affected by the errors of the given values, the geometry of the network and the errors of the measured values.

The a priori analysis of the network is done in order to ensure the defined positional accuracy of the points. A well-designed geodetic network shall mean a network that meets the criteria for quality (accuracy and reliability).

The analysis consists of two parts:

- Choosing the optimal geometric shape of the network with the specified accuracy of the predicted measurements and
- Optimization of the measurement process (development of a measurement method) to ensure the projected accuracy of the measured values.

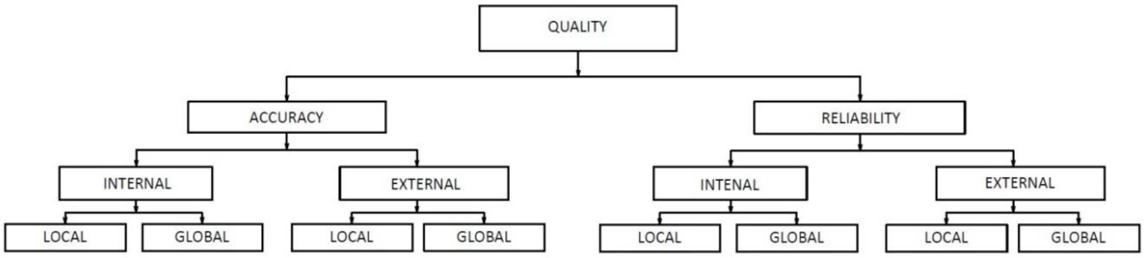

Figure 2. Block diagram - Quality of the geodetic networks

3.1 ACCURACY OF THE GEODETIC NETWORKS

The a priori analysis of the accuracy of the geodetic networks is most often done using the simulation method using the least squares method. To this end, it is necessary to have the approximate coordinates of the points of the network. They are determined by reading from the existing geodetic bases, or by directly measuring the field with a manual GPS.

From the approximate coordinates and the plan of measurements, the configuration matrix $\boldsymbol{A}$ of the network and the covariance matrix of the unknown parameters $\boldsymbol{K}_{\hat{x}}$ can be formed.

- For non-free networks

$$\boldsymbol{K}_{\hat{x}} = \boldsymbol{\sigma}_0^2 \boldsymbol{Q}_{\hat{x}} = \boldsymbol{\sigma}_0^2 \boldsymbol{N}^{-1} = \boldsymbol{\sigma}_0^2 \left(\boldsymbol{A}^T \boldsymbol{Q}_l^{-1} \boldsymbol{A}\right)^{-1} \quad (6)$$

- For free networks

$$\boldsymbol{K}_{\hat{x}} = \boldsymbol{\sigma}_0^2 \boldsymbol{Q}_{\hat{x}} = \boldsymbol{\sigma}_0^2 \boldsymbol{N}^{+} = \boldsymbol{\sigma}_0^2 \left(\boldsymbol{A}^T \boldsymbol{Q}_l^{-1} \boldsymbol{A}\right)^{+} \quad (7)$$

Where it is:

σ_0^2 – a priori standard deviation

$\boldsymbol{Q}_{\hat{x}}$ – cofactor matrix of unknown parameters

$\boldsymbol{N}$ – matrix of the coefficients of the normal equations

$\boldsymbol{N}^{+}$ - pseudo-inversion of the singular matrix $\boldsymbol{N}$

$\boldsymbol{A}$ – configuration matrix of the network

$\boldsymbol{Q}_l$ – cofactor matrix of measured values

Covariance matrix $\boldsymbol{K}_{\hat{x}}$ contains information about the accuracy of the network.

Parameters of accuracy in their character may be local and global. Local refer to each single point, while global parameters refer to the network as a whole.

The accuracy obtained with the previous analysis is compared with the accuracy defined in the project assignment. If there is a lack of fulfilling the defined accuracy with the project task, the design of the network, the plan of measurement and the accuracy of the measurement shall be improved. The procedure of the previous accuracy analysis is repeated until the requirements are fulfilled.

3.1.1 Local accuracy parameters

Local accuracy elements provide information about the accuracy of each point on the network. The cofactor matrix of the unknown can be divided into sub-matrices with dimensions 2x2. Each sub-matrix refers to a single point of the network.

$$\boldsymbol{Q}_{kk} = \begin{bmatrix} q_{xx}^k & q_{xy}^k \\ q_{yx}^k & q_{yy}^k \end{bmatrix} ; \ \boldsymbol{Q}_{kl} = \begin{bmatrix} q_{xx}^{kl} & q_{xy}^{kl} \\ q_{yx}^{kl} & q_{yy}^{kl} \end{bmatrix} \quad (8)$$

The local accuracy is expressed by the position error of the point:

$$\sigma_p = \sqrt{\hat{\sigma}_x^2 + \hat{\sigma}_y^2} = \hat{\sigma}_0 \sqrt{q_{xx} + q_{yy}} \quad (9)$$

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Elements σ_x and σ_y represent standard deviation of the point in the direction of the coordinate axes. From a practical point of view, it is more important to obtain information on the direction of extending the maximum and minimum position error. The problem is solved by searching for the own values of the cofactor matrix of the unknowns. The cofactor matrix values are determined from the characteristic equation:

$$det\begin{vmatrix} q_{xx}^k-\lambda & q_{xy}^k \\ q_{yx}^k & q_{yy}^k-\lambda \end{vmatrix}=0 \qquad (10)$$

Or in a developed form:

$$\lambda^2-\left(q_{xx}^k+q_{yy}^k\right)+q_{xx}^k q_{yy}^k-q_{xy}^k q_{yx}^k=0 \qquad (11)$$

By solving the characteristic equation, own values are obtained:

$$\lambda_1=\frac{q_{xx}^k+q_{yy}^k+z}{2} \; ; \; \lambda_2=\frac{q_{xx}^k+q_{yy}^k-z}{2}$$

Where, $z^2=\left(q_{xx}^k+q_{yy}^k\right)^2+4q_{xy}^k q_{yx}^k$ (12)

From the own values λ_1 and λ_2 the elements of the ellipse of errors are calculated, the big and the small semi-axis and the direction of the big semi-axis:

$$A=\hat{\sigma}_0\sqrt{\lambda_1} \; ; \; B=\hat{\sigma}_0\sqrt{\lambda_2}$$

$$tg2\theta=\frac{2q_{xy}^k}{q_{xx}^k-q_{yy}^k} \qquad (13)$$

As a criterion for position position accuracy, the minimum value of the large semi-axis and the ratio of their own values, i.e.

$$\lambda_1\rightarrow \min \; ; \; \frac{\lambda_1}{\lambda_2}\rightarrow 1 \qquad (14)$$

The fulfillment of the second part of (14) means that the ellipses of errors transform into circles.

Absolute error ellipses do not take into account the point-to-point ratio. This disadvantage is partially overcome by the relative ellipses of errors, which most often refer to two adjacent points. The elements of these ellipses of errors are determined according to the same expressions (13), only the cofactor matrix refers to the coordinate differences.

$$\boldsymbol{Q}_{kl}^{\Delta}=\boldsymbol{Q}_{kk}+\boldsymbol{Q}_{ll}-\boldsymbol{Q}_{kl}-\boldsymbol{Q}_{lk} \qquad (15)$$

3.1.2 Global accuracy parameters

Parameters of global accuracy of geodetic networks are derived from the own values of the entire covariance matrix $\boldsymbol{K}_{\hat{x}}$. When analyzing the quality of the network, it should be borne in mind that these elements are not invariant in the choice of the coordinate system.

The starting basis for determining these parameters is the standard hyper-ellipsoid given by the following equation:

$$\hat{\boldsymbol{x}}^T\boldsymbol{K}_{\hat{x}}^{-1}\hat{\boldsymbol{x}}=1 \qquad (16)$$

Semi-axis of the standard hyper-ellipsoid are calculated from their own λ_i from covariance matrix $\boldsymbol{K}_{\hat{x}}$.

As a measure of global accuracy, the maximum own value of λ_{max} is used from $\boldsymbol{K}_{\hat{x}}$. Small value of λ_{max} indicate the good accuracy of the network i.e.

$$\lambda_{max}\rightarrow min \qquad (17)$$

The most commonly used measure of global accuracy of networks is the mean arithmetic mean of the own values from covariance matrix $\boldsymbol{K}_{\hat{x}}$.

$$\bar{\sigma}_{\hat{x}}^2=\frac{1}{u}\sum\lambda_i=\frac{1}{u}trag\boldsymbol{K}_{\hat{x}}\rightarrow min \qquad (18)$$

Also, as a measure of global accuracy, the geometric mean of its own values is used:

$$\bar{\bar{\sigma}}_{\hat{x}}^2=\sqrt[u]{\lambda_1\cdot\lambda_2\cdot\lambda_3\cdot\ldots\cdot\lambda_u}=\sqrt[u]{det\boldsymbol{K}_{\hat{x}}}\rightarrow min \qquad (19)$$

In addition to the above measures, the difference in the maximum and minimum own value as well as their quotient is used in practice:

$$\lambda_{max}-\lambda_{min}\rightarrow 0 \; ; \; {}^{\lambda_{max}}/_{\lambda_{min}}\rightarrow 1 \qquad (20)$$

The small differences between the maximum and the minimum own value indicate the homogeneity and isotropy of the network.

3.2 RELIABILITY OF THE GEODETIC NETWORKS

The reliability of geodetic networks is defined through internal and external reliability. Internal reliability suggests the ability of the model to identify the presence of rough errors in the measurements, while external reliability represents the ability of the model to control the impact of possibly undetected rough errors in the measurements of unknown parameters.

3.2.1 Internal network reliability

Internal reliability of geodetic networks is controlled through global and local criteria.

3.2.1.1 Global internal reliability

Global internal reliability means the ability to detect gross errors regardless of their location. The most simple criterion is the number of excess measurements. If the measurements are not burdened with gross errors then the square form of the vector of the corrections:

$$\frac{\boldsymbol{v}^T\boldsymbol{P}\boldsymbol{v}}{\sigma_0^2} \sim \chi^2 \quad (21)$$

There χ^2 central distribution. Otherwise, the square form has a non-centralized distribution with a non-centered parameter λ:

$$\lambda = \frac{\Delta^T\boldsymbol{P}\boldsymbol{Q}_v\boldsymbol{P}\Delta}{\hat{\sigma}_0^2} \leq \frac{\Delta^T\Delta}{\hat{\sigma}_0^2}\lambda_{max} \quad (22)$$

The non-centered parameter is in function of the maximum self-value of the matrix product $\boldsymbol{P}\boldsymbol{Q}_v\boldsymbol{P}$ and the vector of possible errors. Global internal reliability increases with an increase in the non-centered parameter λ, which means its self-value λ_{max} can serve as a measure of global internal reliability. Hence, measures for global internal reliability can be defined through the following criteria:

$$\lambda_{max}(\boldsymbol{P}\boldsymbol{Q}_v\boldsymbol{P}) \rightarrow max \quad (23)$$

$$trag(\boldsymbol{P}\boldsymbol{Q}_v\boldsymbol{P}) \rightarrow max \quad (24)$$

3.2.1.2 Local internal reliability

Local internal reliability closely related to the possibility of localizing measurements that contain a rough error. The influence of errors in measurements on the vector of corrections is realized through the elements of the matrix $\boldsymbol{R}$:

$$\boldsymbol{R} = \boldsymbol{Q}_v\boldsymbol{P} = \boldsymbol{E} - \boldsymbol{A}\boldsymbol{Q}_x\boldsymbol{A}^T\boldsymbol{Q}_l^{-1} \quad (25)$$

$\boldsymbol{Q}_v$ **–** cofactor matrix of corrections

$$\boldsymbol{Q}_v = \boldsymbol{P}^{-1} - \boldsymbol{A}\boldsymbol{Q}_x\boldsymbol{A}^T \quad (26)$$

Of particular importance are the elements r_i on the main diagonal of the matrix $\boldsymbol{R}$.

These elements are at the range $0 \leq r_i \leq 1$ and give the degree of error transmission in the measurements of the corresponding corrections. These elements can be calculated at the design stage of the network, and their analysis can detect the weak spots in the network. By introducing additional measurements, the model or the geometry of the network can be improved. When designing the network, care must be taken for the values r_i to be higher and properly distributed. The optimum value is 0.4, however, this indicator should be secured against falling below 0.3. Also of interest is the average value of r_i to be higher. The measures for local internal reliability can be defined with the following criteria:

$$r_i = q_{vv}p_i \rightarrow 1$$

$$\bar{r} = \frac{\sum r_i}{n} = \frac{1}{n}trag(\boldsymbol{Q}_v\boldsymbol{P}) = \frac{n-u+d}{n} \quad (27)$$

3.2.2 External network reliability

The external reliability of the geodetic networks as well as the internal ones is controlled through global and local criteria.

3.2.2.1 Global external reliability

With the procedures of internal reliability, we should achieve the removal of measurements that are burdened with rough errors. But despite all the efforts, there is always the possibility that certain errors will remain undetected. The analysis of their influence on unknown parameters is performed with measures of external reliability. The model has good external reliability if it does not respond to undetected gross errors.

The measurement vector containing a rough error Δ, affects the change in the vector of unknown parameters $\boldsymbol{x}$:

$$\Delta\hat{x} = \boldsymbol{Q}_{\hat{x}}\boldsymbol{A}^T\boldsymbol{P}\Delta \quad (28)$$

The criterion of global external reliability is determined by the following inequality:

$$\Delta^T\Delta\lambda_{max} \geq \Delta^T\boldsymbol{P}\boldsymbol{Q}_l\boldsymbol{P}\Delta \quad (29)$$

Where λ_{max} is the maximum self-value of the matrix product $\boldsymbol{P}\boldsymbol{Q}_l\boldsymbol{P}$. If λ_{max} has a lower value, then the impact of undetected rough errors of unknown parameters is lower, i.e. global external reliability is greater.

Accordingly, the criterion for global external reliability is:

$$\lambda_{max}(\boldsymbol{P}\boldsymbol{Q}_l\boldsymbol{P}) \rightarrow min \quad (30)$$

$$trag(\boldsymbol{P}\boldsymbol{Q}_l\boldsymbol{P}) \rightarrow min \quad (31)$$

Additional measurements do not contribute to improving the criteria, but only increase the number of excess measurements.

3.2.2.2 Local external reliability

Local external reliability shows the impact of a measure burdened with a rough error on the unknown parameters:

$$\Delta\hat{x}_i = \boldsymbol{Q}_x\boldsymbol{A}^T\boldsymbol{P}\boldsymbol{a}_i\Delta_i \tag{32}$$

Where a_i is *i*-th column in the matrix $\boldsymbol{A}$. The Presence of one measurement with rough error affects all unknown parameters. A better measure of local external reliability is obtained using the square shape $q_{\Delta\hat{x}_i}$:

$$q_{\Delta\hat{x}_i} = \Delta\hat{x}_i^T\boldsymbol{Q}_x^-\Delta\hat{x}_i = \Delta_i^2 p_i^2 a_i^T\boldsymbol{Q}_{\hat{x}}a_i \tag{33}$$

A smaller value of the square shape means better local external reliability.

Accordingly, the criterion for local external reliability is defined by the expression:

$$p_i^2 a_i^T\boldsymbol{Q}_{\hat{x}}a_i \rightarrow min \tag{34}$$

The mean value of local external reliability is obtained from the individual values:

$$\frac{1}{n}\sum_1^n p_i^2 a_i^T\boldsymbol{Q}_{\hat{x}}a_i = \frac{1}{n}trag(\boldsymbol{P}\boldsymbol{Q}_l\boldsymbol{P}) \rightarrow min \tag{35}$$

Reliability is greater if the mean value is lower.

4. EXAMPLE

The data on the quality of the special purpose geodetic network for the structure "Kula Vodno" are presented below.

In [1] several variants for which the accuracy and reliability parameters are simulated are presented. Here are shown the parameters for the finally adopted variant of the network that has been implemented.

The final variation envisages the measurement of all directions with a priori adopted standard $\sigma_0 = 1.5''$, and measured lengths with standard $\sigma_D = 1mm + 1.5ppm$.

Table 1. Approximate coordinates of the points

Point	Y	X
1	533 470	646 840
2	533 455	646 880
3	533 490	646 885
4	533 450	646 890
5	533 375	646 920
6	533 380	646 935
7	533 310	646940
8	533 280	646 910
9	533 270	646 850

Table 2. Parameters for position accuracy of the points

Point	$\sigma_x[mm]$	$\sigma_y[mm]$	$\sigma_p[mm]$
1	0.74	0.67	1.00
2	0.27	0.64	0.69
3	0.32	0.89	0.95
4	0.39	0.66	0.75
5	0.35	0.57	0.67
6	0.44	0.59	0.74
7	0.44	0.75	0.87
8	0.43	0.89	0.99
9	0.60	0.93	1.11

Table 3. Parameters for the absolute error ellipses

N	λ_1 $[mm]$	λ_2 $[mm]$	A $[mm]$	B $[mm]$	θ [°]
1	0.32	0.12	0.85	0.52	146
2	0.20	0.01	0.67	0.15	108
3	0.36	0.05	0.90	0.34	90
4	0.23	0.03	0.72	0.26	115
5	0.16	0.05	0.60	0.34	108
6	0.17	0.07	0.62	0.40	114
7	0.27	0.07	0.78	0.40	108
8	0.35	0.08	0.89	0.42	47
9	0.45	0.10	1.01	0.47	70

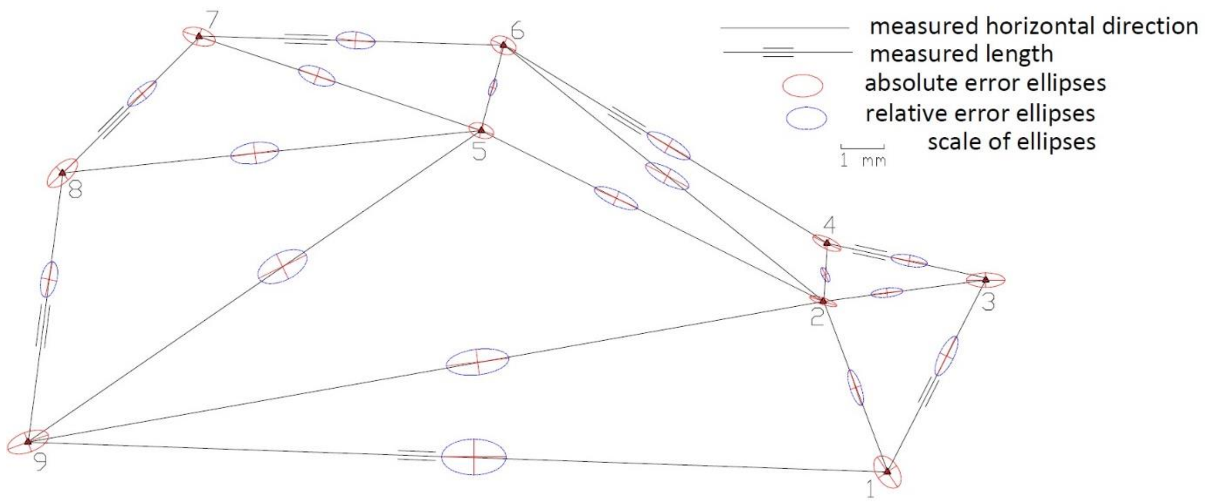
Table 4. Parameters for the relative error ellipses

From -To	λ_1 $[mm]$	λ_2 $[mm]$	A $[mm]$	B $[mm]$	θ [°]
1-2	0.34	0.03	0.87	0.26	162
1-3	0.45	0.05	1.01	0.34	26
1-9	1.02	0.31	1.51	0.84	91
2-3	0.25	0.02	0.75	0.21	84
2-4	0.06	0.01	0.37	0.15	103
2-5	0.54	0.05	1.10	0.34	115
2-6	0.57	0.06	1.13	0.37	118
2-9	0.96	0.16	1.47	0.60	83

3-4	0.33	0.03	0.86	0.26	100
4-6	0.59	0.06	1.15	0.37	120
5-6	0.07	0.01	0.40	0.15	20
5-7	0.35	0.07	0.89	0.40	110
5-8	0.57	0.11	1.13	0.50	82
5-9	0.68	0.19	1.24	0.65	64
6-7	0.37	0.07	0.91	0.40	96
7-8	0.32	0.04	0.85	0.30	50
8-9	0.36	0.06	0.90	0.37	12

Table 5. Parameters for the reliability of the network

St.	Si.	Meas.	p_i	q_{ll}	q_{vv}	r_i
1	9	h.dir	1.0	0.69	0.32	0.31
	2	h.dir	1.0	0.65	0.35	0.35
	3	h.dir	1.0	0.75	0.25	0.25
2	9	h.dir	1.0	0.54	0.46	0.46
	5	h.dir	1.0	0.42	0.58	0.58
	6	h.dir	1.0	0.43	0.57	0.57
	4	h.dir	1.0	0.64	0.36	0.36
	3	h.dir	1.0	0.72	0.28	0.28
	1	h.dir	1.0	0.69	0.31	0.31
3	1	h.dir	1.0	0.73	0.27	0.27
	2	h.dir	1.0	0.65	0.35	0.35
	4	h.dir	1.0	0.70	0.30	0.30
4	6	h.dir	1.0	0.69	0.31	0.31
	3	h.dir	1.0	0.76	0.24	0.24
	2	h.dir	1.0	0.66	0.34	0.34
5	9	h.dir	1.0	0.61	0.39	0.39
	8	h.dir	1.0	0.59	0.41	0.41
	7	h.dir	1.0	0.65	0.35	0.35
	6	h.dir	1.0	0.65	0.35	0.35
	2	h.dir	1.0	0.64	0.36	0.36
6	4	h.dir	1.0	0.45	0.55	0.55
	2	h.dir	1.0	0.44	0.56	0.56
	5	h.dir	1.0	0.62	0.38	0.38
	7	h.dir	1.0	0.74	0.26	0.27
7	6	h.dir	1.0	0.62	0.38	0.38
	5	h.dir	1.0	0.60	0.40	0.40
	8	h.dir	1.0	0.76	0.24	0.24
8	7	h.dir	1.0	0.72	0.28	0.28
	5	h.dir	1.0	0.64	0.36	0.36
	9	h.dir	1.0	0.74	0.26	0.26
9	8	h.dir	1.0	0.71	0.29	0.29
	5	h.dir	1.0	0.52	0.48	0.48
	2	h.dir	1.0	0.43	0.57	0.57
	1	h.dir	1.0	0.52	0.48	0.48
1	3	dist	0.88	0.45	0.68	0.60
1	9	dist	0.59	1.01	0.67	0.40
3	4	dist	0.89	0.33	0.79	0.71
4	6	dist	0.78	0.59	0.68	0.54
6	7	dist	0.82	0.36	0.86	0.70
7	8	dist	0.88	0.32	0.81	0.72
8	9	dist	0.84	0.36	0.84	0.70



5. CONCLUSIONS

The quality of the geodetic networks can be checked by means of a prior analysis of accuracy and a prior reliability analysis.

Analysis of accuracy and reliability is done through global and local criteria. Global criteria provide information about the network as a whole, while local criteria offer information on individual points in the network. It should be borne in mind that local criteria are not invariant from the choice of the coordinate system.

The article analyzes the quality of the special purpose geodetic network for structure "Kula Vodno".

From the numerous indicators in Chapter 4 it can be concluded that the network meets the requirements regarding the accuracy and reliability defined in the project task.

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COMPARATION OF CALCULATED AND SURVEY MONITORING DISPLACEMENTS FOR ST. PETKA DAM

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The assessment of dam's safety is complex task that has to be considered from numerous aspects by including of various factors. The application of the finite element method has lead to significant changes in the treatment of the arch dam stability, enabling complex spatial analysis and obtaining output results for various loading stages of the dam. The process of calibration of the results obtained by numerical analysis and monitoring data is continuous in the same time improving the numerical model and monitoring instrumentation. In this paper a comparison of part of some of the output results from the numerical model with survey monitoring data is illustrated on the case of St. Petka dam, a 64 m high arch dam on River Treska, commissioned in 2012.

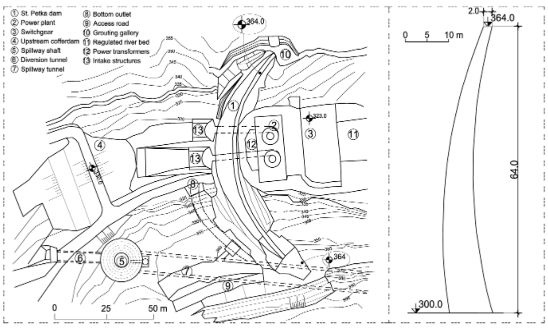
Keywords: arch dam, numerical model, survey monitoring data.

1. INTRODUCTION

The dams, having in consideration their importance, dimensions, complexity of the problems that should be solved during the process of designing and construction along with the environmental impact are lined up in the most complex engineering structures [1, 2].The ICOLD Register of dams lists around 45,000 dams higher than 15 m. According to the rapid population increase, foreseen to reach 10 billion inhabitants by the end of the century, more dams will have to be built in order various water demands to be satisfied. So, theassessment of the stability and the behaviour of dams during construction at full reservoir and during service period is of vital meaning.

In August 2012 was commissioned Saint Petka arch dam, in nearby the city of Skopje, as final part of the cascade system on river Treska, along with dams St. Andrea and Kozyak. The paper deals with comparison of results from static analysis of St. Petka dam, performed with application of the program package SOFiSTiK with survey monitoring data.

St. Petka dam is double curved thin arch dam, with height of 64.0 m (Fig. 1-a,b). The crest elevation is at 364.0 masl, with crest thickness of 2 m and length of 115 m, while the lowest elevation is at 300.0 masl, thickness of 10.0 m. On the right bank the low quality zone of the rock foundation is replaced by concrete block, thus avoiding the weak foundation zones. The dam site is characterized by symmetric shape with steep slopes, apropos the left abutment is with inclination of 60°, while the right abutment has an inclination of 50°. The normal water level is at 357.30 masl, while the reservoir volume is 12.4×106 m^3. The main purpose of the dam is electric power production.



a) b)

Figure 1. St. Petka dam. a) Dam layout, b) Central cross-section.

2. ST. PETKA DAM SURVEY MONIORING SYSTEM

Within the monitoring system of St. Petka dam is foreseen and survey (geodetic) monitoring. The survey monitoring system consists of survey points located at crest and on the downstream face of the dam body, schematically displayed on Fig. 2 and Fig. 3.

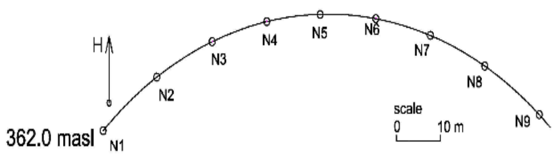


Figure 2. Survey points at elevation 362.0 masl at St. Petka dam.

For the period May-December, 2012 are conducted total of 6 control series of measurements, along with the “zero” position series, dating from 22.5.2012.Also, for the period December, 2011-April, 2012 are carried out special measurements series, such as series during construction, before grouting and upon grouting stage, for which are prepared special elaborates.For number of measuring points as “zero” position is adopted position upon grouting stage on 20.4.2012, while for the remaining points the “zero” state is the measured series on 22.5.2012.

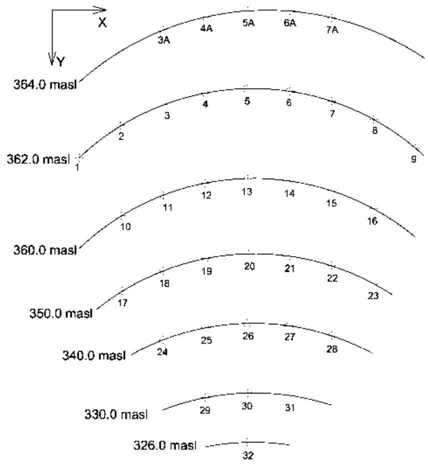


Figure 3. Survey points on downstream face of St. Petka dam.

In Tab. 1-5 are displayed series of vertical displacements for survey pointsN_1, N_3, N_5, N_7 and N_9(Fig. 2), where are specified the actual height H [m] and incremental displacements dH [m], along with the series number, reservoir level and date.

Table 1. Vertical displacements foe survey point N_1.

Series	Date	Reservoir level	Survey point N_1	
			$H_{[m]}$	$dH_{[mm]}$
0	22.05.2012	empty	364.0790	
1	12.06.2012	325.00	364.0796	+ 0.6
2	09.07.2012	340.00	364.0809	+1.9
3	02.08.2012	357.30	364.0809	+1.9
4	19.09.2012	340.00	364.0804	+1.4
5	12.10.2012	357.40	364.0792	+0.2

Table 2. Vertical displacements foe survey point N_3.

Series	Date	Reservoir level	Survey point N_3	
			$H_{[m]}$	$H_{[m]}$
0	22.05.2012	empty	364.0734	
1	12.06.2012	325.00	364.0735	+ 0.1
2	09.07.2012	340.00	364.0775	+4.1
3	02.08.2012	357.30	364.0785	+5.1
4	19.09.2012	340.00	364.0746	+1.2
5	12.10.2012	357.40	364.0735	+0.1

Table 3. Vertical displacements foe survey point N_5.

Series	Date	Reservoir level	Survey point N_5	
			$H_{[m]}$	$dH_{[mm]}$
0	22.05.2012	empty	364.0640	
1	12.06.2012	325.00	364.0675	+ 3.5
2	09.07.2012	340.00	364.0695	+5.5
3	02.08.2012	357.30	364.0708	+6.8
4	19.09.2012	340.00	364.0657	+1.7
5	12.10.2012	357.40	364.0641	+0.1

Table 4. Vertical displacements foe survey point N_7.

Series	Date	Reservoir level	Survey point N_7	
			$H_{[m]}$	$dH_{[m]}$
0	22.05.2012	empty	364.0766	
1	12.06.2012	325.00	364.0797	*+ 3.1*
2	09.07.2012	340.00	364.0807	*+4.1*
3	02.08.2012	357.30	364.0821	*+5.5*
4	19.09.2012	340.00	364.0783	*+1.7*
5	12.10.2012	357.40	364.0767	*+0.1*

Table 5. Vertical displacements foe survey point N_9.

Series	Date	Reservoir level	Survey point N_9	
			$H_{[m]}$	$dH_{[m]}$
0	22.05.2012	empty	364.0582	
1	12.06.2012	325.00	364.0603	*+2.1*
2	09.07.2012	340.00	364.0598	*+1.6*
3	02.08.2012	357.30	364.0604	*+2.2*
4	19.09.2012	340.00	364.0600	*+1.8*
5	12.10.2012	357.40	364.0572	*-1.0*

From the table display it can be concluded that for the period May-August, 2012 are occurred incremental displacements in opposite direction of the gravity apropos in upwards direction (rising), with maximal value of approximately 7 mm at middle point of the arch.

3. DAM MODEL

The static analysis of St. Petka dam is conveyed with application of the program package SOFiSTiK, based on the finite element method. In order to perform the numerical analysis following steps are undertaken: (1) choice of material parameters – constitutional laws (one of the most complex tasks during the analysis), (2) adoption of dam geometry and (3) simulation of the dam construction and reservoir filling.

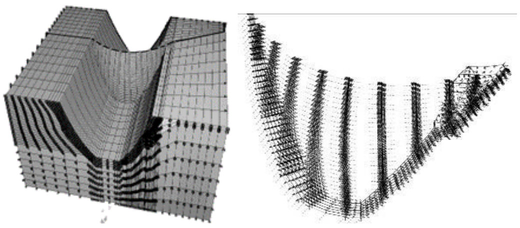
The terrain is composed of mainly of marble. The carbon schist appears as plates with mica sub-layers between them. At the upper zones of the dam site are detected diluvia and alluvial sediments, later excavated during the construction stage.The geotechnical input data for the modelled three different zones of the rock foundation (Tab. 6) are adopted on base on overall data from the geotechnical investigations and control testing before and during construction process [3].Linear constitutional law is applied for the materials in dam foundation.

The constitutional law for the concrete is adopted according to EC 2, concrete grade CG 30 [4, 5], based on performed probe and control testing of the concrete before and during construction stage.

Table 6. Input parameters for dam foundation.

Zone	Deformation modulus*D* [MPa]	Poison's coefficient*μ*
Fault zones	2500	0.30
Left bank	7000-8000	0.24
Right bank	5000-6000	0.26

The spatial analysis of St. Petka dam is performed in stages. The numerical model is composed of the dam body and the rock foundation. The dam body is limited by the dam site shape, and rock foundation, with length upstream and downstream of the dam central cantilever of 100 m [6], while the rock foundation under the dam is adopted at depth of 65.0 m (Fig. 4a). By such parameters is defined the non-deformable limit boundary condition. The discretization is conducted by capturing zones with different materials – concrete and rock foundation in groups. The dam's thickness is divided in 6 layers (groups). The applied numerical model includes interface elements at dam joints and at the contact dam-foundation (Fig. 4b), whose behaviour is described bynormal and tangential stiffness parameters. Their values are adopted on base of laboratory testing of the shear strength in Hoek's apparatus at contact zones concrete-rock foundation and concrete-grout mixture in the dam joints, as well on performed "in situ" testing of the rock mass deformability [7].



a) b)

Figure 4. St. Petka dam model. a) Spatial view from upstream side, b) Interface elements at contact dam-foundation and at contact concrete-grout mix in dam joints.

The analysed loading states of the dam include state after dam construction, before grouting, upon grouting and first reservoir filling. The dam joint grouting was performed in March-April, 2012. The dam filling commenced in June, 2012 and reached normal water elevation of 357.30 masl at end of July, 2012. The temperature load is adopted in accordance with monitoring data of the temperature in the dam body for the specified loading states (Fig. 5).

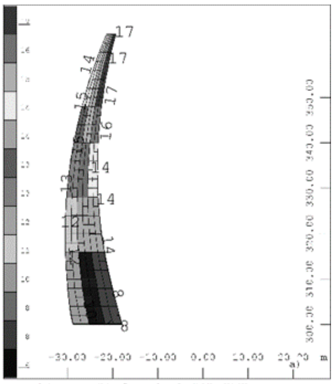


Figure 5. Temperature load applied for various loading states.

4. OUTPUT RESULTS

On Fig. 6 and 7 are displayed isolines of vertical displacements for the state at empty and full reservoir adequately („-“denotes settlement), thus simulating the “zero” state dating from 22.5.2012 and state at full reservoir, dating from 2.8.2012. The displacements (settlements) are with maximal values of approximately 24 mm in right bank of the dam in the zone of the concrete blockfor both states. However the incremental displacements at elevation 362.0 masl are characterized as rising for the period of reservoir filling apropos the values for the settlements at state of full reservoir are decreased compared to the state at empty reservoir.

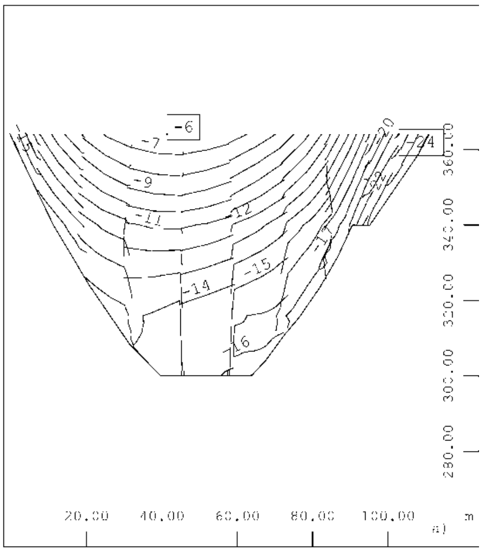


Fig. 6. Isolines of vertical displacements in longitudinal section at dam axis [mm] at empty reservoir.

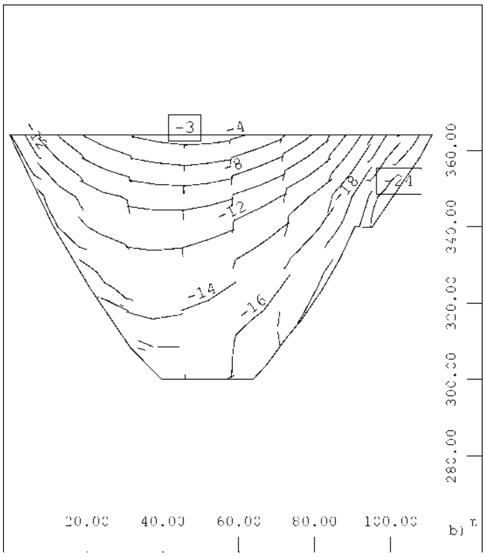


Fig. 7. Isolines of vertical displacements in longitudinal section at dam axis [mm] at full reservoir.

On Fig. 8are displayed curves forincremental calculated and measured vertical displacements of the survey points at elevation 362.0 masl for period May-July, 2012 [7]. From the curves it can be concluded that calculated and measured values have similar pattern and values apropos the maximal displacements occurs in the middle part of the dam crest, while in direction of both banks the displacements values are decreasing.

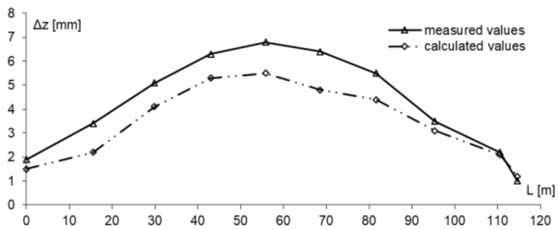


Figure 8. Incremental calculated and measured vertical displacements at elevation 362.0 masl during reservoir filling (“+” denotes rising).

5. CONCLUSIONS

The prediction of the behaviour of the concrete arch dams during construction and at full reservoir is essential for ensuring and providing interval data for the dam engineers – designers of these structures. The dam behaviour is assessed by comparation of the measured survey monitoring data for vertical displacements and calculated data for the displacements by numerical model of St. Petka dam.

The obtained values for the vertical displacements are in the range of expected ones as well its distribution (isolines) in the longitudinal section regarding the specified loading states. Namely, the vertical displacements are dominantly generated by temperature variation for the analysed period, while the hydrostatic pressure caused by reservoir filling slightly affects the displacements.

The comparison of the incremental calculated and measured vertical displacements was undertaken. Namely, the deformation pattern and displacements values for both calculated and measured values shows good matching, analysed for the period before reservoir filling (empty reservoir) and grouting till reservoir filling. The comparison analysis gives valuable findings for the dam behaviour, and it serves as base for the future calibration process for both - numerical model and technical monitoring data, a process which is continuous.

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ANALYSIS OF MID-TERM NATIONAL SPATIAL DATA INFRASTRUCTURE STRATEGIES IN THE WESTERN BALKANS

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National Spatial Data Infrastructure (NSDI) strategies are key tool for establishment and development of Spatial Data Infrastructure (SDI) on national level. The quality of content and completeness of specific NSDI strategy is therefore essential for efficient development of NSDI. One of the components of the completeness is also representation of all three main NSDI contributing stakeholder groups (government, business and education sector) in strategy with proper addressing of their tasks and needs. It is not seldom that this representation of stakeholder groups in NSDI strategies is not well balanced, affecting the impact capacity of such NSDI strategies.

Another important aspect in NSDI strategies is promotion of SDI concept and services. Based on experience gathered in frame of BESTSDI project, presence of promotional activities in NSDI strategies are subject of analysis and evaluation. Namely, level of awareness about SDI among stakeholders and users has direct impact on efficiency in implementation of SDI among them.

Having in mind that establishment and development of NSDI is presently important activity for National Mapping and Cadaster Authorities (NMCA) in the region of Western Balkans, in this paper analysis of NSDI strategies of Federation of Bosnia and Herzegovina, Croatia and Macedonia is presented pointing out their strengths and weaknesses in regards of mentioned factors.

Keywords: Spatial Data Infrastructure, National SDI, NSDI Strategy, components, BESTSDI project

1. INTRODUCTION

Spatial Data Infrastructure (SDI) is defined as a collection of technologies, policies and institutional arrangements that facilitate the availability of and access to spatial data. The SDI provides a basis for spatial data discovery, evaluation, and application for users and providers within all levels of government, the commercial sector, the non-profit sector, academia and by citizens in general [5]. Establishment of SDI is recognized as important element of development of e-Society, especially e-Government. Therefore, SDI establishment is usually regulated by special legislation, national SDI law.

Those legal acts give rules for establishment, maintenance and development of National SDI (NSDI) while operational implementation of NSDI establishment is arranged through adoption of NSDI strategies. One NSDI strategy, usually for mid-term period of 3 – 5 years, defines goals and describes activities which should enable accomplishment of set goals detecting also necessary institutional, organizational, financial and human resources capacities for execution of defined activities. Well defined and comprehensive NSDI strategy is therefore key document for establishment and development of SDI in specific country.

Related to the level of SDI development, the focus of NSDI strategies is either on establishment of SDI or on further development of SDI in respective country. Regardless to the focus of NSDI strategy, it should cover all aspects of establishment and development of SDI including tasks and needs of all three major contributing stakeholder groups:

- governmental sector (institutions and NSDI bodies) responsible for legal, organizational, financial and strategical aspects of NSDI,
- business sector (companies) as a key provider of SDI services and products to the users and
- educational sector (institutions and companies) ensuring necessary well educated and skilled human capacities for contributing stakeholders and users.

Interaction between those three main SDI stakeholder groups and balanced development are essential for establishment of sustainable and progressing SDI. The level of interaction can be expressed as influence of each stakeholder group on other two groups in predefined areas of contribution. The interaction among stakeholder groups and main areas of contribution are shown if Figure 1.

Main incentive and guidance for balanced development of main stakeholder groups is given through the NSDI strategy, by defining goals, activities and resources covering all three groups.

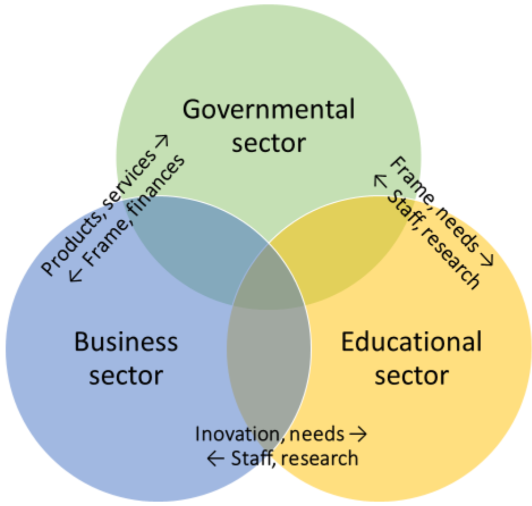

Figure 1. Interaction between main SDI stakeholder groups and their areas of contribution in establishment of NSDI

Neglecting tasks and needs some of stakeholder groups brings strategy in disbalance, resulting ultimately in development of SDI in specific country which will not achieve its full potential. Therefore, SDI strategies should be analysed by completeness of their content, but also contextually, do they, and to which extent, cover all three stakeholder groups. Answer on this question can provide clear indication to creators of any SDI strategy what will be impact of the strategy and respectively what should be corrected to achieve expected (maximum) impact.

2. NSDI FRAME AND STRATEGIES IN THE WESTERN BALKANS REGION

In the region of Western Balkans most countries have adopted some form (law or governmental decision) of NSDI legislation, while several countries, like Bosnia and Herzegovina, Croatia and Macedonia, have also developed and adopted their mid-term NSDI strategies in their effort to establish efficient SDI. Because of mentioned relevance of NSDI strategies, it is worth to compare and evaluate existing strategies in the region providing analysis of their content and completeness trying to estimate their possible impact on development of SDI in respective countries.

2.1 BOSNIA AND HERZEGOVINA

Federation Bosnia and Herzegovina (FB&H) started with establishment of SDI, in late 2014 when the Government of (FB&H) passed the Decree of SDI in the FB&H. The key role in the supply of spatial data in FB&H is held by Administration for Geodetic and Property Affairs of the Federation of Bosnia and Herzegovina (FGA). This was recognized by the Government, and the Regulation gave FGA the authority to establish the SDI Geoportal for FB&H [7].

The following year, the Government appointed members of the SDI FB&H Council, which adopted the three-year work plan. One of the Council's priority objectives was the adoption of SDI Strategy for FB&H. The FB&H Government adopted on September 1, 2016, the SDI FB&H Establishment and Maintenance Strategy [4, 11].

Strategy has defined five basic and ten implementation goals. Basic goals are:

- to establish a spatial data service and to organize the spatial data infrastructure of the FB&H,
- enable SDI FB&H users with easy, fast and efficient spatial access,
- improve the basics of good governance,
- to support the economic development of the FB&H,
- provide basic spatial data to support user needs and EU requirements.

The implementation goals are:

- Adoption of the Strategy for establishing and maintaining the spatial data infrastructure of the FB&H by the Government of FB&H.
- Adoption of the Law on Spatial Data Infrastructure of the FB&H.
- Adoption of a 3-year Program for the Establishment of Spatial Data Infrastructure of the FB&H.
- Mobilize bodies and entities of spatial data infrastructure of the FB&H at all levels and include them in the construction of the SDI.
- Adopt implementing acts: standards, specifications, terms and conditions and the other, in accordance with the standards of the INSPIRE Directive the EU.
- Upgrade existing FGA services that are in function of SDI FB&H to ensure the availability of all FGA data and customer service users with which they will be satisfied (National Geoportal Exchange).
- Establish Registry of SDI Subjects of the FB&H.
- Establish the SDI Metadata Service of the FB&H.
- Streamline SDI FB&H entities, establish partnerships and efficient SDIs.
- Fulfill the basic criteria in the INSPIRE directive for EU accession.

2.2 CROATIA

Republic Croatia started with preparations to establish its NSDI already in year 2001 when first study on EU requirements on Geographical Information Infrastructure for Croatia [3] resulting in Study on development of NSDI [13]. Those studies enabled to introduce NSDI in Croatian legislation in February 2007 as a part of the Law on State Survey and Real-estate Cadaster [8]. Whit this Law Croatia has adopted most important provisions of EU INSPIRE Directive [10].

The Law on National Spatial Data Infrastructure [9] has been adopted in Croatian parliament in April 2013 in process of becoming member of European Union on July 1st 2013. As a member of European Union Croatia is obliged fully to implement INSPIRE Directive till year 2021. In this context all components of NSDI, like NSDI bodies, national geoportal, interoperability infrastructure, necessary registers and services have been established in past period.

Recently, in September 2017, Croatian government has adopted NSDI Strategy for 2020 and Strategic NSDI Plan for period 2017-2020 [6]. The NSDI Strategy has defined seven strategic goals:

- NSDI and benefits which he brings are well known.
- Spatial data and services are available and satisfy user needs.
- Conditions and fees for use of spatial data are easy understandable.
- NSDI use is arranged by appropriate rules and politics.
- There are enough operational possibilities available for efficient and effective use of NSDI.

- NSDI supports other important politics and programs on national and international level.
- NSDI stakeholders (NSDI subjects and users) cooperate through partnership and other forms of agreement.

2.3 MACEDONIA

Republic of Macedonia adopted its first NSDI strategy in July 2012. [1], even before the Law on NSDI in Republic of Macedonia has been adopted by the Macedonian parliament in February 2014. [12]. Based on mentioned strategy and law, NSDI bodies have been appointed and Agency for Real-estate Cadaster (AREC) entrusted for operational establishment of NSDI components. In accordance to the strategy and decisions of NSDI council AREC has developed national SDI geoportal, national metadata profile and metadata editor and several registers like:

- NSDI dictionary,
- NSDI functional concept dictionary,
- register of NSDI stakeholders,
- register of coordinate systems and
- register of spatial data collections.

The subject of NSDI in Macedonia are obliged to use operational services of developed interoperability infrastructure and provide for their data discovery, view and download services.

Although not obliged by EU INSPIRE directive, all established components of Macedonian SDI are INSPRE, ISO and OGC compliant.

Following the developments in establishment of Macedonian SDI based on first NSDI strategy AREC has prepared second NSDI strategy in January 2017 [2], which is, due to the change of Government waiting on adoption. This second NSDI strategy, covering period 2017. - 2019., provides critical (SWOT) analysis of present status of Macedonian SDI, defines strategic goals:

- to enrich and modernize national geoportal with updated data and services,
- further develop interoperability infrastructure and
- develop human and technical capacities for production of standardized collections of spatial data and services,

and defines operational activities for achievement of set strategic goals.

3. COMPARATIVE ANALYSIS OF STRATEGIES

The form of NSDI strategies is not strictly defined, but it is well known what are the structural parts of any NSDI strategy. Each NSDI strategy should for introduction provide overview about history of NSDI (situation) and present status of development of NSDI. Second part of strategy includes definition of NSDI mission and vision, and list of strategic goals defined for specific strategy and specific period. It is worth to mention hear that definition of mission, vision and strategic goals between strategies can variate very much. The variation itself is not critical so long there is consistency between defined strategic goals and defined operational activities which should ensure acquirement of strategic goals. Third part of each strategy contains definition of operational goals and list of activities foreseen to achieve set goals as well as estimation of financial, technical and human resources necessary to implement the strategy.

Following this structure of NSDI strategy building elements, NSDI strategies recently adopted in Bosnia and Herzegovina and Croatia and proposed second NSDI strategy in Macedonia are analyzed from content point of view, see Table 1.

Table 1. Content comparison of analysed strategies

Content	FB&H	CRO	MAC
Situation overview given	Yes	Yes	Yes
Starting position described	Yes	Yes	Yes
Vision/Mission defined	Yes	Yes	Yes
Strategic goals defined	Yes	Yes	Yes
Operational goals defined	Yes	Yes	Yes
Operational activities and indicators defined	Yes	Yes	Yes
Financial costs estimated	Yes	Yes	Yes

The comparison presented in Table 1 is showing that all three strategies are complete from the content point of view, although there are visible differences in style and way how specific parts are defined, like strategic goals listed in chapter 2. Those differences are logical, because of different level of establishment and development of NSDI in analysed countries resulting in different priorities and relevance of specific goals. Despite this, there is still room to detect strengths and weaknesses of each strategy.

The strength of NSDI strategy of Federation of Bosnia and Herzegovina is in the fact that strategy recognized short-, mid- and long-term strategic goals providing well-structured stepwise approach. The weakness of this strategy is lack of risk analysis (like SWOT or similar) and lack of definition of resources (human, technical and financial) necessary for execution of operational activities.

The strength of Croatian NSDI strategy is in extensive chapter on study of costs and benefits and given indicators of expected advance for each strategic goal. As a weakness of this strategy lack of risk analysis (like SWOT or similar) and lack of resources (human, technical and financial) for execution of operational activities can be indicated.

Proposed second Macedonian NSDI strategy includes detailed risk (SWOT) analysis what represents its strength. As weakness of this strategy, like in case of Federation of Bosnia and Herzegovina and Croatia, lack of definition of resources (human, technical and financial) necessary for execution of operational activities, as well as indicators of expected advance can be seen as weakness.

Second analysis is looking for completeness of analysed strategies from the perspective of main contributing stakeholder groups. As discussed in chapter 1, to achieve proper interaction among those stakeholder groups and full potential of strategy it is necessary in NSDI strategy to cover tasks and needs of all those three groups. For purpose of this analysis list of goals and activities is defined and their coverage in observed strategies analysed, see Table 2. Additionally, promotional activities are added as separate category to this analysis, as input for discussion in chapter 4.

The results presented in Table 2 are showing that all three strategies are mainly focused on tasks and needs of governmental sector. This is partly acceptable, because activities for which governmental sector (NSDI bodies and institutions) is responsible are first in sequence of execution for establishment of NSDI. At the same time, lack of goals and operational activities which are covering needs and tasks of business and educational sector can results in disbalanced development of NSDI and serious gaps in implementation of strategy (slow development of business sector and lack of skilled professionals). Another problem which is occurring in such situation is that there is not enough incentive from business sector towards users, resulting with slugged interest of user community for use of SDI products and services. This gap in not possible to catch up with additional engagement of governmental sector towards users, since the way of approach and methods are different.

Table 2. Completeness of strategies considered from perspective of main stakeholder groups

Goals and activities covered	FB&H	CRO	MAC
Legal and organisational	Yes	Yes	Yes
Technical	Yes	Yes	Yes
Financial	Yes	Yes	Yes
Dissemination of use	Yes	Yes	Yes
Commercial exploitation plan	No	No	No
Creation of business environment	No	No	No
Ensuring human capacities	No	No	No
Support for academic sector	No	Yes	No
Promotion	No	No	No

Similar situation is with ensuring human capacities. The main difference to engagement of business sector lies in the fact that with import of proper measures business sector can in relatively short time achieve results, while ensuring well educated and skilled human capacities requires longer period. This means that lack of measures in NSDI strategies which are focused on human capacities can result in long lasting structural problems in development of NSDI.

4. USER AWARENES ABOUT NSDI

Even the best NSDI strategy covering tasks and needs of all three contributing stakeholder groups may fail if users are not aware about NSDI or have insufficient knowledge what SDI stands for and what are the benefits of NSDI. NMCA's responsible for establishment of NSDI in Bosnia and Herzegovina, Croatia and Macedonia are well aware of this fact, and they have undertaken number of promotion activities. They published leaflets and brochures, organized conferences and workshops, produced video clips, etc. Those activities doubtlessly achieved results among users which participated in them. Since SDI users are numerous, resulting in fact that promotion activities are costly and demand lot of human capacities, the challenge for NMCA's is to define target groups to be addressed assuming that those target groups cover significant number of users.

In promotion activities undertaken by NMCS in analyzed countries focus of promotion activities was mainly on ministries and governmental agencies, geodetic and geoinformatic professional society, public enterprises and local and regional governments. This results in fact that many other professions were not in, or were weakly included in promotion activities and have limited knowledge about SDI and NSDI activities in their countries concerning not only users but also stakeholders from business and education sector.

Being aware of this fact, consortium of universities from Belgium (Catholic University Leuven), Croatia (University of Zagreb and University Split), Germany (University of Applied Sciences Bochum) and Macedonia (University of Ss. Cyril and Methodius in Skopje) were awarded to execute Erasmus+ Capacity Building in field of Higher Education project "Western Balkans Academic Education Evolution and Professional's Sustainable Training for Spatial Data Infrastructures" – BESTSDI. Beneficiaries of this project are 15 faculties form Albania, Bosnia and Herzegovina, Kosovo, Montenegro and Serbia which should introduce or improve their study programs with curriculum and courses on SDI.

Those beneficiary faculties are covering bright spectrum of study programs: geodesy and geoinformation, technical professions (civil engineering, architecture, geology and mining, IT) and other non-technical professions (agriculture, forestry, philosophy). In the preparatory phase of BESTSDI project, survey has been conducted about the status of SDI at beneficiary faculties.

Results in table 3 are showing that high education institutions, except those which provide study programs on geodesy and geoinformatics, have limited awareness about SDI and are not involved in NSDI activities. The fact that non-geodetic faculties lecture about GIS and use of spatial data for different applications without connecting it with SDI as a platform for this course is directly opposite to basic concept of SDI. Since this situation can also be copied on respective business sectors it is clear that majority of professions are not well included in NSDI activities. This fact decreases the potential impact of NSDI strategies and positive effects of SDI implementation on society.

Table 3. Level of awareness about SDI at the beneficiary faculties of BESTSDI project

Group of faculties by study program	Level of awareness about SDI
Geodesy and geoinformation (4)	High
Technical studies (5)	Medium to low
Non-technical studies (6)	Low
	Level of involvement in NSDI activities
Geodesy and geoinformation (4)	High
Technical studies (5)	Low
Non-technical studies (6)	Low

This is the reason why BESTSDI project has spread it focus on bright spectrum of study programs trying to broaden the SDI education to other professions aiming that future professionals coming out from those faculties are educated about SDI and in parallel raising awareness about SDI and NSDI activities among academic staff and their students. Being aware that spreading knowledge and awareness about SDI can't be based on one project, there is need for continuous and broaden systematic promotion of SDI what will directly support implementation of NSDI strategy and effects which will be achieved through it.

5. CONCLUSION

Relevance of NSDI strategies for establishment and implementation of SDI in respective countries is recognized and confirmed in this research. The analysis of NSDI strategies recently adopted in Bosnia and Herzegovina and Croatia, and proposed in Macedonia showed that they are well structured and comprehensive, but also that there is space for their improvement. The analysis is also showing that strategies are focused mainly on tasks of governmental sectors, while tasks of business and education sector are mentioned in strategy goals but without defining operational activities and resources necessary for implementation of those tasks.

The importance of continuous promotion of SDI and need to systematically broaden this promotion to bright spectrum of professions including business and educational stakeholder groups has been elaborated on example of high education institutions, showing that lack of systematic promotion is directly influencing results which can be achieved through implementation of NSDI strategy.

Therefore, well balanced NSDI strategy priorities and defined activities regarding major stakeholder groups, including also promotional activities, should ensure achievement of better results during strategy implementation.

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WESTERN BALKANS ACADEMIC EDUCATION EVOLUTION AND PROFESSIONAL'S SUSTAINABLE TRAINING FOR SPATIAL DATA INFRASTRUCTURES

BEST SDI

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FROM ERASMUS TO ERASMUS+ A STORY OF 30 YEARS

START: 2016 END: 2019

PREFERENCES OF SERVICES FROM CONTEMPORARY 3D OVER TRADITIONAL 2D CADASTRE SYSTEMS

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The period of socialist system in R. Macedonia had its own characteristics which made an impact in many segments of the state management. The impact was made in the land management segment as well, especially in the part for definition of the property rights and borders in the space. In this research the focus laid upon relation between the parcel (land) and the erected constructions (buildings, utility lines, etc), or so to say, the rights which relate or separated objects with land.

In the socialistic period the urban land was proclaimed for a good of common interest, and ownership of the urban land was unreachable category for individuals. The land was proclaimed as socially owned, individual ownership was possible to begained only upon the buildings.

This principle of duality where the land and the building on the land do not have the same owner last until 2001. The change in the *law for ownership* and *law for urban land*, return the concept for delimitation of the space in horizontal by principle *from hell to haven,* meaning that registration of the property rights in the cadastre should be registered according that principle.

This approach for delimitation of property borders, in the process of registration of property rights, has shown inconvenient in many situations. In many situations where buildings were established and governed by the state, buildings which are privately owned now, registration in the cadastre system has shown as unreal compared with the actual situation. Beside the replacement of the maxim *Superficieisolumcedit* with the maxim *Superficies solo cedit*, difficulties in the registration of this situations are caused by unused possibilities that legal system has provided. Namely, existence of the properties in so called 3D situations is not a new phenomenon, this type of properties existed long before. The registration and securing property rights is based on registration of ownership rights on the land to one person and then restricting that right by easements or other property rights in the favour of all other persons who have some right related with that land. What makes this situation even more difficult for R. Macedonia is that easement as a type of property right is very seldom used in the registration of property rights. In fact, in this research not even in one 3D situation that was analysed easements were not registered. In those situations, the registration has very significant drawbacks.

Additional, problem with registration of utility lines exists and its importance constantly increases. Utility lines in relation with parcels are one more 3D situation that needs to be treated with attention and seriousness as same as the situations with buildings. This problem consists of two components, the first one is in the domain of cadastre system, and the ability to register utility lines and the second problem has roots in the legal system which is not adequality tailored for treating this 3D situations.

In this research an analyse were conducted on registration of 3D situations and problems have been emphasized, problems that Macedonian cadastre system experience in the registration of property rights regarding those situations.

Keywords: Cadastre, 3D Cadastre, Superficies solo cedit, Superficieisolumcedit.

1. RELATION PARCEL – BUILDING

Registration of the property rights in the cadastre systems and delimitation of space where the property rights exists is closely related with the basic maxim Superficies solo cedit used for relation between parcels and the buildings erected on it (Superficies solo cedit, Superficieisolumcedit). Concerning this issue Macedonia has a specific situation, as several other former socialistic countries. If we look in the past we can distinct several periods concerning relation between parcel and the erected building.

The first period is the period before 1958 when basic principle for delimitation of the ownership in horizontal sense was the concept *from hell to heaven* (superficies solo cedit) with all the characteristics which this maxim includes.

The crucial movement concerning property rights and relation between parcel and building in R. Macedonia was made in 1958 with the adoption of the *Law on Nationalisation of Leased Buildings and Construction Land* ("Official Gazette of the FPRY", No. 52/58). By this law, land within urban regions which was privately owned becomes social property. In practice, a nationalization of urban land was conducted. It is important to underline that this transfer of ownership of urban land included only the land in the delimited regions, urban regions. The property rights out of these regions stayed intact. People were still able to acquire ownership to agriculture land.

The transformation of the ownership right to *right to use urban land* was also supported by the *Law on Nationalisation of Leased Buildings and Construction Land* ("Official Gazette of the FPRY", No. 52/58). As urban land, according this law, is referring to the built up or not built up land which is announced as urban region. The urban regionsare defined by comprehensive plans and detailed development plans or other similar documents which can declare urban land. The spatial definition of the urban regions was approved by the municipal council. By the decision of the municipal council to declare some area as an urban area, the ownership right of the land was transformed to *right to use urban land*.

This change of the property rights imposes change to the basic principle of delimitation of the ownership of the building in relation to the land under it. With the adopted law in 1958 the basic maxim Superficies solo cedit was replaced with the maxim Supericieisolumcedit which was in force until 2001 when *Law on construction land*(Official Gazette of R. Macedonia 53/2001)was adopted.

Between 1958 and 2001 the basic maxim in the legal system which regulates the relation between the building and the parcel, as it can be seen from the *Law for basicownership relations,*is the maxim Superficieisolumcedit. This means that the owner of thebuilding has only right to use the parcel on which the building is erected but could not obtain ownership on the land. In practice, whenever the building has been sold the right to use the land was also transferred to the new owner of the building. With this concept of transferrin property rights land had same legal destiny as the building.

The right to use socially owned urban land do not last in perpetuity, or we can also say that the *right to use urban land* is not the right that does not have time limit as ownership does.

However, the limit in time has never been mentioned before in any other law, where time frames or intervals would be stipulated, until the*Law on ownership and other real rights (*Official Gazette of R. Macedonia18/2001) come to force in 2001. However, the *right to use urban land*, under some circumstance can cease. The regulations regarding ending of the *right to use urban land* until 2001 was regulated within the *Law on Basic Ownership Relations(*Official Gazette of SFRY6/80)*,* and after 2001 the*Law on construction land*(Official Gazette of R. Macedonia 53/2001)*.* Law on construction land beside otherthings also regulates the transformation and conditions under which the land (owned by the state, previously socially owned) can be sold to the current holders of the *right to use* the urban land.

According the *Law for basic ownership relations (*Official Gazette of SFRY6/80)*,* the right to use urban land can cease if the building erected on it will be demolished, or with the removing of all building materials for constructing the building which is not finished yet. The right to use urban land also cease if the duality ceases, that is to say, if the building and the land have the same owner.

Since 2001 when the *Law on construction land*(Official Gazette of R. Macedonia 53/2001) was voted in the parliament, the right to use urban land is not one of the rights that a person can have to urban land because that right is not stated in the law. In the section 13 of this law it is stated that: “Urban land owned by R. Macedonia can be sold, a concession can be granted for the land, or it can be established a lease”, which means that the right to use urban land, socially owned, cease to exist in the Macedonian legislation. This law also has sections which regulate transformation of right to use urban land to ownership.

This transformation has its own characteristics, rules that regulate the transformation of right to use urban land to the ownership right, with or without money payment.

Giving up the right to use socially owned urban land (later state owned) and introducing the right of ownership to urban land as well as giving up of the Superficieisolumcedit maxim, can be directly seen from several sections at the *Law onconstruction land.* The sections of this law which is directly related to the horizontal delimitation of the space, say that duality, different owners between the parcel and the building, will not exist anymore.

At the article 7 of the law for urban land is defined explicitly what ownership of land includes, and it is stated:

> *The ownership of the urban land includes, surface of the land and everything else which is permanently connected to the land, and it is placed on the surface or below the surface, if the law does not state it otherwise.*

This section of the law presents maxim *superficies solo cedit* in its purest form. This means that everything which is placed on the parcel is fixture to the parcel and the owner of the parcel is the owner of the buildings and everything else built within the parcel boundaries over or under the surface. However, at the end of the section there is one part which says “*ifthe law does not state it otherwise”,* but we have to have in mind that in Macedonian lawsystem condominium rights are present, and of course the long lease and concession. In the last two cases erecting buildings on someone else’s land is allowed. This is the reason why it is important for the law to allow exception from the basic maxim. The discussion about condominium property will follow later in the text. The same context has also article 10 from the same law which says:

> *The buildings erected on the surface of the urban land or below the surface with intention permanently to stay there, are part of that urban land until some property right do not separate building from the land. The right which separates building from the land has to allow to the holder of that right to own building on someone else’s property or based on the concession right the holder is authorized to have building which is owned by him.*

Similar to the article 7, article 10 it is emphasized the connection of the building to the land but at the same time says that building erected on the urban land can be legally separate from the land. The legal separation of the land from the building is possible by long lease and concession or *some other right* as it is stated in the law. Until July 2008 long lease and concession were the only two rights that can separate the building from the land. The change in the *Law on construction (*Official Gazette of R. Macedonia 82/2008*)* in July 2008 brought some changes which will be presented later, and it is only applied to the new buildings that have not been constructed yet, for which the building permit is necessary. The rights that can be obtained to the urban land are regulated with the article 12 from the *law for construction land* which says:

> *The holder of the right of ownership of the urban land can sell the land or leased it on long or short terms*.

However, article 12 refers to the situations when the owner of the land is anyone else except the state, but when it comes to the land which is owned by the state then the rights that can be obtained to that land are regulated in the article 13, which says:

> *Urban land owned by Republic of Macedonia can be sold, leased or granted concession for it*.

The reason which separates rights toward urban land owned by the state and the land owned by anyone else in two different sections of the law is that the concession right cannot be established to the land which is not owned by the state. In those two sections it can be seen that *right to use urban land* is not mentioned at all, or to say more explicitly, is not allowed in the future to be granted to someone who wants to erect building on someone else's property orthe persons who already have this right to keep it in a future. According to the *Law for constructionland* in the R. Macedonia erecting a building on a parcel which is not owned by the owner ofthe building can be done by means of long lease, if the land is privately owned, or by long lease or concession right, if the land is owned by the state. In July 2008 the change in the *Lawonconstruction*introduced a new way of establishing a building on someone else's property. Thenew changes provide an opportunity beside long lease and concession, building can be established on someone else's parcel based on the easement right, and in one more case, if the owner of the parcel transfer his building right to other person who is not the owner of the land. Those new changes from July 2008 apply only to the new buildings that will be established in the future. According to the legislation in the R. Macedonia long lease and concession can last no longer than 99 years. After the end of the long lease or concession period the building erected on the land becomes fixture to the land.

2. REGISTRATION OF 3D SITUATIONS IN THE CADASTRE DATABASE

The practice of registration of the properties and property rights n 3D situations will be present by examples. This way of presentation of the practice in registration is most convenient since law for cadastre and other regulations which regulate delimitation and registration of the space and the property rights do not give much information how this properties and properties rights should be registered. Delimitation of real property rights, concerning chosen examples, could not be administrated according to the base principle of cadastral registration in Macedonia.

The presentations of this case will be made in two parts. The first part will present the technical aspects, graphical presentation of the properties on the maps and the second part of the presentation will focus on the legal aspects and registration of property rights.

2.1 COMPLEX OF SHOPS ESTAKADA

One of the characteristic cases which reveal very clearly the problem with registration of 3D situations is a registration of ownership rights for properties in the complex of shops called Estakada.

This situation is about properties (shops) which are located under a public road. The properties are retail shops and all of them are part of one "subsurface" building. Each property (shop) is a subject of separate property right registration, according condominium property rights. From picture 1, situation can be seen more clearly.

Figure 1. Properties

When it comes to graphic presentation of the properties concerning location of the building and parcel, the situation is very unclear. On the cadastral map the building below the surface is not presented in any way.

In this case, there is a map where only objects which can be seen from above are presented or so to say, orthogonal projection of the objects above the surface. These properties are below the road, so the road as an object on the surface is presented on the map. This is why the properties below the road are not presented on the map at all. The position of the shops and their location inside the building is determined by the special drawings that presents the layout and identification number of the properties. This type of graphical presentation does not provide possibilities for spatial reference with the cadastral maps. These drawings only present the position of shopsinside the building. The reason for this type of registration is that on the cadastral maps can be found only objects that are above the surface. The buildings that are below the surface are not recorded on cadastral maps. On the other hand, even though the buildings are not registered on the maps, property rights are registered for these buildings.

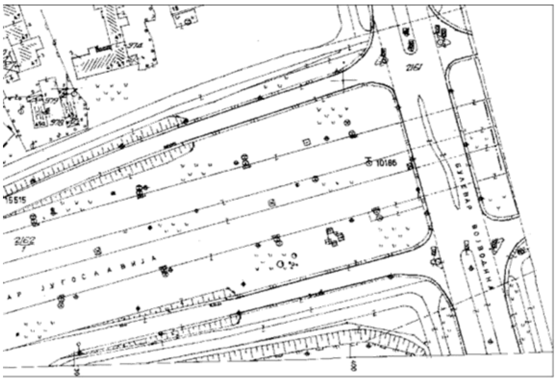

Figure 2. Map of the location

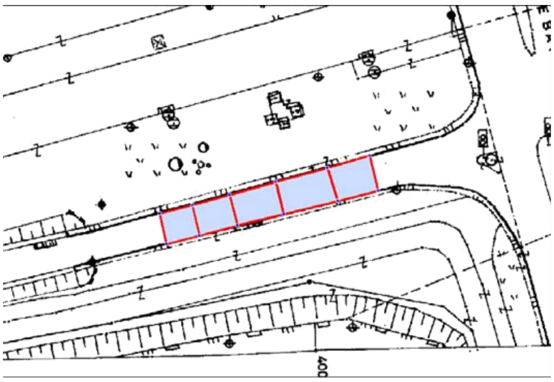

Figure 3. Building with the shops and its location within the parcel.

This particular building is partly above the surface, can be seen from a side, but presentation on the cadastral map still cannot be seen, because “big and more important” object is placed over this building (road). The road is presented on the map. The next picture is a part of the cadastral map which presents the parcel below where the building is settled.

On the other hand, property rights are always registered despite position of the buildings, below or under the surface. In this particular case, regardless of the property position, below the surface, property rights are registered in the cadastral database. There are several important moments concerning the registration of the property rights in this case, which should be emphasized, so the core of the problem could be more clearly seen.

The cadastral database has record which says that over the parcel with the number 2162/1 there is one building. However, since that building is under the surface it is not presented on the map. Missing building on the map creates feeling of insecurity in the registration system, since the location of the building form the records could not be determined. At this point a question could be raised: what if there are two or more buildings under the surface of this parcel, how could we know which building the record refers to? In this case that is the exact situation. There are two buildings on the same parcel and in cadastre database is registered just one building. All condominiums within those two buildings are registered like they are located in the same building.

The second crucial moment regarding property rights of the parcel is that the state is registered as an owner to the land, which actually is very logical since the roads in R. Macedonia are owned by the state.

When it comes to the property rights concerning condominiums (the separate properties inside the building) several irregularities of the registration could be underlined concerning property rights between parcels, building and condominiums. This complex of shops, has been established after the road construction, so at the beginning another question rises, how could be a building permit granted for building construction on the parcel which has the main goal to serve as a public road? In this case the problem is purely administrative since in reality the space actually exists and the building could be built on it, but the cadastral registration says that the parcel is a road and at the first glance we have very illogical situation. The building permit is granted for constructing a building on the parcel which has the same number with the parcel which delimitate the public road.

Furthermore, the owners of the condominiums have purchasing agreements made between them and investors of the building and based on those agreements they have registered the ownership rights in the cadastre offices. In the period when these properties were established the land, because it is urban land, was owned by the state. It is logical for the owners of the condominiums to have gained right to use the parcel. The thing that makes this registration even more interesting is that owners of the condominiums today but also in the past do not have registered *right to use* the parcel. The cadastre office has not registered any right on a behalf of the owners of the condominiums upon the parcel, ownership, use right, easement, lease nothing that will make relation between the building and the parcel and will secure rights to the owners of the shops. The buildings, as well as shops, are treated as a separate property from the parcel. This registration is not in line with the principles that define and delimit the property rights between the building and the land. The basic maxim in the period when the building was erected was *Superficieisolumcedit* so it is expected the *right to use* to be registered on the parcel. That right was never registered on the land and the situation has not changed yet.

It is interesting to state that regular registration of the property rights could not be made for these properties in the past also, because the *right to use urban land* could not be gained on the parcel with main purpose as public road. This means that this problem has not raised up with the change of the maxim from *Superficieisolumcedit* to *Superficies solo cedit.* The problem for this particular property, exists also in the period when urban land was state owned, so proper registration according the principles and rules could not be properly done for this particular property.In this case the actual problem can be located in 2D orientated approach.

The change of the basic maxim, in relation between the building and the parcel, has caused one more problem regarding property rights registration in the previous elaborated case. Since this parcel is a road, it cannot be made any privatization of the land. In this case only two options can be used, the owners of the building can establish a long lease on the land, or obtain easement. This means that the owners of the condominiums in the building will have to pay monthly or yearly a rent to the owner (if lease is used), in this case to R. Macedonia. However, establishment on a long lease in this situation it is not also an easy task, because the parcel is a public road and because the exact location of the parcel that should be leased is under the road. This even creates a problem which means that even the space where the lease will be established should be delimited in 3D. If the lease will be established on the area where the building is actually located, with the area, space, delimited in 2D then the actual road where cars drive, according the presentation in the cadastre, would be leased.

This type of situations is not very common but exists in reality. The cadastre system should provide mechanisms for registration of this properties since the main role of cadastre system is to register and secure property rights as well as to support property market.

Driven by this role Macedonian cadastre system has made certain changes in the structure and its domain. Since 2013, cadastre system has expanded its domain and in the definition for real estate properties has included infrastructure objects. By infrastructure objects the law refers to utility lines, underground or above ground objects, like pipes, cables, channels, roads etc.This change has provided opportunity to treat utility lines as any other real estate property and register property rights (ownership, lease, etc.) as same as it has been done on other properties like buildings or land. Infrastructure objects by its nature are not objects that are located within one cadastre parcels but are usually spread on more than one parcel, so this is clearly a step toward introduction of 3D cadastre system and slowly moving away from traditional 2D cadastre system.

2.2 CONSEQUENCE OF THE IRREGULAR REGISTRATION

The presented 3D situation and many other used in the research do not have records in cadastral database which provide security for all rights that exist or should exist in the reality. In this section of the paper two completely similar cases will be presented, but with the different outcomes. These cases will reveal the danger of not registered property rights.

It is about two passages under the building.

Both are very similar and spatially close one to another. The main function of these two tunnels is for communication, pedestrian roads. These pedestrian roads in the past and today also, are very frequently used. Over the roads in the both cases there are erected buildings about thirty years ago. The buildings were public property and were govern by public companies. The roads in R. Macedonia, in the past were socially owned, after 2001 become ownership of R. Macedonia.

The situations are presented on the maps:

Figure 4. Case 1

On the map, blue lines present the tunnel.

Few years ago, both buildings become privately owned. The land was also bought from the state and now it is also privately owned in both cases. The interesting thing is that the space which is marked with the blue line, the road, is registered as a part of the parcel on which the building is erected. When the building become privately owned the owner of the building also become owners of the space where the tunnels exist.

At the second case especially, the road was there for long years before the building was erected. When a building was built the space with the blue line was covered with the extension of the building. Both properties, the land and buildings were public property. At that time there was no problem with the property rights. Since all of the properties which intersect, the building, the parcel and the road were owned by the same owner, and no problem could arise.

Figure 5. Case 2

Later, with the privatization of land and registration of the property rights in the cadastre system, the part of the road was registered as a part of the parcel on which the building is erected. Because the building cannot be placed on two parcels, the land where the tunnels are situated become part of the parcel under the building. Today, the situation regarding ownership rights is clear and the tunnels are privately owned in both cases at least according the rights registered in the cadastre database. This registration is not presenting the real situation and all necessary rights are not secured with those registrations.

Something which makes these cases interesting is that space used for the road below the building in both cases is privately owned and the owner of the building has ownership right to that part of the road. The owner has right to place fence to protect his property. The exact thing happened to the first property presented. The owner files request to the municipality to close the tunnel and make shop instead of the tunnel. Since he has ownership of the space which is used for the passage and it is a part of his property the municipality issued permit the tunnel to be closed and the shop to be established. Today the tunnel is closed and there is a shop at the place where the tunnel existed years ago.

The tunnel, according the Macedonian mechanisms for registering the property rights could not be registered as a separate property below the building. Something which could be used in this situation for securing right of tunnel is an easement. In both cases there is no easement registered in the cadastreregarding the tunnel. Many 3D situations are similarly registered and very often property rights are insecure. This is just one of the examples that could be met in the reality. Many of the buildings which are intersecting with the roads are registered as this one.

3. CONCLUSION

The research has intention to provide an insight intoregistration of 3D situations into cadastre system from legal and technical aspect. Overview of the legal side focused of property rights that create relation between objects erected on a parcel and the parcel itself, while technical side is focusing on spatial representation of the properties.

From all analysed3D situations within this research (not just presented one) several conclusions regarding registrations can be made:

- very often the rights upon the land in 3D situations are not registered. This land very often is owned by R. Macedonia. The buildings erected on this land are usually privately owned. The right which allowed the building owner to have building on the state-owned land is not registered in the cadastre as well.
- registration of the building in the cadastre records which exceeds the parcel boundaries, surface borders, is not possible even if the building is below the surface. The building cannotbe spreadover two parcels.
- the easement right in 3D situations is very seldom used, if it is used at all (that kind of case was not met during the research) to protect or secure the existence of the building on the parcel with separate owner then the owner of the building.
- the actual space where the easement refers to is not registered at all on the cadastre maps or other documents.
- any building which is placed below the surface is not presented on the cadastre maps.
- Infrastructure objects (utility lines, communication lines etc.) are legally proclaimed as real estate and property rights are registered as same as the buildings and land. The infrastructure objects can exceed cadastre borders and be spread on more than one cadastre parcel. Only in this situation the construction can be legally spared on more than one cadastre parcel.

Overall conclusion for registration of 3D situations is that property rights and actual registration of the properties on the maps is very poorly done. It is necessary to improve all aspects of the registration processes and securing property rights. The registration of properties and property rights will provide greater security, less disputes and clearer situation for all interested parties. Development or transformation of traditional 2D cadastre system into 3D system is difficult process which needs to be made very carefully and based on very deep and comprehensive analysis.

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Republic of Macedonia
AGENCY FOR REAL ESTATE CADASTRE

KATACTAP

PROFESSIONAL USERS

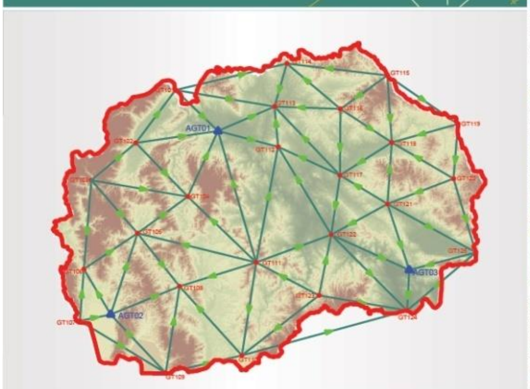
DISTRIBUTION GEOPORTAL

NSDI GEOPORTAL

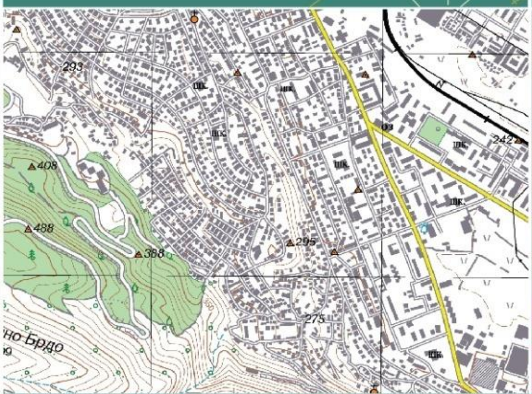
MACEDONIAN POSITIONING SYSTEM

VIEWING APPLICATION STATUS

PROPERTY LIST SEARCH



GEODETIC REFERENCE NETWORKS



TOPOGRAPHICS MAPS

REGISTRE OF PRICES AND LEASES

MOBILE APPLICATION iKAT

PUBLIC RELATIONS

PUBLIC PROCUREMENTS

TITLE – VALUE – UTILIZATION – FUNCTIONALITY, A NEW NECESSITY IN THE NATIONAL CADASTER SYSTEM

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Macedonian cadaster system and the position in the current real estate administration system imposes a role to base its service domain to the practical service requirements, with open capacity and service efficiency. On the other hand, each service component should be unambiguous, with clear goal for service outputs, to provide legal, technical and technological legitimacy.

Following the effort for modernization of cadaster system (system with complex objects, and role to support the services oriented toward real estate) with effort for wide and legitimate domain of service policy are only a part of system ambitions.

Toprovide closer knowledge about the needs of an integrated concept with market oriented service, the paper will focus on invariant relations on basic pillars title – value – use – functionality. The discussed relations are product of long years of research which extends current system views, oriented only toward the title as one of the pillars.

Keywords: Cadastre, real estate, market oriented service.

1. ASSUMPTIONS AND DIRECTIONS

The complexity of real estates and processing of real estates in cadastre system in Macedonia, in the periods when requirements/needs are pointing toward moredynamic service, initiates ideas for rethinking of system construction to get it ready to accept and process new relations in real property administration at a national level. In order to make more clear explanation regarding this directions in the paper dominant indicators which will provide opportunity to give insight from legal, technical and management aspectare going to be presented.

Nacional cadastre system with its own concept and established system levels has a valuable position in national legal and economics system. Considering that basic object in the system has high complexity, it is necessary to be clearly/precisely defined according the domain and service policy of cadastre system.To identify real estate properties which come out of the definition for real estate, there should be a strong matrix, by which on a simple way it will be recognised and extracted as spatial object interesting for cadastre system domain.

Even though in current cadastre system basic entities has their owncomponents, those components have peripheral significance in service performance of thecadastre.It is evident that in cadastre system real estate properties are identified, registered,with characteristicsoriented toward main pillar, the title, and based on that kind of concept, mechanisms are created for supporting services policy.

Analysis will be conducted, for the current status of cadastre system with only one pillar, with relations which have only one direction, toward the title, and those relations will be critically observed with an effort for implementing new pillars.

The system properties around the title have created support from legal and technical framework coming out of the current legal acts which emphasizereal estate property and title.This strong concept for creation of cadastre system has security, legal and technical closure which makes it authoritative in completing service politics.

However, concentrating activities only toward the title, imposes restriction of the possibilities for wider service domain.As it was noticed, services around property titles are existing and well-functioning,established on a principle of trust on data, legitimacy and constitution.In this sense it should be emphasized downsides that the system can create by principle of *trust in data* and at the same time possibility for correction of data caused by technical mistakes. This two principles *trust in data* and error *correction* are contradicting.

Previous discussions which came out of the contradicting principles (trust in data, and error correction) as well as concentrated relations in service policy toward the property title create need to test it on practical example. This practical example is made on single family house.It is important to emphasize, to stabilise legitimacy for each transaction, internal or external, and to have it in consideration that existence of real pillar relations will have tocontribute for providing procedures, principles and mechanisms for compensation from any aspect.

Current legal definitions for real estate properties threats building as real estate properties even though should be emphasized that until now there is no registration of a property classified as a building. Registrations in the cadastre system this type of property (building) are introduced through differentiation of the building into separate segments, recognisedas condominiums, which in the definition are explicitly stipulated as a real estate properties.This aforementioned condominiums (functional segments of the building) are fundament for conducting of all transactions related with the real estate properties.

This approach is not fully implemented in a case of a single family house, where pillar *title*, is not complemented on an equal level with additional pillar *functionality*, which at the end creates inconsistency with the reality and additionally reflects on a results from property appraisal.

The existing systems concept with the title as the only affirmed pillar concentrated legal-technical and technological norms with sufficient formalization in providing security and protection of real estate rights regarding title.However, it should be noted that property market transactionsmore frequently imposeneed for more prospectsincreation of newpillars which will be foundationfor creating more secure property transactions on the property market.

The affirmation of relations between pillars are competences whose powerwill not allow to make any changesby activating service in the cadastre system for *error correction* because by changes the data in the cadastre records through*error correction* will be reflecteed on already conducted transactions.

How big the risk is, if with the mechanism of “error correction” is applied and registered property title is changed?Technically speaking,the wrong title could be part of alegitimate property transaction, because it is based on data from the cadastre system which is guided according the principle of *faith in cadastre data*.

Through legal norms for property right protection, there are possibilities if certain error in cadastre data is detected, to be adequately corrected and by that fulfilling the institute for protection of property and property rights as a whole. The question remains, however, what about the consequences, losses, the decreasing of the system authority and the order of inconsistencies that have also the legal, technical and value implications?

2. SPECIAL ASPECTS OF THE TECHNOLOGICAL LEVELS OF CADASTRE SYSTEM

The intention to present the national cadastre system, while moving only within the legal framework defined by the law on cadastre, we will set an open dialogue between the law and the expected service policies which come out of the law.

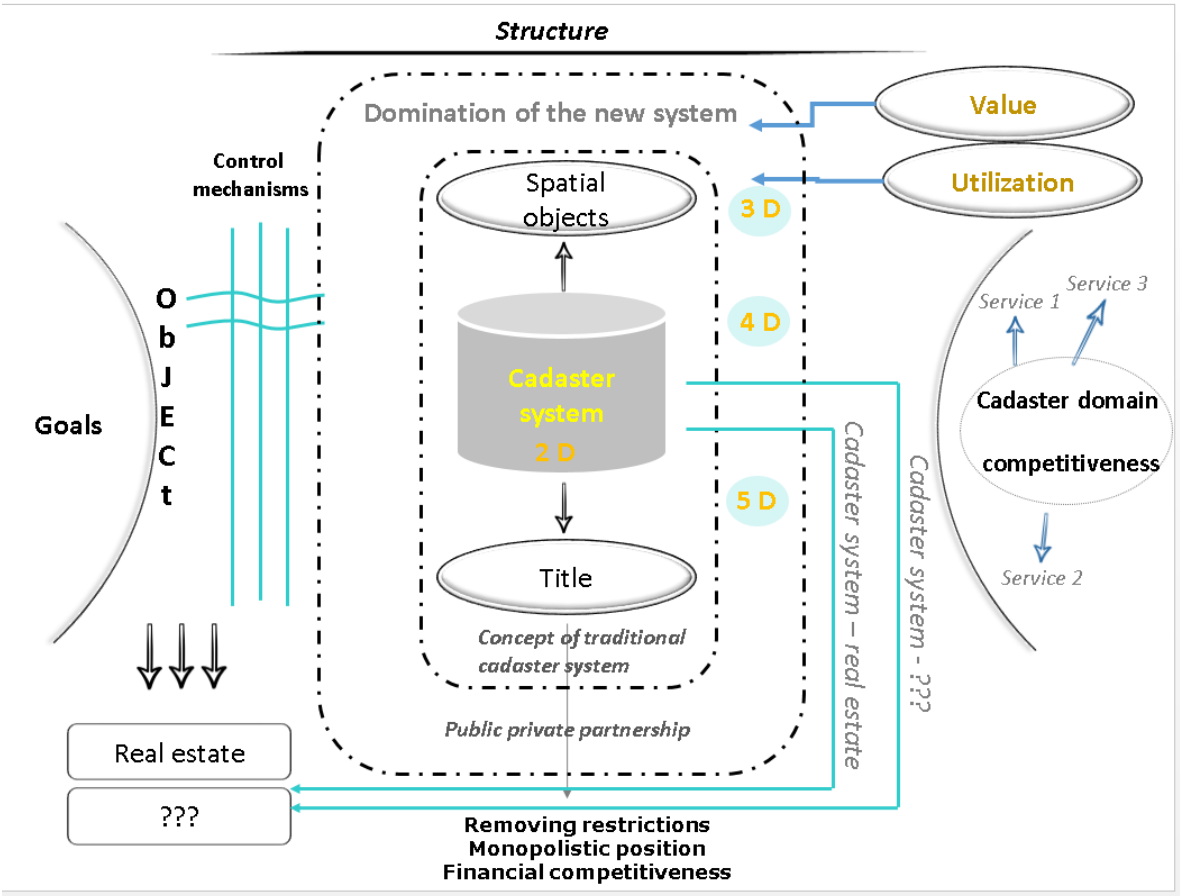

Figure 1. National cadastre system

By describing development of the cadastre system on the picture 1.0 is presented so call concept of dual shell, following genetic properties of the real estate. Chronologically, current status of the cadastre system raise discussions for its sustainability in the future, if it keeps the same level of administrative functioning and power concentration. There are always two approaches, one that promotes current system setup without any significant changes, and the second progressive one, which promote introducing active-operative principles based on effective economic concepts and introduction on new business models in the service policy. The progressive models are present even more because there organizational concept allows access of public private partnership, through new positions and relations between active parties and progress, since there is new and fresh capital involved.

By accepting components of the second cell of the shell, they will, of course, impose systemic changes and new policies in organization, positioning the system at the national level, transformation of external users as internal users, market oriented financial models,real time services, real time service fees calculations etc.

It is anticipated that this concept will make room and will contribute to the rapid implementation of competitive service policies, which are non-restrictive and are promoting recognition and incorporation of new market challenges as an authoritative influence on real estate inaccomplishingend user interests. If the first cell of the shell opens opportunities for entry of new services and actions, recognized and emerged as affirmation of the pillar*value* and pillar*utilization*, it can be expected that will be accomplished better and more stable system construction. This directions will provide new approaches which will be initiated new correlations and new connections between old and new system components.

What will rise and/or contribute the presence of this concept?

By upgrading cadastre system with all four pillars (title- value-utilization-functionality) will expand system domain and will provide legitimacy and higher security on all real estate transactions. Additional significant effects,with implementation of mentioned four pillars, will berecognised through introduction of 3D, 4D and 5D cadastre concepts. As an example which initiate upgrade of the cadastre system is the new technologies in construction and utilization of the space, one of the current implemented technologies that have been introduced in the new buildings are dynamic parking spaces, something that cadastre registration should be able to accept.

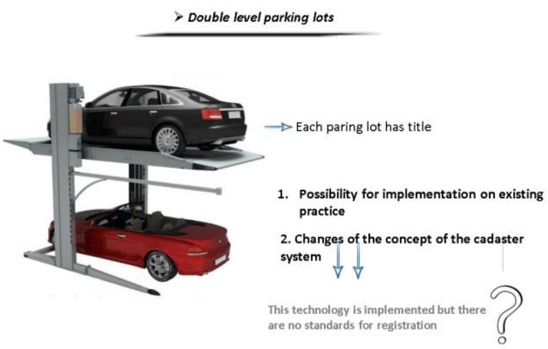

Figure 2. Dynamic parking spaces - needs for upgrade of the cadastre system

It is evident that the double-shell has multifunctional relations, which this paper will focus only on the invariant actions, stabile relations for transferring of unique properties between four pillars, through which we will promote the *four-leaf clover concept*.

What essentially this symbology should contribute to the affirmative and operational system conceptualization?

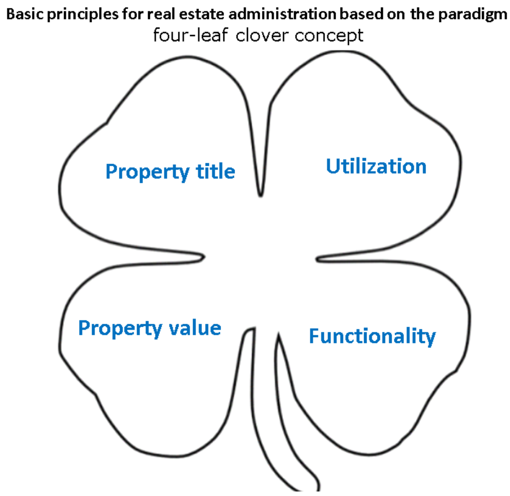

Figure 3. Four leaf clover concept

It is a fact that in the current cadaster system, apparently this concept exists, but with only one direction, to protect the property title.In this context, will be needed differentiation of actions for each pillar as well as definition of set of real estate properties belonging to that particular pillar. It is about activities located and activated through pillars*Title – Value-Utilization– Functionality.* This means that the approach must provide rotation of services and coordination with each pillar.

The affirmation of the concept in the future should create new views with legal-technical predispositions to any new embedded service line, which basically means a complete change of the existing philosophy of the system itself. In this respect, the principles on which the system concept is built upon will have to obtain new, reformattedand adequate principles. It is a significant need which aimed at stabilization,more precisely to provide legitimacy for each executed transaction. The executed transaction cannot be conditioned solely on firm and constitutive principles related exclusively to the property title. Each change made in the cadaster records has to be reflected on other records, data, outcomes that are influenced by the changes that has been made.

3. PROCESSES WITH *TITLE* COMPONENT

The pillar *title* have full protectionin the existing traditional system andpractice, by fulfilling the basic principles in administering with the title and rights associated with it. Currently there are many strongly developed procedures and guidelines for securing real estate property title. The existing situation within legal framework and cadaster system have important elements and sufficient active mechanisms for accessing procedures for acquiring, protectionand administering with property rights. Practically, property rights transaction in the current cadaster system are conducted efficiently and without obstructions.

4. PROCESSES WITH COMPONENT *VALUE*

The processes that engage pillar *Value*, are concentrate in transforming real estate in value, by implementing stabile and calibrate approaches for uniqueness in verification, and application of the appraised value in property transactions.In case of established rights, acquired title in the cadaster system and conducted transaction, any instability in the registration will initiate significant consequences in the transactions. For these reasons, the existing concept that has a unique orientation towards the acquisition and protection of property rights must be adjusted technically and legally in the protection of conducted transactions.

If we follow the technological line of property valuation, it is evident that multifunctional component of the value component is present in many activities that are value based (Picture 1.2). The basic real estate characteristics (area, title, type of building etc.) which are essential components in property valuation should be stable and unchanged since any changes cause appraised value to be changed as well.

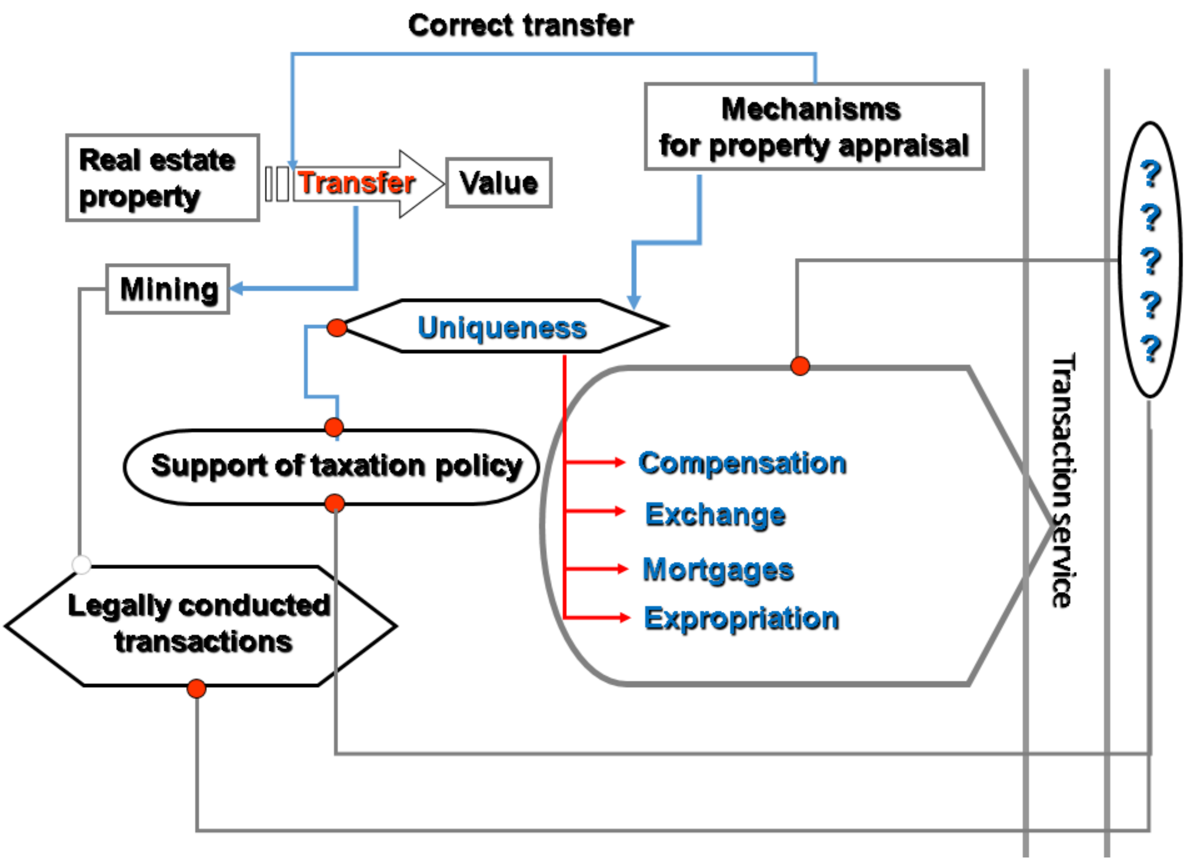

Figure 4. Value based activities

4. PROCESSES WITH COMPONENT *FUNCTIONALITY*

Functionality is technologically understood as a delimitatedspace of the construction/building where life cycles take place, in accordance with the classification (single family house, apartment, retail store etc.) of the real estate. Those classesinitiate the needs of precise definition as mechanisms through which they will uniquely determine and used in determining the macro and micro cofactor sets and their influence onproperty value.

It has to be emphasized that in the current registration of single family houses, separate functional units as it can exist, are not precisely defined, or precise mechanisms are not established for making distinction for each functional unit, mechanisms which addressing separate unit can be uniquely recognized with its functionality and independence.

Apartmentbuildings have much clearer situation where each apparent is clearly delimited and defined, and numeration of the apartments clearly addresses it.

In order to further clarify the need and importance of uniqueness in the addressing, we will make an example and discussions about single family house with the following components:

- Ground floor, apartment 00,
- Floor 1, apartment 00
- Attic, apartment 00

In practice this concept of addressing cannot clearly, uniquely give an insight for functionality of each separate part of the building. If we observe the structure of the addressing model it is inexplicit if the floor can be accepted as a separator for different functional units. In the given example, the only differences between each line in the registration is the floor. It is clear that the floor cannot be the indicator which should separate functional units, since one functional unit can be extended on more than one floor.

From the example of Figure 1.3, it is evident that clear picture of the functionality has great significance in the appraisedproperty value. The difference between correct and incorrect functionality recognition, is 57000 euro which has a significant effect in terms of the market transaction. The numbers are extracted from an example of property valuation that took place on the market.

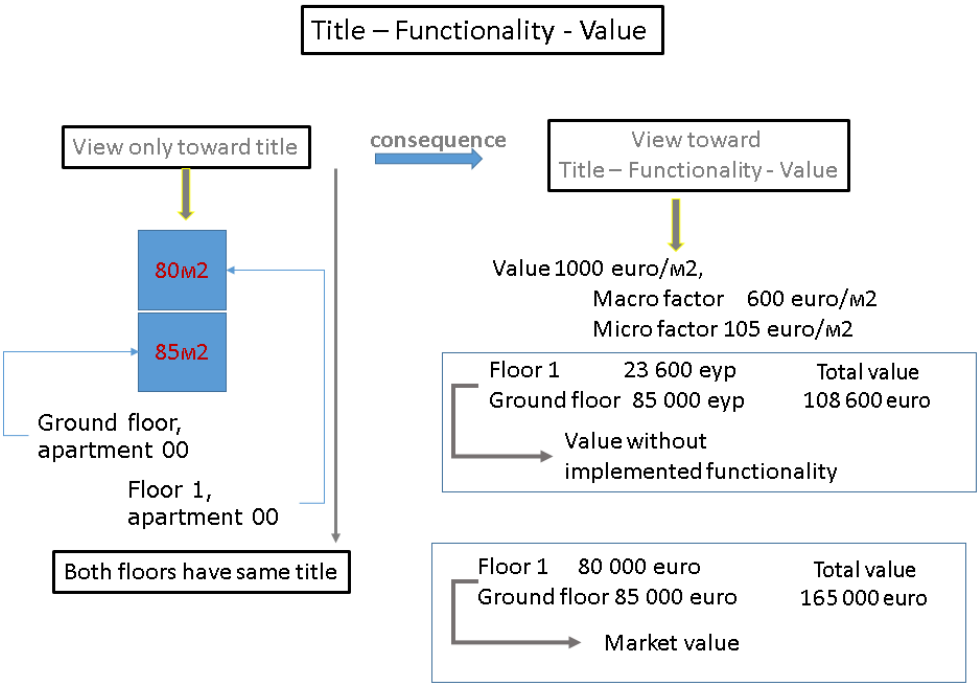

Figure 5. Example of functionality

4. PROCESSES WITH COMPONENT *UTILIZATION*

The classification of the building utilization has intention to differentiate object by type of activities that are going to be practiced within the buildings. In this respect,according the importance of the buildings, precise guidelines are established for their classification, but for the specific parts/units (condominiums) within the building, as objects of all further activities regarding valuation and transaction, there is a simple/global not very detail classification.

The buildings according law for cadaster are classified in many classes, but we will focus only on classification of *commercial buildings* with sub-classification *retail stores*.In this case, according the legal classification, retail stores classification it is referring to the building as a whole, which is not very convenient since there can be many retail stores in one building, the classification of retail stores should come in the section for classification of separate parts/units of the building.

In the same law for cadaster, in the section for classification of separate units there is classification *commercial premises*, which means offices, retail shops, stores, restaurants etc. At the same time, according the classification in the methodology for property valuation with this different classifications (retail shops, offices etc.) the results in value is very different.

It is important to be emphasized that classification *commercial premises* which has to be used by the real estate valuer in property valuation, gives a space for free judgment of the classification group. However, taking in consideration for dynamic change of the actual exploitation of commercial premise from retail store to office, it has significant property value implications. This condition is much highlighted in case of mortgages. Property value for this different types of classifications, in the moment of mortgaging property and at some later stage when premises have different utilization in practice, but still within classification *commercial premises*, have very different value which can cause big financial loss.

Values differences caused by changes in the actual property utilization can go up to 5000-6000 euros/m2 which is very significant price difference.

In order to avoid this differences between classification types there should be synchronization between law for cadaster and law for property valuation where same classes will be stipulated in both laws.

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IMPACT OF ENERGY CLASSES ON THE REAL ESTATE MARKET IN MACEDONIA

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This paper introduces concepts and methods for determination of the market value of the real estate in Republic of Macedonia, from the point of view of estimation of their energy certificate. The energy efficiency of buildings and their energy certificates classification in appropriate energetic classes have become very actual topics in the last years in Macedonia. Research up to date represent that the location of the building has the biggest influence on the market value of real estates. Neither the type of construction, neither any other aspect which includes the energy have not been included in the buildings' assessment, as a part of the energy classification segment.

The research showed that the energy efficient buildings offer possibilities for measurable financial benefits comparing to the classical non-efficient buildings, from the point of view of higher rentals and prices, lower operational costs etc. Furthermore, a legitimacy of embedding the cofactor for energy efficiency classes in the National methodology for determination of the real estate value is emphasized and certain recommendations for a particular implementation are presented. The information weather the real estate possess an energy efficiency certificate is a necessary information for the real estate estimation.

Based on the numerous world experiences, as well as the analysed examples, a special variable is created for each energy class. Further division to fifteen subclasses in the energy certificate is suggested. The first subclass of the class C (with 51 to 67 kWh/m^2 annual) is proposed as a referent one.

Keywords: real estate, estimation of real estate, energy classes, energy efficient building, energy certificate

1. INTRODUCTION

The energy efficiency of buildings and their energy certificates classification in appropriate energetic classes have become very actual and interesting topics in the last years in Macedonia. Therefore, this paper is a trial to sublimate the influences of the energy classes on the market price of the real estate in Republic of Macedonia.

With entering into force of the new by-laws and secondary legislative for energy efficiency in buildings in Republic of Macedonia (Rulebook on energy characteristics of buildings, and Rulebook on energy auditors [18]), a period of essential revision in the treatment of the real estate, their market price and value is forthcoming. On the other hand, the energy class of the building, as a sublimate of many parameters influencing the value and the price of the building, contained in the certificate for energy characteristics of the buildings, is not considered in the Methodology for estimation of the market value of the real estate property, [16].

Research up to date represents that the location of the building has the biggest influence on the market value of real estates. Neither the type of construction, neither any other aspect which includes the energy efficiency (orientation of the building, its energy performances, the possibility of saving any type of energy for heating and cooling, the use of renewable energy sources etc.) have not been included in the buildings' assessment, as a part of the energy classification segment.

2. WORLD STATE OF THE ART

The available literature about the value of the energy classified commercial and residential buildings is in a relatively small number. Studies show positive impact. Nevertheless, a consensus about the dimensions of that impact is not obtained. One of the first studies is Banfi et al. [4], who investigated the willingness of the inhabitants to pay more for energy efficient buildings in Switzerland, based on random choice and not on market data. Around 8% were ready to pay for improvement of the ventilation in new and existing buildings, while 6-7% for facade insulation. First study that analyses the data of the real estate market is done in the Australian department for environment, water heritage and culture [3]. According to this study, in 2005, for each additional 0.5 points on the scale of energy ranging, the prices of the houses increase for 1.23% in 2005, while for 1.91% in 2006. Brounen and Kok, [5], investigated the influence of the energy classification in houses in Holland. Bigger buildings have lower chances for energy classification, which is connected to the harder market conditions. Houses with A, B or C energy class (green houses) obtain higher price for 3,7% ceteris paribus. Especially important price obtain buildings of class „A", which have market price for 10,2 % higher than similar buildings of class „D". On the other hand, houses of class „G" were sold for 5% less than the ones of class „D". Zheng et al. [21], investigating the eco-friendly houses in China, concluded that the green real estate have starting higher price, but later on their sale or rent for decreased prices. This may be a consequence that sold green buildings were not energy efficient. They recommend an official system of energy efficient classification. All of these studies agree on the positive connection among the real estate values and the energy efficiency. However, studies of Yoshida and Suguira, [20], and Amecke, [2], present mixed results. According to Yoshida and Suguira, while the greener buildings are sold for higher prices in general, if the age and quality of the building are controlled, this influence disappears, and in some cases the possession of energy efficient class may introduce a decrease in the market price. Eichholtz, Kok & Quigley, [9], find a significant positive effect for buildings which were certified "green": green labels increase effective rent (rent adjusted for occupancy) by 7% and sales prices by 16%. The summary of research results across the world is presented in the Table 1.

The theoretical research based on the numerous world experiences, as well as the analysed examples, confirmed that there must be a link, i.e. mutual correlation between the energy characteristics of the buildings presented in the certificates and their market value. The energy class given in the certificate should have significant impact on the price for buying or rent of the real estate. The estimation performed is based on the analysed specific information for particular countries and the differences in the implemented schemes for certification, aiming to support the interpretation of the results of the economic analysis in this research. The low-budget design and the demands in the certificate, insufficient realization, and a low public conscience for its acceptance, or the quality of the staff involved in the energy audits, may influence on the manner and the size of the certificate's impact on the market.

Table 1. World research in estimation of energy efficient buildings

no.	authors	country	real estate	type of transaction	main results
1	Brouen & Kok, 2011	Holland	residential	sales	Buildings certified as green obtain approx. 3,7% premium
2	ABS, 2008	Australia	residential	sales	Building prices increase of 1.2% in 2005 and 1.91% in 2006 for each level on EE scale
3	Yoshida & Suguira, 2011	Japan	residential	sales	Green buildings are sold at a price discount of approx. 5.5%
4	Zheng et al., 2011	China	residential	sales	Green buildings receive an initial sales price premium, but resell or let at discount
5	Amecke, 2012	Germany	residential	sales	Energy certificates have a limited effect on purchasing decisions
6	Hyland et al., 2012	Ireland	residential	sales or rent	Certified real estate have only 2% rental premium and 11% higher price premium
7	Kok & Jennen, 2011	Holland	commercial	rent	Energy inefficient buildings trade at a 6.5% discount
8	Eichhlotz, Kok,Quigley, 2010	USA	commercial	sales or rent	Green buildings receive approx. a 3% rental premium and 16% price premium
9	Reichardt et al., 2012	USA	commercial	rent	Energy efficient buildings have higher price for 2,5-2,9% averagely
10	Wiley et al., 2008	USA	commercial	sales or rent	Rental premium for green buildings is between 7% and 17%
11	Fuerst and McAllister, 2011	USA	commercial	sales or rent	Rental price premium of 4-5% and sales price premium of approx. 30% for certified green buildings
12	Fuerst and McAllister, 2011	Great Britain	commercial	sales or rent	Energy efficiency certificates had no significant effect on the financial performance of properties
13	Chegut et al., 2011	Great Britain	commercial	sales or rent	EE buildings receive 21% rental premium and 26% price premium. Increasing the number of green buildings decreases the premium.

2.1 METHODOLOGY

In order to estimate the value of specific attributes of a property whose prices are not directly observed, hedonic regression techniques are used in general. As presented by the researchers in this field, hedonic prices are revealed by the observed price of the house and the attributes associated with it. The implicit prices of the characteristics are calculated by regressing the observed prices of a building on its attributes (number of bedrooms, bathrooms, size, location etc.). In the hedonic regression, the size of the coefficient on each variable represents the value each characteristic contributes to overall value. A hedonic regression takes the following form:

$$\mathrm{p} = f(x,n,c)+\varepsilon \qquad (1)$$

where,

p - price of the property,

x - vector with buildings characteristics,

n - vector with location characteristics,

c – energy class of the property in the energy certificate,

ε – error term.

Running this regression should yield an estimate of the implicit value of a better energy efficient building.

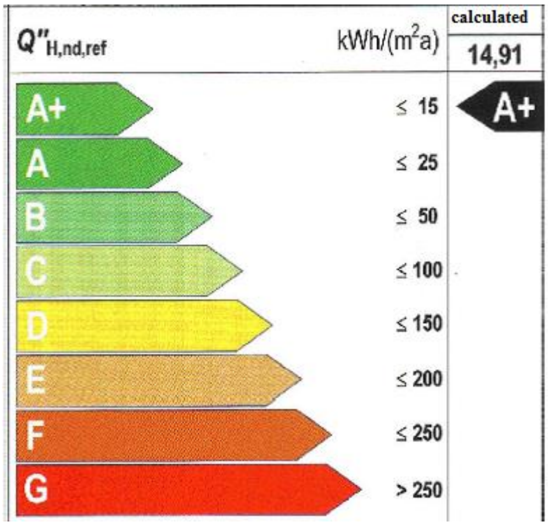

Figure 1. Energy class for a residential building in the energy certificate

The procedure of compulsory energy labelling of residential and commercial real estate is relatively new in Macedonia, and not many buildings do have an energy certificate with specified energy consumption. Furthermore, for those buildings that already have certificate, not all owners advertise it when listing the property for sale or rent. Thus, it is possible that the sample used in this study is subject to selection bias, meaning it would be unsafe to apply the inferences from a simple hedonic regression to unobserved groups, i.e., the results may apply only to an atypical set of houses.

3. EMBEDDING ENERGY CLASS IN ESTIMATION

Due to the short period for enforcement of the energy efficiency certification in Macedonia, there is no effective database which would be useful for detail analysis and application of the methodology of hedonic regression.

However, based on the research in the world and Europe, the Macedonian relatively new practice of energy certification can be successfully included in the estimation of the real estate market price: If the energy ranging is introduced as a scale with 15 levels, from the highest A+ class to the lowest G class, it is recommended that every level differs from the subsequent one for 1%. The first subclass of the class C (with 51 to 67 kWh/m^2 annual consumption for heating) is proposed as a referent one. The real estate properties classified as low-energy houses should have market value of 1 to 4 % higher than the referent one, while the properties certified as F and G energy classes should have a price discount of 9 to 11 % in comparison with the referent class, ceteris paribus. Exemplify, for the estimation of the real estate value, the estimators can follow the instructions in Table 2, Aceski [1].

Modelling of the energy certificate as a continuous variable in the estimation of the property price for rent, would introduce the following mathematics: for each lower level in the energy efficiency on the scale of 15 subclasses (i.e. each calculated or spent 15 kWh/m^2 annually) for the analysed property, its rental price should be decreased for 0.5%.

Table 2. Embedding the co-factor of energy class

energy class	energy consumption [kWh/m^2 a]	increase /decrease in selling price of the property
A+	≤ 15	+4 %
A	15 ÷ 25	+3 %
B	26 ÷ 38	+2 %
	39 ÷ 50	+1 %
C	**51 ÷ 67**	**referent value**
	68 ÷ 84	-1 %
	85 ÷ 100	-2 %
D	101 ÷ 117	-3 %
	118 ÷ 134	-4 %
	135 ÷ 150	-5 %
E	151 ÷ 167	-6 %
	168 ÷ 184	-7%
	185 ÷ 200	-8%
F	201 ÷ 225	-9 %
	226 ÷ 250	-10 %
G	≥ 250	-11 %

4. ANALYSIS OF EXAMPLES

Estimation of two new designed neighbouring commercial buildings has been performed. All the parameters for the buildings are identical: location (Old Bazaar in Prilep), time of construction, choice and thickness of the materials for the structural system, as well as for the thermal insulation, identical design conditions, and identical future conditions for exploiting and maintenance.

The main designs and elaborates for energy efficiency have been performed for both buildings. According to the calculated energy needed for heating, they have been classified in the appropriate energy class, see Table 3, and adequate measures for energy efficiency are recommended. Furthermore, the thermal insulation has been treated equally: identical roofs are designed, identical external walls of ceramic blocks are proposed, with equal thickness of polystiren from the external side. Therefore, the thermal coefficienmts for the walls, for the roof and for the floors are identical for both buildings.

Table 3 Characteristic values in the Elaborates of energy efficiency for both buildings

	Building 1	Building 2
net heated area [m^2]	205	111
envelope area [m^2]	307,2	218,7
heated volume [m^3]	590	319
form factor [m^{-1}]	0,406	0,551
U_{wall}[W/m^{2}K]	0,33	0,33
U_{roof} [W/m^{2}K]	0,18	0,18
U_{floor} [W/m^{2}K]	0,26	0,26
U_{window}[W/m^{2}K]	1,8	1,8
coefficient of specific heat losses	0,76	0,686
energy demands for heating [kWh/m^2 a]	48,5	57,5
energy class [W/m^{2}K]	**class B**	**class C**

Based on all included works (soil works, masonry works, concrete works, reinforcement works, roofing works, insulating works, carpentry works, tinsmith works and other remaining works) total prices for investment of the buildings are obtained. Total prices, according to the bills of quantities in the main designs for both buildings, are shown in Table 4.

Table 4. Bill of quantities for both buildings

	Building 1	Building 2
gross area [m^2]	122	64
total price with VAT included [MKD]	5.352.463,36	2.796.293,00
price per m^2 [MKD/ m^2]	43.872	43692
price per m^2 [euros/ m^2]	713,4	710,4

For the purposes of this research, estimations of both buildings have been performed according to the National methodology for estimation of real estate properties, [16], respecting the directions for commercial buildings. According to the actual methodology, many important influent parameters cannot be included in the buildings estimation. Namely, the windows are the weakest part of the building envelope, in terms of energy efficiency. Depending on the ratio glass/frame, their area, frame material, double or triple glazing, (not) filling with argon or krypton, they are responsible for the huge amount of heat losses. According to the methodology, the windows are classified into two main groups only, depending on their height.

Furthermore, according to the methodology, facades with marble tiles have the highest price in the property estimation, due to the high market price of the marble. But the marble is not the most adequate material in terms of heating insulation. Few types of façade systems are included in the methodology. The buildings are in the construction phase; therefore no amortization is included in the estimation. Their location is in the central city area of Prilep and they are priced in the first zone according to the m^2 functional area. The factor which refers to the frequency of the location is not included, due to the fact that both buildings are at the same location. For the same factor, the final values of the properties will be proportionally increased. The National methodology for estimation of properties estimates the factor of attractiveness, which does not include the energy efficiency of the building.

The final values of the estimation for both commercial properties, based on the detail estimations, are presented in Table 5.

Table 5. Estimation of both buildings

	Building 1	Building 2
functional area [m^2]	307	168
value of tax base [euros]	125.106	68.556
price per square meter [euros/ m^2]	407,5	408

According to the presented numerical data for the example buildings, some conclusions and appropriate recommendations for embedment of the parameter energy class in the real estate property estimation are given. Different energy demands for both properties are calculated for the same location of the buildings, identical inbuilt materials, and same design outdoor and indoor temperatures. The smaller property has greater energy spending per square meter heated area than the bigger one. The bills of quantities in the main designs give the initial investment for the materials and their construction. Approximately same prices are calculated for both properties, per square meter gross area in the layout. The energy class has no influence on the initial investment for buildings. However, the better energy efficiency, the higher property value must be included in the estimation, in order to emphasise the future savings in the exploiting and maintenance of the building. The energy efficiency should be treated in a similar way as the exclusivity in the estimation of real property value.

Applying the recommendations showed in the Table 2 in the presented examples of two commercial properties, after the embedment of the energy class in the estimation of the property's value, the real market price for both buildings is obtained, Table 6.

Table 6. Estimation of both buildings with included energy class

	Building 1	Building 2
functional area [m^2]	307	168
value of tax base without energy class [euros]	125.106	68.556
energy demands for heating [kWh/m^2 a]	48,5	57,5
energy class [W/m^2K]	class B	class C
increase of the value due to the energy class	+ 1 %	/
value of tax base with included energy class [€]	126.357	68.556
price per square meter [euros/ m^2]	411,5	408

As presented in the Table 6, with inclusion of the co-factor energy class in the estimation of the two buildings, their price and their correlation changes. The price of the second building is not changed, because it belongs to the proposed referent energy class for estimations. The price of the first building has been increased for 4 euros/m^2. Apparently, the difference is not very significant. However, the fact that both properties belong to the group of energy efficient buildings should not be neglected. According to the Rulebook [18], the lowest permitted energy class for new buildings is class C (with maximum annual demand of energy for heating of 100 kWh/m^2).

For numerous existing buildings in Macedonia, as well as for the relatively new ones, since the requirements for energy savings were not obliged, the energy class is worse than E. That would meant that if they are eventually repaired and energy conservation measures are performed in order to satisfy the requirements of the Rulebook, their market value can be increased for more than 10%, for all other identical parameters (ceteris paribus).

5. SUMMARY AND CONCLUSIONS

The results of the research in this paper indicate towards implementation of new aspects and measures in real estate assessment, depending on their energy class.

The contemporary sustainable energy efficient building must obtain its real valuation at the market, in comparison to its "sisters" which have identical form, architecture, location and function, but with weak energy properties. In this direction, the inclusiveness of the co-factor of energy class in the national methodology for determination of real estate is proposed, with accurately specified parameters. The research showed that the energy efficient buildings offer possibilities for measurable financial benefits comparing to the classical non-efficient buildings, from the point of view of higher rentals and prices, lower operational costs etc.

Furthermore, a legitimacy of embedding the co-factor for energy efficiency classes in the National methodology for determination of the real estate value is emphasized and certain recommendations for a particular implementation are presented. A special variable is created for each energy class, from A+ to G, and further division to fifteen subclasses is suggested. The first subclass of the class C (with 51 to 67 kWh/m^2 annual) is proposed as a referent one. The real estate properties classified as low-energy houses should have market value of 1 to 4 % higher than the referent one, while the properties certified as F and G energy classes should have a price discount of 9 to 11 % in comparison with the referent class, ceteris paribus.

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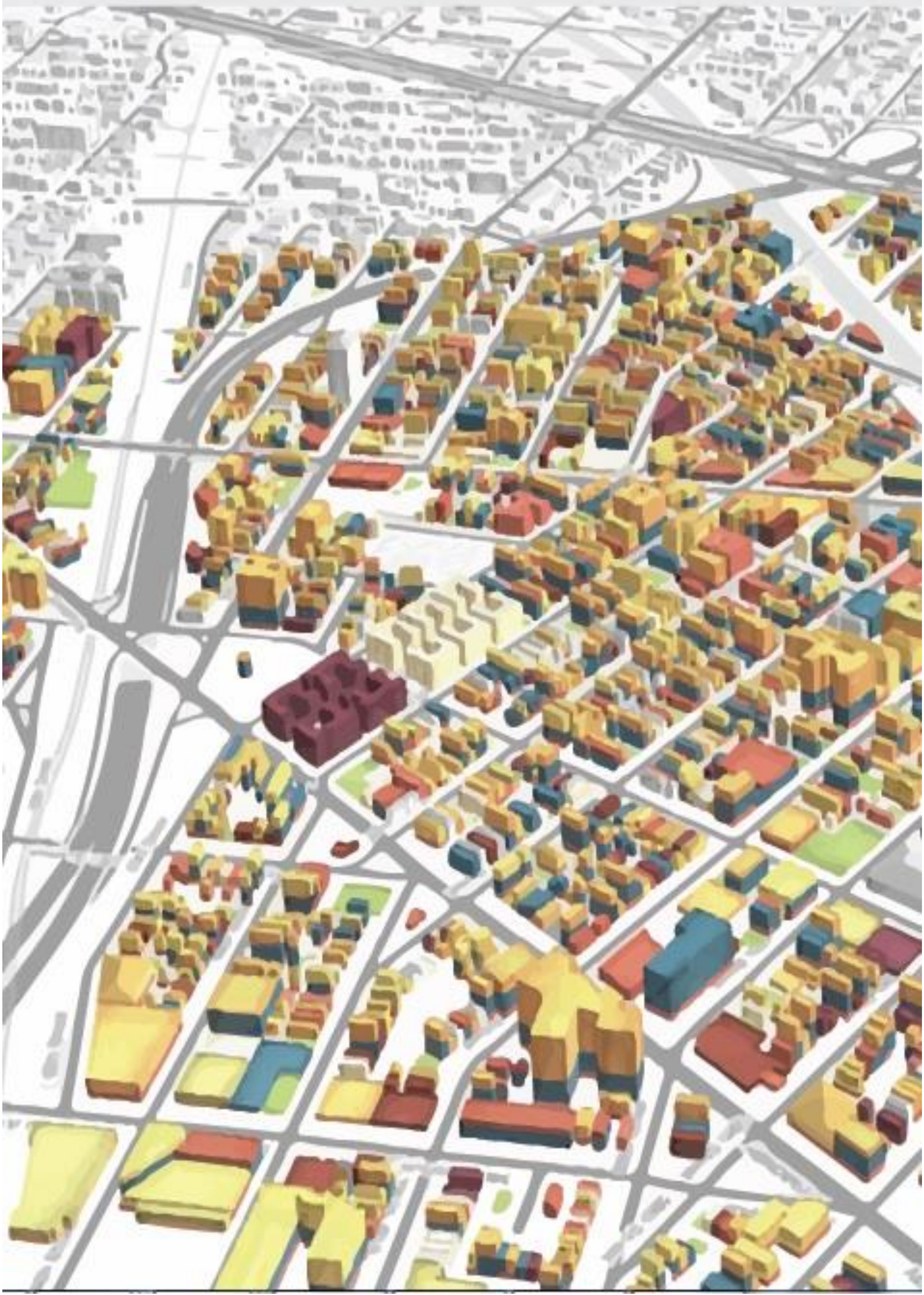

INFLUENCE OF PARKS AND URBAN FORESTS ON THE PRICES OF RESIDENTIAL REAL ESTATES IN SKOPJE

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The focus of this research was to evaluate the influence of the Vodno urban forest and the City Park on the prices of apartments in Skopje, Republic of Macedonia. Detailed investigation and examination of the spatial relations between the residential real estates and the open green spaces (parks and urban forests) was performed utilizing the hedonic pricing method and multiple linear regressions. Quantitative research method was applied for data analyses and processing.

Presented results indicate moderate negative correlation between Vodno and the apartment price in the sample, as well as weak negative correlation between the City Park and the apartment price in the sample. The Vodno urban forest and the City Park are regarded as predictors of the apartment price in the sample.

Keywords: parks, urban forests,Vodno, City Park, hedonic pricing method, multiple linear regression.

1. BACKGROUND AND PROBLEM STATEMENT

In the modern lifestyle and the rapid rhythm of living in recent years, there is an evident increase in the environmental awareness and need for greater contact with nature. Parks, urban forests and green spaces directly and indirectly affect human life. They are a source of various benefits such as recreation and aesthetic experience.The city as a system represents different layers of built environment, in which urban forests, parks and green public spaces exist as a common good for all.

International scientific research finding sindicate that the park is consideredan advantage and a desirable amenity in purchasing a property, (Ståhle, 2006; Sander &Polasky, 2009; More et al., 1988; Kestens et al., 2004; Luttik, 2000; Morancho, 2003). Central Park is the first example of a designed park with a professional landscape architecture in the

United States, which contributes to increasing the value of the surrounding properties as well as increasing city tax revenues from property taxes (Crompton, 2007; Luttik, 2000). According to McCormack et al. (2010), the park or public green spaces positively influence the perception of people for that area. However, this does not always happen. If the crime rate in the park has increased, local residents perceive it as unsafe, in which case there may be a negative effect on the prices of surrounding residential buildings, (Troy & Grove, 2008; Sampson &Raudenbush, 1999; Knutson, 1997).

Research findingsindicate that the proximity of parks and urban forests has an influence on the value of the surrounding properties (Crompton, 2004). Therefore, this paper is focused on examining the influence of the City Park and the Vodno urban forest on the price of the apartments in Skopje.Based on the literature findings the following hypotheses can be formulated:

- H_0 hypothesis: The urban forest Vodno and the City Park do not influence the price of apartments in Skopje.
- H_1 hypothesis: The urban forest Vodno and the city park influence the price of the apartments in Skopje.

2. RESEARCH METHODOLOGY

2.1 RESEARCH DESIGN AND RESEARCH METHOD

Presented research can be classified as descriptive. Quantitative research method was appliedfor data analyses and processing.The research uses a hedonic pricing method and multiple linear regression that was suitable for analysis and explicit explanation of real estate variations such as number of bedrooms, area or proximity to open green space.

2.2 TARGET POPULATION AND SAMPLE

Target group of interest for this research are residential real estate i.e. apartments in Skopje. The sample consists of 501 apartments in several Skopje neighborhoods, randomly selected according to the principle of intentional (non-probability) sampling, based on researchers' personal conviction.

2.3 MEASURING INSTRUMENT

Data collection included distance measuring using the ArcGIS tool, available on the official portal of the City of Skopje (http://gis.skopje.gov.mk/skopjegis).Microsoft Excel and IBM SPSS software packagewere used for data coding, grouping and statistical processing.

3. DATA ANALYSIS AND RESEARCH FINDINGS

The analysis of collected data wascompleted using descriptive and inferential statistical methods.

3.1 DESCRIPTIVE ANALYSIS

The research compiled data of 501 apartments distributed in various neighborhoods across the city of Skopje.

Table 1. Total price of apartments per neighborhoods

Neighbourhood	N	Min. price (EUR)	Max. price (EUR)	Mean price (EUR)	Std. deviation
Avtokomanda	17	31000	72000	50705,88	11686,07
Aerodrom	57	36900	123050	68418,25	15457,64
Butel	2	46000	52000	49000,00	4242,64
Vlae	1	138900	138900	138900,00	.
Vodno	64	46200	350000	113034,66	55128,73
Gazi Baba	2	38000	42000	40000,00	2828,43
GjorchePetrov	29	26500	85000	50121,45	13496,01
Debar Maalo	17	59000	183000	95217,06	32062,16
Zhelezhara	9	30000	79000	48442,67	15109,98
Kapishtec	11	46000	130000	84219,82	24169,11
Karposh 1	6	35000	66700	53175,00	12318,03
Karposh 2	3	57600	94800	71133,33	20566,32
Karposh3	15	55000	159850	81435,33	29144,04

Table 1. Total price of apartments per neighborhoods (continue)

Neighbourhood	N	Min. price (EUR)	Max. price (EUR)	Mean price (EUR)	Std. deviation
Karposh 4	6	59000	89000	71333,33	13775,58
KiselaVoda	53	29000	98000	59873,75	16822,33
Kozle	22	49500	180000	78320,45	26806,73
Madjari	3	44000	66400	56800,00	11537,76
Novo Lisiche	24	39000	94000	63706,88	11680,93
Przhino	2	51660	82770	67215,00	21998,09
Radishani	4	38000	55000	46750,00	6994,05
Skopje Sever	1	51000	51000	51000,00	.
Taftalidze	20	46000	110000	72760,00	19299,02
Topan. Pole	5	40000	60590	49140,00	8843,42
Hipodrom	2	40000	42000	41000,00	1414,21
Centar	85	25000	154000	79633,06	27756,36
Crniche	9	50600	118800	86077,78	21723,02
Chair	30	27000	86250	46511,63	14912,74
Chento	2	35000	35000	35000,00	0,00
TOTAL	501	25000	350000	73232,47	33782,55

For greater relevance of the research, most of the apartments or 58.5% are concentrated in and around the central city area, i.e.the neighborhoods: Centar, Vodno, Debar Maalo, Kapishtec, Crnice, Kozle, Przino, Karpos 1, 2, 3, 4 and KiselaVoda. Those locations are near the City Park or the urban forest Vodno and the city center. The research also includes the variable Distance to the center of Skopje due to its close connection with the two points of interest, especially to the City Park. This has been utilized in order to avoid the potential influence of the city center on the apartments located close to the City Park, Vodno and the city center.

The price of the apartments, as representation of their value, is of special interest to this research, and in the inferential statistical analysis, it is a dependent variable. Table 1 presents the values of the total price of apartments per neighborhoods.

It is obvious that the apartments in Vodno have the highest mean value of 113034.66 EUR. The apartments in Debar Maalo have amean value of 95217,06 EUR, in Crniche 86077,78 EUR, Center 79633,06 EUR and Kapishtec 84219,82 EUR, which corresponds with the research of Davidovska Stojanova et al. (2008).

Table 2. Mean prices of apartments grouped by proximity zones from Vodno, City Park and Center

	zone 0 – 400m	zone 400m – 800m	zone 800m – 1200m	zone over 1200m
Distance to Vodno	*N=61 Mean price: 110257,32 €*	*N=70 Mean price: 77456,54 €*	*N=74 Mean price: 71800,39 €*	*N=296 Mean price: 64961,42 €*
Distance to the City park	*N=25 Mean price: 91324,00 €*	*N=43 Mean price: 71900,93 €*	*N=43 Mean price: 77889,07 €*	*N=390 Mean price: 71706,14 €*
Distance to Center	*N=9 Mean price: 97221,11 €*	*N=19 Mean price: 75889,47 €*	*N=53 Mean price: 81023,02 €*	*N=420 Mean price: 71615,35 €*

As represented in *Table 2*, there are overlapping zones of potential influencethat may be most pronounced in the 800m - 1200m zone. Because of the potential overlapping influences of Vodno, Center and the City Park, further analyses will be conducted with simultaneous examination of all three potential centers of influence.

Correction of the sample has been performed in order to get a normal sample distribution histogram. All apartments with a price higher than EUR 170.000 have been excluded from further analysis. The sample has been reduced to 491 apartment and ln(Price) has been accepted as a dependent variable.

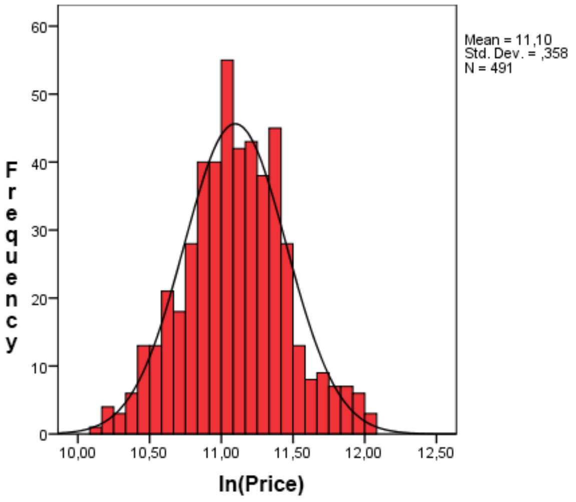

Figure 1. Reduced sample distribution histogram

3.2 INFERENTIAL ANALYSIS AND HEDONIC PRICING MODEL

Several inferential statistical techniques have been applied to investigate the influence of the urbanforestVodno and the City Park on the price of the apartments in Skopje. A correlation test between the variables was made, by examining the Pearson Correlation Coefficient.Furthermore,utilizing multiple linear regression method, a hedonic pricing model of the sample was created, which determines which independent variables can be considered as price predictors of the apartments.

Due to the large number of variables and further simplification of output, only an extract from the Pearson correlation matrix for the locational attributesis presented in *Table 3*.

Table 3. Pearson correlation matrix for locational attributes of the sample

		ln(Price)	Center(m)	Vodno (m)	City Park (m)
ln(Price)	Pearson Correlation	1	-,362)**	-,474)**	-,293)
	Sig. (2-tailed)		,000	,000	,000
	N	491	491	491	491
Center (m)	Pearson Correlation	-,362)**	1	,651**	,779
	Sig. (2-tailed)	,000		,000	,000
	N	491	491	491	491
Vodno (m)	Pearson Correlation	-,474)**	,651**	1	,492
	Sig. (2-tailed)	,000	,000		,000
	N	491	491	491	491
City Park (m)	Pearson Correlation	-,293)**	,779**	,492**	1
	Sig. (2-tailed)	,000	,000	,000	
	N	491	491	491	491

*. Correlation is significant at the 0.01 level (2-tailed).

The results presented in *Table 3* indicate a moderate negative correlation between the variables Vodno (m) and ln(Price) with r = -0.474 at significance level p <0.01 indicating that the price of the apartments is reduced by increasing the distance from Vodno. The coefficient r = -0.362 with significance level p <0.01 implies a weak negative correlation between the variables Center (m) and ln(Price). Weak negative correlation also occurs between the variables City Park (m) and ln(Price) with r = -0.293 and significance level p <0.01, which again would mean that the price of the apartments is reduced by increasing the distance to the Center and the City Park. The presented results imply interesting correlations between the variables Center and Vodno and Center and the City Park. They indicate a moderate positive correlation with r = 0.651 and significance level p <0.01 between Center (m) and Vodno (m), and a strong positive correlation with r = 0.779

and significance level p <0.01 between Center (m) and City Park (m). There is moderate positive correlation between the variables Vodno (m) and City Park (m) with r = 0.492 and significance level p <0.01. These correlations are probably due to the relatively small distance between these three parts of Skopje. These results provide supporting evidence that H1 hypothesis is supported by this research.

For determining or estimating the hedonic pricingmodel for the sample of 491 apartments, the multiple linear regression method was selected, which was performed using the IBM SPSS software package. Due to the large number of independent variables, a multiple linear regression was first performed using the Stepwise method in order to find the most appropriate linear model. The ln (Price) was taken as the dependent variable, and other variables were taken as independent. This method provided 10 models with a sufficiently high R2 coefficient, which are presented in *Table 4*.

Table 4. Model summary of multiple linear regression with Stepwise method

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	,834[a]	,696	,695	,19748
2	,903[b]	,816	,815	,15379
3	,908[c]	,825	,824	,15016
4	,914[d]	,836	,835	,14543
5	,918[e]	,844	,842	,14219
6	,922[f]	,850	,848	,13938
7	,924[g]	,853	,851	,13798
8	,925[h]	,855	,853	,13733
9	,925[i]	,857	,854	,13675
10	,926[j]	,858	,855	,13626

The variables that are predictors of the dependent variable ln (Price) for each of the proposed models in *Table 4* are as follows:

1. Predictors: (Constant), Size
2. Predictors: (Constant), Size, Vodno(m)
3. Predictors: (Constant), Size, Vodno(m), Age
4. Predictors: (Constant), Size, Vodno(m), Age, Heating
5. Predictors: (Constant), Size, Vodno(m), Age, Heating, City Park(m)
6. Predictors: (Constant), Size, Vodno(m), Age, Heating, City Park(m), Floor
7. Predictors: (Constant), Size, Vodno(m), Age, Heating, City Park(m), Floor, Rooms
8. Predictors: (Constant), Size, Vodno(m), Age, Heating, City Park(m), Floor, Rooms, Garage
9. Predictors: (Constant), Size, Vodno(m), Age, Heating, City Park(m), Floor, Rooms, Garage, Orientation South-west
10. Predictors: (Constant), Size, Vodno(m), Age, Heating, City Park(m), Floor, Rooms, Garage, Orientation South-west, Basement

The ANOVA test for each of the proposed 10 models, as shown in *Table 5* has a high significance p = 0,000; indicating that the sample fits well into each of the 10 regression models.

Table 5. ANOVA test for the 10 models

ANOVA[k]

	Model	Sum of Squares	df	Mean Square	F	Sig.
1	Regression	43,626	1	43,626	1118,616	,000[a]
	Residual	19,071	489	,039		
	Total	62,696	490			
2	Regression	51,154	2	25,577	1081,398	,000[b]
	Residual	11,542	488	,024		
	Total	62,696	490			
3	Regression	51,715	3	17,238	764,496	,000[c]
	Residual	10,981	487	,023		
	Total	62,696	490			
4	Regression	52,417	4	13,104	619,563	,000[d]
	Residual	10,279	486	,021		
	Total	62,696	490			
5	Regression	52,891	5	10,578	523,241	,000[e]
	Residual	9,805	485	,020		
	Total	62,696	490			
6	Regression	53,294	6	8,882	457,226	,000[f]
	Residual	9,402	484	,019		
	Total	62,696	490			
7	Regression	53,500	7	7,643	401,416	,000[g]
	Residual	9,196	483	,019		
	Total	62,696	490			
8	Regression	53,606	8	6,701	355,308	,000[h]
	Residual	9,090	482	,019		
	Total	62,696	490			
9	Regression	53,701	9	5,967	319,059	,000[i]
	Residual	8,995	481	,019		
	Total	62,696	490			
10	Regression	53,784	10	5,378	289,677	,000[j]
	Residual	8,912	480	,019		
	Total	62,696	490			

Model 10 has the highest R2 value and at the same time has the largest number of included independent variables as well as p = 0,000, and is therefore selected for further analysis. The following variables are included in further analysis:

- Dependent variable: ln (Price);
- Independent variables: Size, Vodno_M, Age, Heating, City Park_M, Floor, Rooms, Garage, Orientation South-west, Basement.

As shown in *Table 6*, R2 of this model is 0.858, while the adjusted R2 coefficient is 0.855. This means that this model describes more than 85% of the apartments in the sample.

Table 6. Model summary

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
10	,926[a]	,858	,855	,13626	1,436

a. Predictors: (Constant), Size, Vodno_M, Age, Heating, City Park_M, Floor, Rooms, Garage, Orientation South-west, Basement

b. Dependent variable: In (Price)

Additionally, the Durbin-Watson test value is 1,436, and is at the acceptable lower limit. Although this indicates the existence of a small, but acceptable positive auto-correlation between the independent variables of the model, it can still be concluded that the independent variables in the model are well selected.In addition, the significance level is 0,000. This indicates that the sample of apartments in this analysis has statistical significance and that the regression equation is effective.

Table 7 shows that the level of significance of the T-test for most variables is less than 1%, while only for the variables Garage, Orientation Southwest and Basement is less than 5% indicating that the corresponding coefficients B have statistically significant influence in the model. The variance inflation factor (VIF) is used to monitor multicollinearitybetween independent variables. Since the smallest value of the VIF is 1.027 and the greatest 2.747, which are much lower than the limit value 10, it can be concluded that the degree of multicollinearity of the independent variables is insignificant.

Table 7. Regression coefficients of the model

Coefficients[a]

	Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
10	(Constant)	10,304	,031		335,926	,000		
	Size	,011	,000	,721	25,283	,000	,364	2,747
	Vodno_M	-5,077E-5	,000	-,216)	-9,491)	,000	,574	1,741
	Age	-,001)	,000	-,108)	-5,171)	,000	,675	1,482
	Heating	,047	,008	,112	6,094	,000	,880	1,137
	City Park_M	-2,693E-5	,000	-,101)	-5,027)	,000	,737	1,356
	Floor	-,005)	,001	-,088)	-4,905)	,000	,920	1,087
	Rooms	,047	,014	,098	3,440	,001	,367	2,722
	Garage	,054	,022	,043	2,440	,015	,965	1,036
	Orientation.Southwest	-,033)	,015	-,039)	-2,229)	,026	,974	1,027
	Basement	-,034)	,016	-,041)	-2,116)	,035	,779	1,284

a. Dependent variable: In (Price)

According to the regression coefficients presented in *Table 7*, the regression equation that describes the hedonic pricing model of the apartments in the sample is as follows:

ln(Price) = 10,304 + 0,011 · Size-0,00005077 · Vodno_M-0,001 · Age + 0,047 · Heating - 0,00002693 · City Park_M-0,005 · Floor + 0,047 · Rooms + 0,054 · Garage-0,033 · Orientation_South-west-0,034 · Basement

The regression equation indicates that in addition to the fact that the location attributes distance from Vodno (m) and City Park (m) have a moderate or weak negative correlation with ln (Price) as shown by Pearson's correlation analysis; they can additionally be considered predictors of ln (Price). This is in favor of the complete support of the research hypothesis H1, which meansthat the urban forest Vodno and the City Park influence the price of the apartments in the sample. Therefore, by increasing the distance from Vodno for one unit i.e. for 1m, the value of the apartment decreases by 0.00005077, while increasing the distance from the City Park for one unit i.e. for 1m, decreases the value of the apartment by 0.00002693.

5. CONCLUSIONS

The Pearson correlation test indicates a moderate negative correlation between the distance from Vodno and the apartmentprice in the sample, as well as a weak negative correlation between the distance from the City Park and the apartment price. Additionally, an assessment of the influence of the urban forest Vodno and the City Park on the apartmentprices was performed utilizing multiple linear regression. The results confirmed that the distances from Vodno and the City Park can be considered as predictors of the price of the apartments in the sample. This is in favor of confirmation of the research hypothesis in the focus of this paper. Based on this it can be concluded that the proximity to the urban forest Vodno and the City Park influences the price of the apartments in Skopje.

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STANDARD PARALLELS AND SECANT PARALLELS IN CONIC PROJECTIONS

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It is a common misconception that standard parallels and parallels that appear as intersection of a developable surface and a sphere or an ellipsoid coincide. This paper shows that is not correct for projections which are equidistant along meridians, for equal-area projections and for conformal conic projections.

Keywords: map projection, conic projection, standard parallel, secant projection, secant parallel.

1. INTRODUCTION

In map projection references, map projections are commonly approached as mapping onto developed surfaces – cylindrical projections as mapping onto a lateral surface of a cylinder, and conic projections as mapping onto a lateral surface of a cone. If these developable surfaces are related to the Earth's sphere or ellipsoid so that they intersect each other, they are referred to as secant projections. The intersections of the developing surfaces and the Earth sphere or ellipsoid are identified with standard parallel without proof. This is taken as an obvious fact (Fig. 1), even though it is not. This will be presented in the paper for a sphere, while for ellipsoid it can be shown in an analogous manner.

First of all, let us define geographic parameterization of a sphere with the radius R>0 and its centre in the origin of the coordinate system as mapping.

$$x = R\cos\varphi\cos\lambda,$$
$$y = R\cos\varphi\sin\lambda, \qquad (1)$$
$$z = R\sin\varphi$$

where

$$\varphi \in \left[-\frac{\pi}{2}, \frac{\pi}{2}\right],\ \lambda \in [-\pi, \pi].$$

Parameter φ is geographic latitude, while λ is geographic longitude, as usual. It is not difficult to obtain the first differential form of mapping (1) as

$$ds^2 = R^2 d\varphi^2 + R^2 \cos^2 \varphi d\lambda^2 . \qquad (2)$$

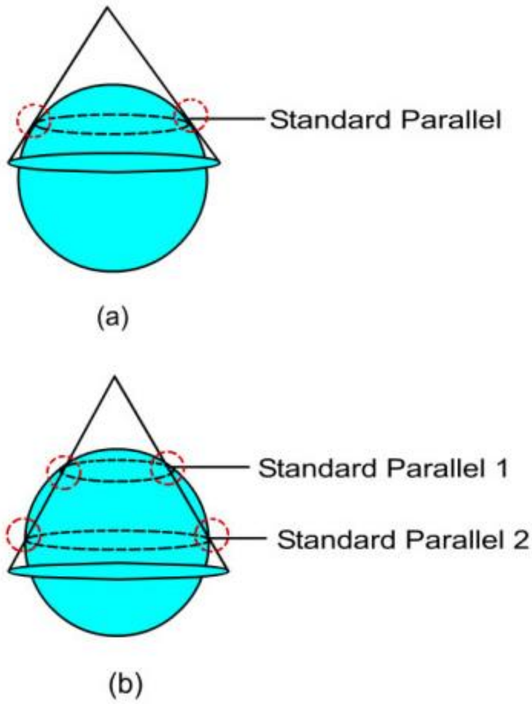

Figure 1. Standard parallels are considered as secant parallels in Fig. 1 (b). Source: NPTEL (2007). This paper shows that such an approach is generally wrong

A map projection is defined as mapping from the sphere (1) into a plane by using formulas

$$x = x(\varphi, \lambda) , \ y = y(\varphi, \lambda) , \qquad (3)$$

where x and y are coordinates in a rectangular (mathematical, right oriented) coordinate system in the plane. The first differential form of the mapping (3) is:

$$ds'^2 = E d\varphi^2 + 2F d\varphi d\lambda + G d\lambda^2 , \qquad (4)$$

where coefficients are:

$$E = \left(\frac{\partial x}{\partial \varphi}\right)^2 + \left(\frac{\partial y}{\partial \varphi}\right)^2 ,$$

$$F = \frac{\partial x}{\partial \varphi}\frac{\partial x}{\partial \lambda} + \frac{\partial y}{\partial \varphi}\frac{\partial y}{\partial \lambda} , \qquad (5)$$

$$G = \left(\frac{\partial x}{\partial \lambda}\right)^2 + \left(\frac{\partial y}{\partial \lambda}\right)^2 .$$

If a map projection is defined in a polar coordinate system, as it is usual in conic map projections, then the relation between rectangular coordinates x, y and polar coordinates ρ, θ is as follows:

$$x = \rho \sin \theta , \ y = \rho_0 - \rho \cos \theta \qquad (6)$$

with

$$\rho = \rho(\varphi) , \ \theta = n(\lambda - \lambda_0) , \qquad (7)$$

where $\rho_0 > 0$, $0 < n \le 1$ and $\lambda_0 \in [-\pi, \pi]$ are constants of projection. It is easy to compute partial derivatives

$$\frac{\partial x}{\partial \varphi} = \frac{\partial \rho}{\partial \varphi}\sin\theta , \ \frac{\partial y}{\partial \varphi} = -\frac{\partial \rho}{\partial \varphi}\cos\theta ,$$
$$\frac{\partial x}{\partial \lambda} = \rho n \cos\theta , \ \frac{\partial y}{\partial \lambda} = \rho n \sin\theta \qquad (8)$$

and then after (5), we have

$$E = \left(\frac{\partial \rho}{\partial \varphi}\right)^2 , \ F = 0 , \ G = \rho^2 n^2 . \qquad (9)$$

The linear scale or the scale factor c is defined by using the following relation

$$c^2 = \frac{ds'^2}{ds^2} = \frac{E d\varphi^2 + 2F d\varphi d\lambda + G d\lambda^2}{R^2 d\varphi^2 + R^2 \cos^2 \varphi d\lambda^2} , \qquad (10)$$

which can also be written as

$$c^2(\alpha) = \frac{E}{R^2}\cos^2\alpha + \frac{F}{R^2 \cos\varphi}\sin 2\alpha +$$
$$+ \frac{G}{R^2 \cos^2 \varphi}\sin^2 \alpha \qquad (11)$$

where

$$\tan\alpha = \frac{\cos\varphi d\lambda}{d\varphi} . \qquad (12)$$

If $\alpha = 0$ or, more generally, $\alpha = k\pi, k \in Z$, where Z denotes the set of all integers, then the linear scale along a meridian is

$$c = h(\varphi) = \frac{\sqrt{E}}{R} , \qquad (13)$$

and if $\alpha = \frac{\pi}{2}$ or, more generally, $\alpha = \frac{\pi}{2} + k\pi$, $k \in Z$ then the linear scale along a parallel is given by

$$c = k(\varphi) = \frac{\sqrt{G}}{R\cos\varphi} . \qquad (14)$$

Now, we are going to find the extremes of the linear scale. For this purpose, let us denote

$$\lambda(\alpha) = c^2(\alpha) . \qquad (15)$$

Using substitutions

$$\sin^2\alpha = \frac{1-\cos 2\alpha}{2} ,$$

$$\cos^2\alpha = \frac{1+\cos 2\alpha}{2} \qquad (16)$$

$$K = \frac{1}{R^2\cos^2\varphi}\sqrt{\left(E\cos^2\varphi - G\right)^2 + 4F^2\cos^2\varphi} \qquad (17)$$

$$\sin 2\vartheta = \frac{2F}{KR^2\cos\varphi} ,$$

$$\cos 2\vartheta = \frac{E\cos^2\varphi - G}{KR^2\cos^2\varphi} \qquad (18)$$

and

$$t = \alpha - \vartheta \qquad (19)$$

we can get

$$\lambda(\alpha) = \frac{E\cos^2\varphi + G}{2R^2\cos^2\varphi} + \frac{K}{2}\cos 2t \qquad (20)$$

from where the extremes can be read:

$$\lambda_{max} = \frac{E\cos^2\varphi + G}{2R^2\cos^2\varphi} + \frac{K}{2} \qquad (21)$$

for $t = k\pi, k \in Z$, or

$$\alpha = \vartheta + k\pi, k \in Z \qquad (22)$$

and

$$\lambda_{min} = \frac{E\cos^2\varphi + G}{2R^2\cos^2\varphi} - \frac{K}{2} \qquad (23)$$

for $t = \frac{\pi}{2} + k\pi, k \in Z$, or

$$\alpha = \vartheta + \frac{\pi}{2} + k\pi, k \in Z \qquad (24)$$

In the previous formulas, the function $\lambda = \lambda(\alpha)$ should not be related to the latitude, which is also indicated by the Greek letter λ, but from the context we can clearly see what it is about. Formula (20) can be transformed into

$$\lambda(\alpha) = \lambda_{max}\cos^2 t + \lambda_{min}\sin^2 t = .$$
$$= \lambda_{max}\cos^2(\alpha-\vartheta) + \lambda_{min}\sin^2(\alpha-\vartheta) \qquad (25)$$

It is not hard to recognize that $\sqrt{\lambda_{max}}$ and $\sqrt{\lambda_{min}}$ are semi-axes of the Tissot's indicatrix or the ellipse of distortion of the map projection.

In a special case when

$$F = 0 \qquad (26)$$

i.e. when images od meridians and parallels are intersecting at right angles in the plan of projection, we have

$$c^2(\alpha) = \lambda(\alpha) = \frac{E}{R^2}\cos^2\alpha + \frac{G}{R^2\cos^2\varphi}\sin^2\alpha$$
. (27)

If $E\cos^2\varphi = G$ then $\lambda = \frac{E}{R^2} = \frac{G}{R^2\cos^2\varphi}$ does not depend on the angle α .

If $E\cos^2\varphi > G$ then $\lambda_{max} = \frac{E}{R^2}$ for $\alpha = k\pi$, $k \in Z$, $\lambda_{min} = \frac{G}{R^2\cos^2\varphi}$ for $\alpha = \frac{\pi}{2} + k\pi$, $k \in Z$.

If $E\cos^2\varphi < G$ then $\lambda_{min} = \frac{E}{R^2}$ for $\alpha = \frac{\pi}{2} + k\pi$, $k \in Z$ and $\lambda_{max} = \frac{G}{R^2\cos^2\varphi}$ for $\alpha = k\pi, k \in Z$.

2. STANDARD PARALLELS

We say that there are no distortions in a point due to the map projection, or that the distortion is zero, if

$c(\alpha)=1$, for each α (28)

where $c(\alpha)$ is defined by (11). This requirement is clearly equivalent to the condition

$\lambda(\alpha)=1$, for each α, (29)

or conditions

$$\lambda_{\min}=\lambda_{\max}=1. \quad (30)$$

It is the Tissot's indicatrix which was transformed into a unit circle. A curve without distortions, or a curve along which the distortion is zero, is a curve satisfying condition (28), (29) or (30) in each point. A *standard parallel* is a parallel without distortion, i.e. a parallel satisfying condition (28), (29) or (30) in each point.

3. CONIC PROJECTIONS

According to the National Atlas of USA, a conic projection: "…projects information from the spherical Earth to a cone that is either tangent to the Earth at a single parallel, or that is secant at two standard parallels.." (Wayback Machine 2014). It is obvious that standard parallels and parallels in which the cone cuts the Earth's sphere are considered the same in the previous sentence.

Conic projections are also defined in the USGS publication on map projections (USGS 2000): "*Conic* – Mathematically projected on a cone conceptually secant at two standard parallels." It is obvious that the authors of this definition consider the standard parallel and parallel in which the cone cuts the sphere the same, whatever the word *conceptually* means in this case.

A conic projection is mapping defined by formulas

$$\rho=Rf(\varphi),\ \theta=n(\lambda-\lambda_0) \quad (31)$$

where

$\varphi\in\left[-\frac{\pi}{2},\frac{\pi}{2}\right]$, $\lambda\in[-\pi,\pi]$, constants are $0<n\le 1$, $R>0$ and $\lambda_0\in[-\pi,\pi]$, and the function $\rho=Rf(\varphi)$ is continuous, with positive values and monotone decreasing, or monotone increasing, depending on whether the North Pole or the South Pole is in the middle of the map. ρ and θ are coordinates of a point in the polar coordinate system in the plane. As it can be seen, it is about mapping into the plane, *not onto a conical surface*. According to (9), we have

$$E=\left(R\frac{df}{d\varphi}\right)^2,\ F=0,\ G=R^2f^2n^2, \quad (32)$$

and the first differential form

$$ds'^2=\left(R\frac{df}{d\varphi}\right)^2 d\varphi^2+R^2f^2n^2d\lambda^2. \quad (33)$$

Square of the linear scale of normal aspect conic projection (31) is

$$c^2=\frac{\left(R\frac{df}{d\varphi}\right)^2 d\varphi^2+R^2f^2n^2d\lambda^2}{R^2d\varphi^2+R^2\cos^2\varphi d\lambda^2}=$$

$$=\frac{\left(\frac{df}{d\varphi}\right)^2 d\varphi^2+f^2n^2d\lambda^2}{d\varphi^2+\cos^2\varphi d\lambda^2}. \quad (34)$$

From (34) we can read linear scales along meridians and parallels, respectively

$$h=h(\varphi)=-\frac{df}{d\varphi},\ k=k(\varphi)=\frac{nf(\varphi)}{\cos\varphi}. \quad (35)$$

The minus sign in the formula for *h* was chosen if functions ρ and *f* are decreasing by hypothesis.

4. STANDARD PARALLELS IN NORMAL ASPECT CONIC PROJECTIONS

In normal aspect conic projections, it is $F=0$ and (35). In this paper, we will limit ourselves to conic projections with no more than two standard parallels. Along a standard parallel $\varphi=\varphi_1$ according to (30) and (35) it should be

$$h(\varphi_1)=k(\varphi_1)=1, \quad (36)$$

i.e.

$$\frac{df}{d\varphi}(\varphi_1)=-1 \quad (37)$$

and

$$\frac{nf(\varphi_1)}{\cos\varphi_1} = 1, \text{ i.e. } f(\varphi_1) = \frac{\cos\varphi_1}{n}. \tag{38}$$

In the same way, along a standard parallel $\varphi = \varphi_2$ it should be

$$h(\varphi_2) = k(\varphi_2) = 1, \tag{39}$$

which is equivalent to conditions

$$\frac{df}{d\varphi}(\varphi_2) = -1 \tag{40}$$

and

$$\frac{nf(\varphi_2)}{\cos\varphi_2} = 1, \text{ i.e. } f(\varphi_2) = \frac{\cos\varphi_2}{n}. \tag{41}$$

Let us compute the shortest distance between the two standard parallels defined by latitudes $0 \le \varphi_1 \le \varphi_2 \le \frac{\pi}{2}$ in any normal aspect conic projection. According to (31), (38) and (41), we have

$$\rho(\varphi_1) - \rho(\varphi_2) = \frac{R}{n}(\cos\varphi_1 - \cos\varphi_2) =$$
$$= \frac{2R}{n}\sin\frac{\varphi_2+\varphi_1}{2}\sin\frac{\varphi_2-\varphi_1}{2}. \tag{42}$$

5. SECANT PARALLELS IN NORMAL ASPECT CONIC PROJECTIONS

Let us imagine a cone with its axis coinciding with the axis which passes through geographic poles of the Earth's sphere. Let the cone cut the sphere along two secant parallels of latitudes $0 \le \varphi_1 \le \varphi_2 \le \frac{\pi}{2}$. The question is: are these two parallels also standard parallels of the normal aspect conic projection? In order to answer the question, let us first note that the (shortest) distance between these secant parallels on the sphere is equal to

$$2R\sin\frac{\varphi_2-\varphi_1}{2}, \tag{43}$$

where *R* is the radius of the sphere and this distance will remain unchanged after developing the conic surface onto a plane. The answer to the stated question follows from the relations (42) and (43)

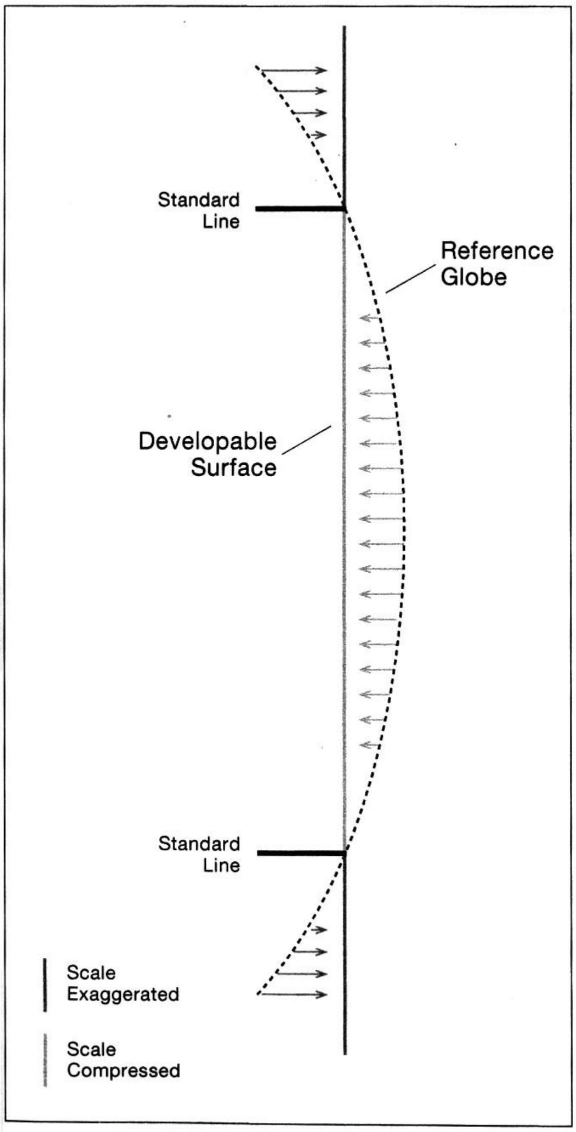

Figure 2. Fig 2. Standard parallels are considered the same as secant parallels in which the developing surface cuts the sphere. Source: *Thematic Cartography and Geovisualization* (Slocum et al. 2001, p. 139, Fig. 8.12). In this paper it is proved that this is generally wrong, i.e. that the standard parallel and parallels in which the developing surface cuts the sphere generally do not coincide

$$\frac{2R}{n}\sin\frac{\varphi_2+\varphi_1}{2}\sin\frac{\varphi_2-\varphi_1}{2} = 2R\sin\frac{\varphi_2-\varphi_1}{2} \tag{44}$$

which will be true if and only if

$$\varphi_1 = \varphi_2 \tag{45}$$

or

$$n = \sin\frac{\varphi_2 + \varphi_1}{2}. \quad (46)$$

6. PROOF THAT STANDARD PARALLELS AND SECANT PARALLELS ARE GENERALLY TWO DIFFERENT TYPES OF PARALLELS

The following approach is described in the book *Thematic Cartography and Geovisualization* (Slocum et al. 2009): "Secant lines and points of tangency each have the same scale as the principal scale of the reference globe. Thus, secant lines are called standard lines, and points of tangency are called standard points. All other lines and points will have either a larger or a smaller scale than the principal map scale of the reference globe. Figure 8.12 illustrates the concept of a standard line and its impact on scale variation across a map. In the figure, a portion of the reference globe is represented by the dashed line, and the developable surface is represented by the solid line of gray values. Note that the developable surface cuts the reference globe, creating two standard lines ..."

These are misconceptions and wrong conclusions! Standard parallels are one type of parallels, while secant parallels are another type. Developing of an auxiliary intermediate surface preserves distances. Is it possible that two chosen standard parallels are mapped at same distances in all conic projections? Obviously not. Let us look at it in some examples.

6.1 NORMAL ASPECT CONIC PROJECTION EQUIDISTANT ALONG MERIDIANS

Equations of a normal aspect conic projection which is equidistant along meridians are

$$\rho = R(C - \varphi), \ \theta = n(\lambda - \lambda_0) \quad (47)$$

where

$\varphi \in \left[-\frac{\pi}{2}, \frac{\pi}{2}\right]$, $\lambda \in [-\pi, \pi]$, constants are $0 < n \le 1$, $C \ge \frac{\pi}{2}$, $\lambda_0 \in [-\pi, \pi]$ and R>0 the radius of sphere.

If $0 \le \varphi_1 < \varphi_2 \le \frac{\pi}{2}$ are latitudes of two different standard parallels in this projection, then according to (37), (38), (40) and (41) for $f(\varphi) = C - \varphi$ it should be

$$\frac{df}{d\varphi}(\varphi_1) = \frac{df}{d\varphi}(\varphi_2) = -1 \quad (48)$$

which is obviously valid for any $\varphi \in \left[-\frac{\pi}{2}, \frac{\pi}{2}\right]$

and

$$f(\varphi_1) = C - \varphi_1 = \frac{\cos\varphi_1}{n}$$

and

$$f(\varphi_2) = C - \varphi_2 = \frac{\cos\varphi_2}{n} \quad (49)$$

from where it directly follows that

$$n = \frac{\cos\varphi_1 - \cos\varphi_2}{\varphi_2 - \varphi_1}. \quad (50)$$

The expression (50) can be transformed into

$$n = \frac{2}{\varphi_2 - \varphi_1}\sin\frac{\varphi_2 + \varphi_1}{2}\sin\frac{\varphi_2 - \varphi_1}{2}. \quad (51)$$

By comparing (46) and (51), we conclude that it should be

$$\frac{2}{\varphi_2 - \varphi_1}\sin\frac{\varphi_2 - \varphi_1}{2} = 1 \quad (52)$$

or equivalently

$$\frac{\varphi_2 - \varphi_1}{2} = \sin\frac{\varphi_2 - \varphi_1}{2}, \quad (53)$$

which is possible if and only if $\varphi_1 = \varphi_2$, which is contrary to the assumption that these are two different standard parallels. Consequently, *the map drawn in the normal aspect conic projection which is equidistant along meridians and bent in the cone surface can not cut the sphere along the standard parallels*. In other words, for a map produced in a normal aspect conic projection which is equidistant along meridians, the representation at the Fig. 1 (b) is not possible.

All that was said in this chapter is, of course, true for special cases of conic projections which are equidistant along meridians such as De l'Isle, Murdoch I and III, Euler's et al. (Snyder 1978).

6.2 NORMAL ASPECT EQUAL-AREA CONIC PROJECTION

The equations of normal aspect equal-area conic projection are

$$\rho = R\sqrt{C - \frac{2}{n}\sin\varphi}\ ,\ \theta = n(\lambda - \lambda_0) \qquad (54)$$

where

$\varphi \in \left[-\frac{\pi}{2}, \frac{\pi}{2}\right]$, $\lambda \in [-\pi, \pi]$, constants are $0 < n \le 1$, $C \ge \frac{2}{n}$, $\lambda_0 \in [-\pi, \pi]$ and R>0 the radius of the Earth's sphere.

If $0 \le \varphi_1 < \varphi_2 \le \frac{\pi}{2}$ are latitudes of two different standard parallels in that projection, then according to (37) and (40) or (38) and (41) for $f(\varphi) = \sqrt{C - \frac{2}{n}\sin\varphi}$ it should be

$$C - \frac{2}{n}\sin\varphi_1 = \frac{\cos^2\varphi_1}{n^2}$$

and

$$C - \frac{2}{n}\sin\varphi_2 = \frac{\cos^2\varphi_2}{n^2} \qquad (55)$$

from where by eliminating the constant C we can obtain the expression

$$n = \frac{\sin\varphi_1 + \sin\varphi_2}{2}\ . \qquad (56)$$

The formula (56) can be transformed into

$$n = \sin\frac{\varphi_2 + \varphi_1}{2}\cos\frac{\varphi_2 - \varphi_1}{2}\ . \qquad (57)$$

By comparing formulas (46) and (57), we conclude that it should be

$$\cos\frac{\varphi_2 - \varphi_1}{2} = 1 \qquad (58)$$

i.e.

$$\frac{\varphi_2 - \varphi_1}{2} = 0 \qquad (59)$$

which is possible if and only if $\varphi_1 = \varphi_2$, which is contrary to the assumption that these are two different standard parallels. Consequently, *a map drawn in the normal aspect equal-area conic projection and bent in the cone surface can not cut the sphere along the standard parallels*. In other words, for a map produced in normal aspect equal-area conic projection, the representation in Fig. 1 (b) is not possible.

6.3 NORMAL ASPECT CONFORMAL CONIC PROJECTION

The equations of a normal aspect conformal conic projection are

$$\rho = RC\tan^n\left(\frac{\pi}{4} - \frac{\varphi}{2}\right),\ \theta = n(\lambda - \lambda_0) \qquad (60)$$

where

$\varphi \in \left[-\frac{\pi}{2}, \frac{\pi}{2}\right]$, $\lambda \in [-\pi, \pi]$, constants are $0 < n \le 1$, $C > 0$, $\lambda_0 \in [-\pi, \pi]$ and R>0 the radius of the Earth's sphere.

If $0 \le \varphi_1 < \varphi_2 \le \frac{\pi}{2}$ are latitudes of two different standard parallels in that projection, then according to (37) and (40) or (38) and (41) for $f(\varphi) = C\tan^n\left(\frac{\pi}{4} - \frac{\varphi}{2}\right)$ it should be

$$C\tan^n\left(\frac{\pi}{4} - \frac{\varphi_1}{2}\right) = \frac{\cos\varphi_1}{n}$$

and

$$C\tan^n\left(\frac{\pi}{4} - \frac{\varphi_2}{2}\right) = \frac{\cos\varphi_2}{n} \qquad (61)$$

from where by eliminating the constant C we can obtain the expression

$$n = \frac{\ln\cos\varphi_2 - \ln\cos\varphi_1}{\ln\tan\left(\frac{\pi}{4} - \frac{\varphi_2}{2}\right) - \ln\tan\left(\frac{\pi}{4} - \frac{\varphi_1}{2}\right)}\ . \qquad (62)$$

By comparing formulas (46) and (62), we conclude that it should be

$$\frac{\ln\cos\varphi_2 - \ln\cos\varphi_1}{\ln\tan\left(\frac{\pi}{4}-\frac{\varphi_2}{2}\right) - \ln\tan\left(\frac{\pi}{4}-\frac{\varphi_1}{2}\right)} = \\ = \sin\frac{\varphi_2+\varphi_1}{2} \qquad (63)$$

or

$$\frac{\cos\varphi_2}{\cos\varphi_1} = \left[\frac{\cos\varphi_2(1+\sin\varphi_1)}{\cos\varphi_1(1+\sin\varphi_2)}\right]^{\sin\frac{\varphi_2+\varphi_1}{2}} \qquad (64)$$

which is generally not valid, but is true in the limit case when $\varphi_2 \to \varphi_1$. Consequently, *a map drawn in the normal aspect conformal conic projection and bent in the cone surface can not cut the sphere along the standard parallels*. In other words, for a map produced in normal aspect conformal conic projection, the representation in Fig. 1 (b) is not possible.

7. CONCLUSION

Identifying the standard and secant parallels is generally incorrect. The standard parallel is one type of parallel, and the parallel along which the conic surface cuts the sphere is another.

It is not recommended to use the developable surfaces in the interpretation of the basis of map projections because it leads to a misunderstanding of the definition and position of standard parallels.

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WORLD PROJECTING SYSTEM - STANDARDS AND USAGE

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The attempts of the Republic of Macedonia for its own cartographic production, as well as the need for integration of our system into the world projection systems, prescribe the adoption of the world standards into areas of definition, production and reproduction of cartographic products. In that context, in this work the basic characteristics of UTM system and the possibilities for transformation of the contents of our state's geodetic date into the date WGS 84 as worldly recognized world standards are exposed.

Keywords: UTM system, WGS 84 datum, cartographic production.

1. INTRODUCTION

It is known that up to the Second World War existed huge differences in geodetic networks of the European countries and also of geodetic networks all over the World. The differences are result from usage of different ellipsoids, fundamental points, coordinate systems, even from usage of different starting meridian for cartographic projections of individual countri-es. In the 50's of this century, noticeable is the tendency of European countries to integrate their networks into one common system. For that aim was adopted Hayford’s’ ellipsoid as a referent ellipsoid with fundamental point in Potsdam and in that time, was performed common adjustment of geodetic networks of many countries. In this direction are the efforts for adoption of one unique projection system, which would enable unified representation of the curved Earth’s surface in plane.

The term **unique projection system** means unity of *cartographic projection* and *cartogra-phic network*. When choosing a cartographic projection from the world projection system, care is taken of the properties and conditions that it needs to satisfy. In relation with that, as a base projection is adopted the modified Gauss-Kruger projection, which is known in countries from west world as Universal Transversal Mercator projection - UTM projection.

In world projection system, the UTM projection is used for representing areas of the Earth between latitudes 80^{o} S and 84^{o} N. For representation of the polar areas is using Universal Polar Stereographic Projection - UPS projection.

In continuation of the paper are presented basic characteristics of the UTM system and WGS 84 geodetic datum, as well as the aspects of their implementation for representing of the territory of the Republic of Macedonia.

2. THE BASIC CHARACTERISTICS OF THE UTM SYSTEM

The UTM system as a projection system that is enabling unified representation of the curved Earth's surface in plane. It is consist of *UTM projection* and *UTM network* which is presenting system for labeling (identification) of points and areas.

2.1 UTM PROJECTION

The UTM projection is conformal, transversal, cylindrical projection of meridian zones, where the Earth's ellipsoid is projecting on secant cylinders.

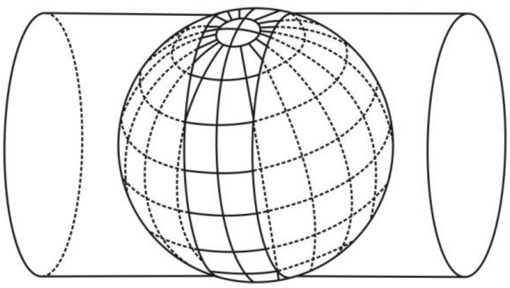

Figure 1. Projecting of the Earth on secant cylinder in UTM projection

The base of the UTM projection is the Transversal Mercator (Gauss - Kruger) projection, where in advanced certain criteria are set that the projection should satisfy, for example:

- The deformations of the distances in projection must be lower than 1:2500 (40 cm/km);
- maximal convergence of the meridians to be 5 ^{o};
- There is a unique grid coordinate system for each zone and formulas for uniform transformation of the grid coordinates between zones.

Taking into account the first two criteria, the projecting of the earth's surface is performing on 60 meridians zones. The width of each zone in UTM projection is with 6^{o} longitude, whereby individual zones include the areas with 3^{o} on west and 3^{o} on east from the central meridian with longitude λ_o.

According to the characteristics of the UTM projection, in frame of each zone, only the Equator and central meridian are projecting in plane as straight lines where the meridian representing "X" - axis and the Equator representing "Y" - axis of the coordinate system. The others meridians and parallels are projecting as curved lines which are symmetrical to the Equator and to the central meridian.

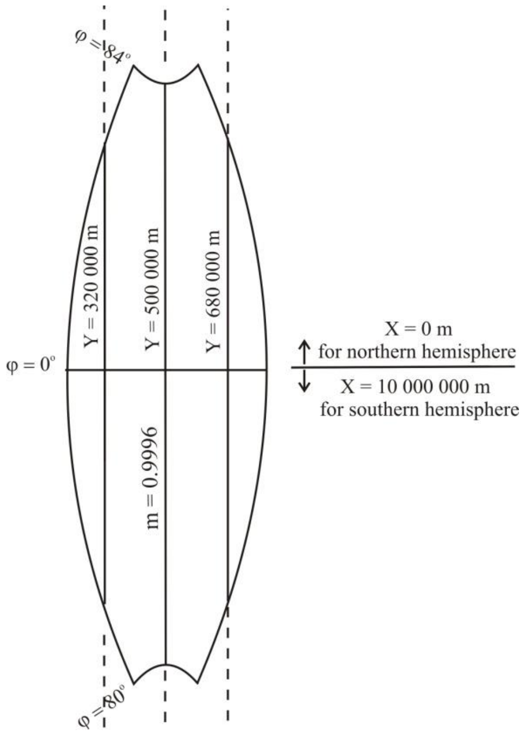

Figure 2. The projecting area in UTM projection

For elimination of negative "Y" coordinates on west from the central meridian it is performed displacement of the coordinate beginning for 500000 m. With that correction, the points that are on the central meridian are with ordinate Y = 500000 m. From the same reasons, for elimination of the negative "X" coordinates for points on south from the Equator it is performed displacement of the coordinate beginning for 1000000 m. With that correction points that are on the Equator are with an abscess X = 1000000 m. This rule is valid only for areas on the south earth's hemisphere.

The enlarging of projecting area in UTM projection it is performed with reduction of grid coordinates by constant linear module (m=0.9996). With this practically is introducing negative linear deformation on central meridian with -40 cm/km.

The lines of zero deformations at the UTM projection are located at approximately distance of 180 km on east and west side from the central meridian.

The labeling system for points and areas in UTM projection is designed for standardization of the common projection networks. This system is a very complicated with many rules and many exceptions which in general is consisting of five labeling levels.

In first labeling level, the Earth is divided with network of meridians and parallels. That network consists meridians on every 6^o of longitude and parallels on every 8^o of latitude (the exception is the last area from $\varphi_N = 72^o$ till $\varphi_N = 84^o$ with width of 12^o). Every limited area in this way is called *zone.* The columns of this division are marked with numbers from 1 to 60 in ascending through on east and with beginning in meridian $\lambda = 180\ ^o$ W. The rows are marked with uppercase letters from the alphabet starting from C till X (the letters I and O are omitted), and in ascending through on north from $\varphi = 80^o$ S till $\varphi = 84^o$ N.

The destination of the zone in first labeling level is defined with number of the column and letter of the row in which belongs.

The second labeling level is performed by division of the zones in squares with sides of 100 km. The number of rows of these squares in every zone is constant, but number of the columns is decreasing with moving from the Equator to the Earths poles. The labeling of the squares is performed with two letters from the Alphabet where first letter is mark for the column with growing array from west to east, and the second letter is mark for the row with growing array from south to north (Figure 3).

The identification of columns begins on meridian $\lambda = 180^o$ W and continues along the Equator. In process of labeling, the letters from A to Z are used (only I and O are excluded), so that set of letters repeats after every 18^o of longitude.

The identification of the rows is very specific and differs among the even and odd zones, and also in northern and southern hemisphere.

Because of problems that are present in second level of labeling, special sketches are drawn where is shown the schedule and labels of the squares that cover the given territory.

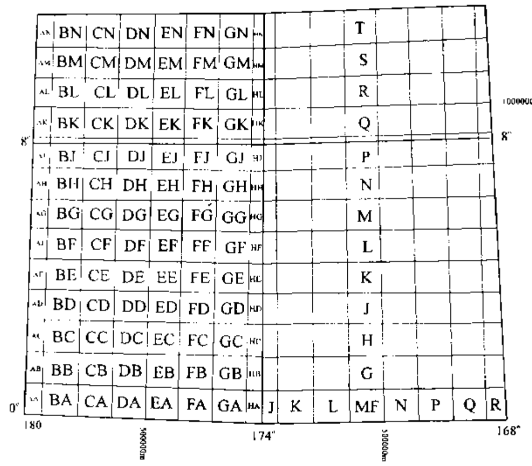

Figure 3. Second level of UTM labeling - division of squares with 100 km sides

The third and *fourth level of UTM labeling* represents process for locating the areas in frame of the 100 km square identification. The third level includes labeling of squares with dimensions 10 x 10 km, and the fourth level includes labeling of the squares with dimensions 1 x 1 km. The identification of a given area is carried out through the coordinates of its lower left corner.

In the *fifth level of labeling,* the position of the given point is determining in frame of the square (100 x 100 km). The point marker contains both coordinates (Y, X) written in succession.

The coordinates of the points can be specified with the desired precision and always are given continuously with the same number of digits.

A very important element of each projection is grid network, which allows orientation in the plane coordinate system. To align the markers of the map with its accuracy related with map scale, usually are used next distances between lines of the network:

- for scale 1 : 1 000 000 - network 100 x 100 km;
- For scales from 1 : 500 000 till 1 : 100 000 - network 10 x 10 km;
- For scales from 1: 50 000 till 1 : 25 000 - network 1 x 1 км.

3. WORLD GEODETIC SYSTEM - WGS 84

The significance of the unique projecting system (UTM) as an integration factor in mapping process of Earth's surface is significantly reduced if certain preconditions are not fulfilled such as: the adoption of the common ellipsoid and the unified orientation of the Global Earth's ellipsoid. The effects of use of different coordinate referent systems in different countries are really negative. This is particularly expressed in sensitive areas such as air transport and geodetic works of global and regional importance.

The first step to integration of referent geodetic networks in one unique system was made by western European countries in 50s years from the past century when was adopted elements of the Earths ellipsoid determined by Hayford. That ellipsoid was called International. After that, was performed common adjustment of national referent networks and was adopted the ED 50 as geodetic datum. With that datum was performed unique orientation of the International ellipsoid. With the development of the measuring technology and especially with use of the satellites measurements were performed new and more accurate dimensions of the Global Earth's ellipsoid which were marked as WGS 84. The tendency of all countries is adoption of the WGS 84 ellipsoid and datum as a substitute for local reference ellipsoids and datums that are still in use.

The WGS 84 is a global conventional terrestrial system realized with modification of NNSS (Navy Navigation Satellite System), by moving the coordinate system beginning, rotation and scale change to bring the starting (referent) meridian to coincide with BIH (Bureau International de l'Heure) the defined zero meridian through Greenwich.

The coordinate beginning and axes in spatial geocentric coordinate system are defined as follows:

- *The coordinate beginning* is located in center of the Earth's mass*;*
- *z - axis* is coinciding with the middle axis of the Earth's rotation;
- *x - axis* is defined as the intersection between zero meridians plane and the Equators plane;
- *y - axis* is orthogonal to x and z axes in Equators plane, and 90° to east from x - axis.

The WGS 84 is global geocentric referent system that includes Earths model defined with 5 primary parameters which are shown in Table 1.

Table 1. Primary parameters of the WGS 84 system

parameter	symbol	value
semi major axis	a	6378137 m
flattening	μ	1/298.257223563
Angle speed of the Earth	ω	7.292115 x 10^{-5} rad s^{-1}
Geocentric gravity constant	ΓΜ	398600.5 km^3 s^{-2}
Harmonious coefficient	$\bar{C}_{2,0}$	-484.16685 x 10^{-6}

The coordinate beginning and orientation of the coordinate axes in WGS 84 system are defined by X, Y and Z coordinates from 5 continuously operating GNSS (Global Navigation Satellite System) monitoring stations from which permanent measurements are performing to define changes in the shape and size of the Global Earth's ellipsoid.

3.1 DATUM TRANSFORMATION

For implementation of the world geodetic system it is important to define the parameters that will allow transformation from local geodetic system (datum) to WGS 84 system. The transformation parameters are determined on the basis of points with known coordinates in both systems. The transformation procedure predicts first coordinates from local system to be transformed into ellipsoidal coordinates, then into geocentric coordinates in local system. With known transformational parameters can be obtained geocentric coordinates in WGS 84 system. From these coordinates can be obtained ellipsoidal coordinates and coordinates in local coordinate system, relating to the WGS 84 ellipsoid and datum.

The general transformation model is illustrated by the following expression:

$$(y,x,H)_{LD} \Rightarrow (\varphi,\lambda,h)_{LD} \Rightarrow (X,Y,Z)_{LD} \Rightarrow$$
$$(X,Y,Z)_{WGS\,84} \Rightarrow (\varphi,\lambda,h)_{WGS\,84} \Rightarrow (y,x,H)_{WGS\,84}$$

There are several models for datum transformation depending on the available data and accuracy to be achieved. The broadest usage has: Helmert transformation, standard Molodensky formula and the formulas of multiple regressions.

For cartographic needs beyond the polar regions, the standard Molodensky formula is usually used, while in the polar regions (between 89° and 90° latitude) the transformation requires special treatment and is used Helmert transformation.

The coordinate conversion for corners and the others general topographic details for each map, should be in accordance with appropriate bases as a part of complete project for whole country.

4. USAGE OF UTM SYSTEM FOR PROJECTING OF THE TERRITORY OF THE REPUBLIC OF MACEDONIA

4.1 UTM LABELING

Taking into account the geographic position of the Republic of Macedonia, materialized through its extreme points (most northern, most eastern, most southern and most western), it is possible to determine the labeling of the points in relation to the world projecting system of the UTM projection.

In Table 2 are presented the geographic coordinates of the extreme points for the territory of the R. of Macedonia.

Table 2. The geographic coordinates of extreme points for the territory of the R. of Macedonia

point	φ	λ
most northern	**42° 22’**	22° 18’
most eastern	41° 42’	**23° 02’**
most southern	**40° 51’**	21° 08’
most western	41° 31’	**20° 27’**

According to the values of the geographical coordinates, and on the basis of the first level of UTM labeling, the territory of the R. of Macedonia completely belongs to zone marked as 34T which boundaries are:

$$\varphi_{min} = 40^o - \varphi_{max} = 48^o;$$

$$\lambda_{min} = 18^o - \lambda_{max} = 24^o$$

Central meridian of this zone is: $\lambda_{central} = 21^o$.

The second level of UTM labeling is with task to locate the territory in relation to the one hundred square kilometer division. Considering that it is about zone 34T, the rules for labeling even UTM zones in northern hemisphere are applying.

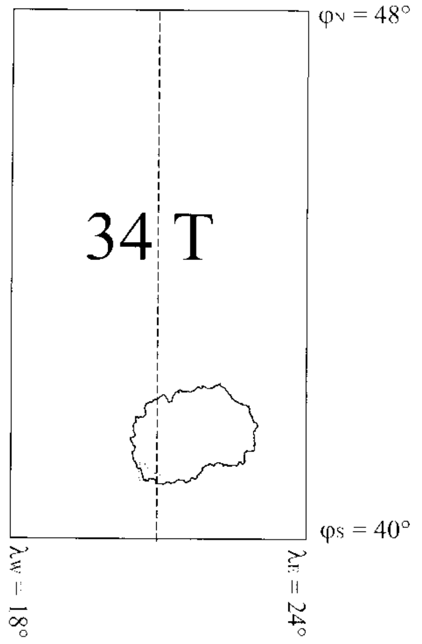

Figure 4. First level of UTM labeling

According to its geographical location and developed schema of UTM labeling, the territory of the Republic of Macedonia covers 6 squares (DL, EL, FL, DM, EM and FM) from second level of UTM labeling.

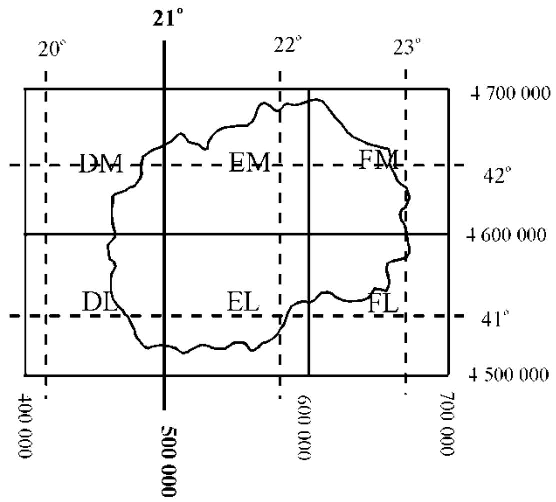

Figure 5. One hundred square kilometer division for territory of R. of Macedonia

4.2 COORDINATE TRANSFORMATION

The choice of the UTM projection, especially as a projection of the topographic maps of the Republic of Macedonia, should be supplemented with the adoption of the WGS 84 geodetic datum, which besides the projecting system it is factor for integration into European and World system. The problem of the transformation (the definition of the transformation parameters) is overcoming with use of modern geodetic methods especially with use of GNSS measurement that enable obtaining coordinates of points in world geodetic system.

Using the available data from the measurements that are performed on the territory of the R. of Macedonia, it is possible to obtained middle values of the parameters for transformation of the geographic coordinates from state geodetic datum to WGS 84 datum. For central point of the territory of the Republic of Macedonia with coordinates

$$\varphi = 41^{\circ}\,36' \qquad \lambda = 21^{\circ}\,45'$$

the values of the transformation parameters are:

$$\mathbf{\Delta\varphi = +1.5'' \qquad \Delta\lambda = -19.4''}$$

The transformation of the geographical coordinates from the local system to WGS 84 system was carried out according next schema:

$$\varphi_{WGS\ 84} = \varphi_{Local} + \Delta\varphi$$

$$\lambda_{WGS\ 84} = \lambda_{Local} + \Delta\lambda$$

In most specific cases of particular interest are the parameters which are allowing transformation of the grid UTM coordinates from one to another system. Their values for the central point of the territory of the R. of Macedonia are:

$$\mathbf{\Delta Y = -442\ m \qquad \Delta X = +506\ m}$$

The transformation of the UTM grid coordinates from local system (Bessel ellipsoid) to WGS 84 is performing with accordance by next schema:

$$Y_{WGS\ 84} = Y_{Local} + \Delta Y$$

$$X_{WGS\ 84} = X_{Local} + \Delta X$$

The accuracy of the transformation depends from many factors including:

- The accuracy of the transformation parameters for central point of the projecting territory;
- The variations of the transformation parameters from the center to the extreme points.

According to the calculations performed by the authors of this paper, the transformation parameters for the center point are determined with errors whose maximum values are:

$$m_{\varphi\ max} = \pm\, 0.06'' = \pm\, 1.9\ m$$

$$m_{\lambda\ max} = \pm\, 0.11'' = \pm\, 2.5\ m$$

while the real accuracy is twice higher.

The above values are defining the absolute accuracy of spatial data in relation to the world system.

Due to the usage of unique transformation parameters ($\Delta\varphi$, $\Delta\lambda$), determined as e result of variation of transformation parameters at the extreme points from the territory of the R. of Macedonia appear errors with values:

$$m_{\varphi} = \pm\, 0.23'' = \pm\, 7\ m$$

$$m_{\lambda} = \pm\, 0.68'' = \pm\, 16\ m$$

These errors are representing the relative accuracy of the spatial data which comes from the defect of the geographic coordinate network (the usage of unique transformation parameters).

According to the above data, the transformation parameters can be used in map production of cartographic products in scale range from 1:200000 till 1:1000000.

4. CONCLUSION

The needs for integration of our system in world projecting system, as well as efforts in the Republic of Macedonia for own cartographic production, require the adoption of the world standards in area of defining, producing and reproducing of the cartographic products. Therefore, this paper deals with the problems of the world projection system in order to gain a theoretical knowledge of the standards of this system and its practical application in the preparation of maps for the territory of the R. of Macedonia. In that context, the basic characteristic of the UTM system and WGS 84 geodetic datum are presented as basic components of the world projecting system. In addition, a special emphases is put on defining the levels of the UTM labeling for our country, as same as defining of the transformation parameters from state geodetic datum to WGS 84 system.

The introduction of the geodetic datum WGS 84 and UTM system in process of map preparation (especially topographic maps) for the territory of the R. of Macedonia is a requirement that should ensure compatibility with modern tendencies of our country for associative membership in NATO alliance, in which these elements represent standard in the cartographic production.

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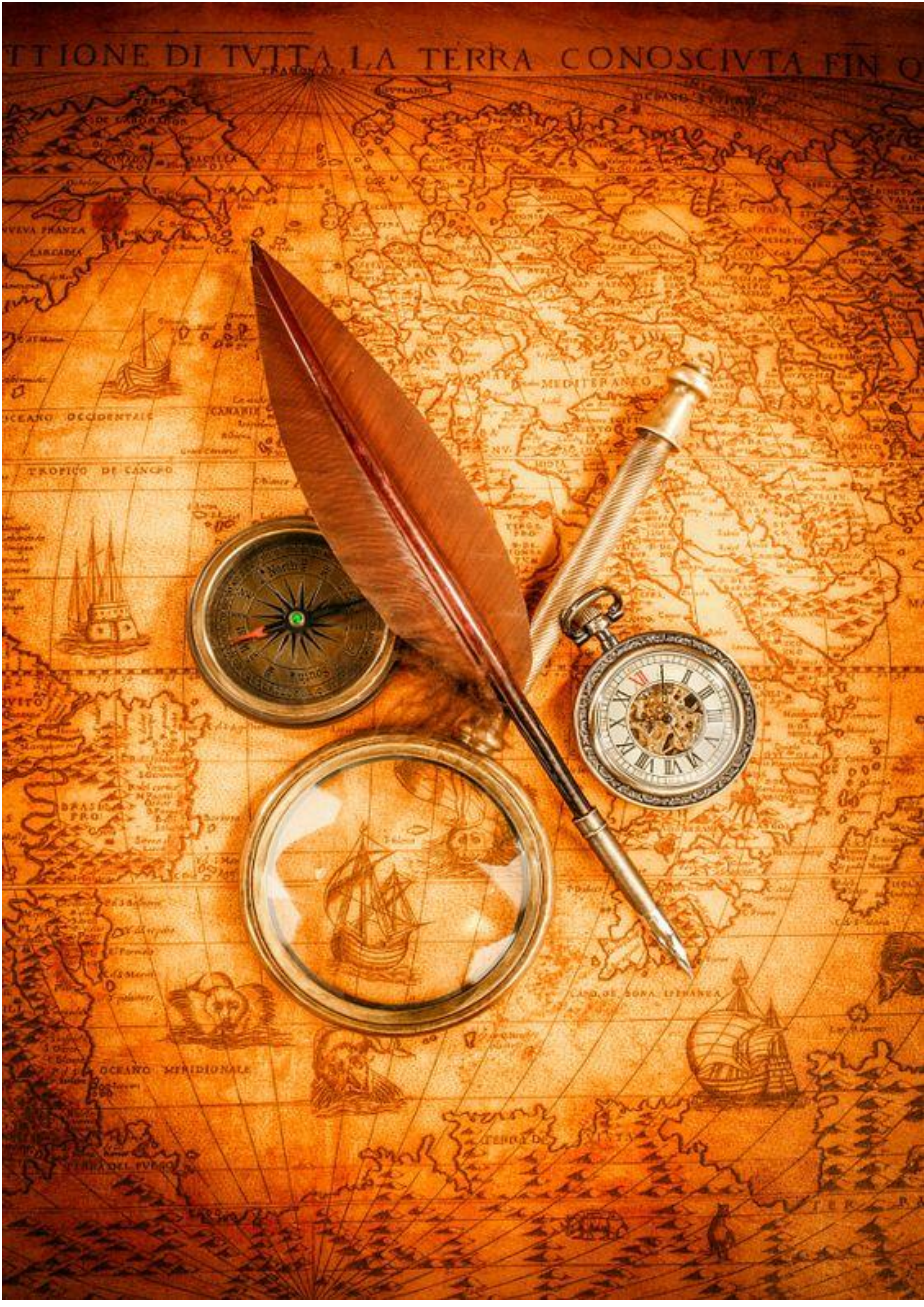
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THE USE OF DRONES IN THE DEVELOPMENT OF CADASTRAL SYSTEMS AND SMART CITY PROJECTS IN REPUBLIC OF MACEDONIA

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This thesis elaborates the method of obtaining spatial data using drones and their application in order to develop the cadastral systems and set the foundations for the smart city project in Republic of Macedonia. The aim is to see the advantages in using drones and the power of data received with the help of drones. Recognizing its capabilities, provocations are created on ideas that would use the obtained product with the aim to enter into higher detail levels of the cadastre system allowing monitoring already existing data. These data would also represent a good base for the development of smart city projects, by providing the other scientific disciplines a 3D model overview of the whole city area giving them the opportunity to implement their innovations accurately based on a realistic view of the area which is the subject of work.

Keywords: Drones, cadastral systems, smart city.

1. DRONES, PART OF THE UAV (UNMANNED AERIAL VEHICLE) TECHNOLOGY

Within geodesy, one of the main challenges is the elaboration of manner, procedures and methods for spatial data acquisition. With the development of technology we are witnessing many innovative solutions that deviate from the classic geodetic methods used in the past. Their creation has the aim to facilitate the way of spatial data acquisition as well as to improve the quality and accuracy of their collection. One of these methods is the use of UAV (Unmanned aerial vehicle) technology, that is, technology in which the main element is the use of drones.

The advantage in the use of drones is the rapid acquisition of data, access to all kinds of terrain, coverage of larger areas of operation, as well as the economic factor that makes this technology very competitive on the market.

2. THE ROLE OF GEODESY IN THE DEVELOPMENT OF SMART CITY PROJECTS

The smart city project is a vision of an urban development in a particular area in order to integrate information and communication technologies into one set that would enable easier management and development of urban areas. This system includes all the elements that participate in the development of a certain area such as: economic development, infrastructure development, communication technologies, vegetative belt management, water resources management, natural resources, cultural heritage protection, etc. in order to increase the efficiency of services in more areas of functioning of a particular city.

This would also increase the monitoring of the specific city area, as well as the control over its progress and development. The main goals of implementing this type of project are to involve people in its creation, to familiarize people with its possibilities, as well as their adaptation to the innovations that such project offers.

Figure 1. The position of the geodesy in the smart city project

Image one shows the position of geodesy in the smart city project where it's noticable that in the first step it gives the base for its creation and development and in the next uses the benefits of the designed project in order to improve the environment.

Geodesy standard used in the smart city projects is the CityGML (Geographic Markup Language) standard which foresees creation of a 3D model display of the whole city area. This standard is defined by a consortium that builds this standard on the base of several layers of detail.

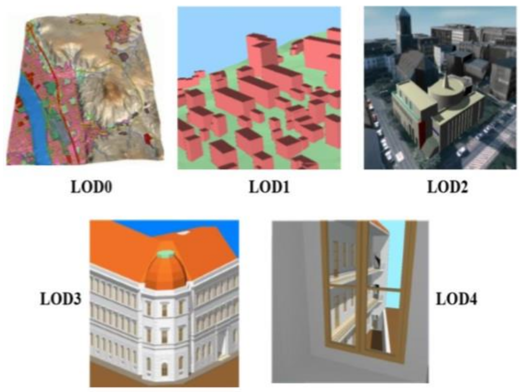

Figure 2. Layers of detail which define the CityGML standard

The first layer of detail LOD0 (Layers of detail) contains data for a two-dimensional view of the field. This layer is called by many researchers in this area 2.5 dimensional due to the picturesque representation of the texture on the ground. The second layer LOD1 is also known as a block model that contains data for a three-dimensional view of the terrain, but there are no details of the terrain configuration. The third layer LOD2 contains a three-dimensional view of the terrain with display of the configuration of the terrain, but in a weaker resolution. This layer contains data on the roofs of the buildings and the land, but it doesn't contain a detailed overview of the facades, a detailed overview of areas covered by vegetation, infrastructure, water surfaces, etc. This section is covered in the fourth layer of detail LOD3 which contains all the date for the subject area and their display is in high resolution. The last layer of detail LOD4 upgrades all these data with a detailed overview of the interior of all the premises of objects located in the subject area.

3. METHOD OF OBTAINING SPATIAL DATA BY USING A DRONE AND TYPES OF RECEIVED OUTPUT PRODUCTS

The procedure for obtaining spatial data using a drone begins with the preparation of the terrain. The preparation of terrain is based on setting photo signals on the ground, which are measured by using some of the classical geodetic methods. The purpose of this preparation is to optimize the project in the State Coordinate System. Therefore, the whole project is properly oriented, positioned and with the correct rate size. The next processing stage is defining a flight plan by defining the following segments:

- Scope of the area subject of the recording process;
- Flight plan type, which defines the drone's motion trajectory;
- Drone's flight height;
- Longitudinal and transverse overlap between photos;

The third stage of getting the final product is the processing of photos collected on the ground in a particular software platform. The procedure takes several steps. In the first, the software products available on the market are mapping the characteristic dots that are visible on multiple photos. This way, the photographs create 3D dots in space which are mutually relatively oriented. Such dots are numerous and create a sparse cloud. In this section, with the help of multi view technology based on epipolar geometry, besides determining the 3D dots in space, the projection center of each of the cameras as well as the ratio of the edge marks in relation to the projection center are determined. This automatically determines the parameters of the internal orientation, that is, the process of calibration of the camera. However, in this process, it is advisable to enter the parameters manually, with the calibration of the camera being determined in advance by the laboratory path. The next step in the processing of the photographs is the geo-referencing of the project, its optimization in the State Coordinate System, creating the connection between the control points marked in the field and the relatively oriented 3D model. After this procedure, the whole project is precisely oriented, positioned and has an exact size. In the next step the software solutions based on the previously specified parameters create a dense cloud of dots. This dots' cloud represents the base for creating a network model (mesh) based on a triangulation (tin) network, which is the base for creating all output products of the project. Such a triangulation network can generate a block model that is parallel to the LOD1 level, but it can also create 3D models with an exactly expressed structure that are parallel to LOD2 and LOD3 of the CityGML standard within the smart city projects. The final step in processing the photos is generating the final shape of the 3D model, with the highest resolution generating several types of 3D models that differ in certain characteristics.

With the process the following output data are obtained:

- Ortho-photo products;
- Dot clouds;
- 3D field models;
  - Digital elevation model.
  - Structured model.
  - Tile model.

The last stage before the implementation of the obtained product is the examination of quality. The quality is examined in the following way: some of the dots defined in the first phase with the preparation of field participate in the project's geo-referencing, and some aren't taken into account during the processing, but serve to test the accuracy of the developed project. The software solutions that exist in the market for the assessment of project's quality generate a report in which all the segments and stages in the processing and the obtained accuracy during its preparation are shown in details.

4. IMPLEMENTATION OF THE RECEIVED PRODUCTS FOR THE PURPOSE OF DEVELOPING THE CADASTRAL SYSTEMS AND LAYING THE FOUNDATIONS FOR THE SMART CITY PROJECTS IN REPUBLIC OF MACEDONIA

The obtained products with the help of drones can be used in order to update and monitor the existing geometric and attribute data contained in the cadastre system in Republic of Macedonia. Image 3 shows a situation from the portal of the Agency for Real Estate Cadastre on a specific area on which the recordings were made with the use of drone.

Figure 3. Recorded area on the portal of the Agency for Real Estate Cadastre

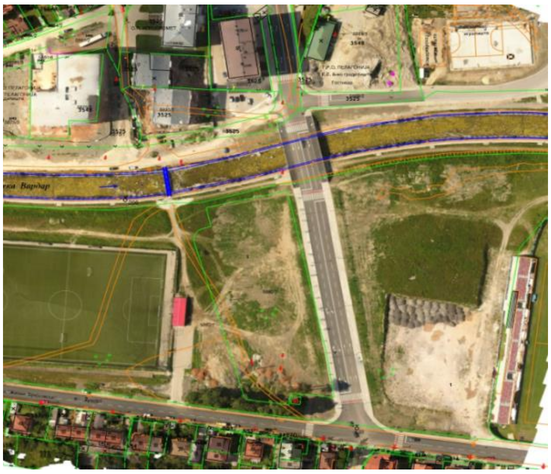

Figure 4. Ortho-photo product created using drone

After conducted recordings on the subject area an ortho-photo product was created shown on image 4. The image displayed shows the cadastral plan that is in force for the subject area overlapping with the ortho-photo product. From both images, a number of latest changes can be noted, such as: road construction, construction of a football field, construction of buildings, beginning of construction of other buildings, etc.

This shows that the resulting product with its power imposes itself as one of the unbreakable segments in geodesy. However, a question arises: "How to implement these products?". In this segment, one thing is certain the products that would be implemented must pass strictly defined norms and standards that would guarantee their quality. Also, as one of the main prerequisites is the expansion of the cadastre system domain which would open the possibility for setting 3D models of entire urban areas in one geo- information system (Image 5).

Figure 5. 3D model of a city area made by drone

Such importing would be a good opportunity for monitoring as well as developing 3D cadastral systems and entering higher levels of detail of the cadastre system

As stated before, the geodesy standard used in the smart city projects is the CityGML standard, which is based on the five layers of detail. Image 6 shows the connection between the layers of detail defined by the CityGML standard and the segments that create the cadastre system where we can notice a great similarity between them.

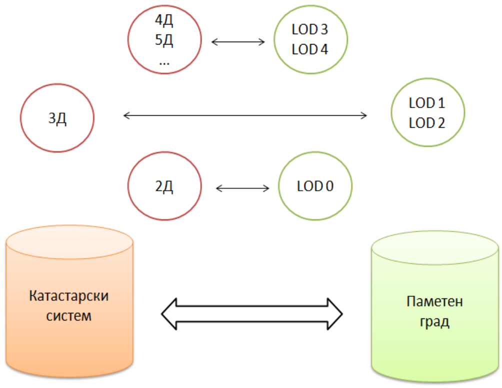

Figure 6. Connection between the cadastre system and the layers of detail defined with the CityGML standard

The idea of this comparison is based on the fact that the products obtained with the help of drones, backed up with other geometric and atypical data contained in the cadastre system in Republic of Macedonia, would be a good ground for creating the smart city project base in Republic of Macedonia. The ultimate goal is besides predicting further development of the smart city project the fact that by the development of such project and its upgrading by other scientific disciplines it will be possible to upgrade the cadastral system and upgrade it into its higher levels (4D, 5D etc).

4. IMPLEMENTATION OF THE OBTAINED PRODUCTS IN OTHER THEMATIC AREAS

When we talk about the implementation of products obtained from a drone in certain thematic areas, we are talking about their implementation individually in specific spheres of public interest for a particular environment:

- Infrastructure;
- Management of natural resources
  - Water surfaces;
  - Areas covered by vegetation;

- Protection of cultural heritage
  - Memorial landmarks;
  - Religious objects;
  - Archeological sites;

Figure 7. 3D model of a religious object made by drone

Image 7 shows the 3D model of the church St. Dimitrija in Veles, where all the details and mosaics from the façade can be seen and the goal is to maintain the authenticity in further reconstructions. The following image 8 shows the possibility of measuring the tiniest details that exist in the building, which would enable precise creation of multiple profiles that later on can be used in the preparation of, elaborates and project documentation for the protection of cultural heritage. The purpose of showing the use of drones in the protection of cultural heritage has a deeper background, that is presenting the possibility of registration of all real estate of public interest which may be a subject of registration. By doing so geodesy will go a step further in some other segments where now it's used less or it's not represented at all.

Such an example is the registration of all green areas located on a certain territory, their monitoring, quality examination with the help of the variety of sensors that can be carried by drones.

The testing of land quality, predicting the most suitable places for cultivation of certain crops, for afforestation, for the construction of settlements, can also be conducted with drones.

Knowing this, drones are seriously considered as a tool for upgrading the future of geodesy.

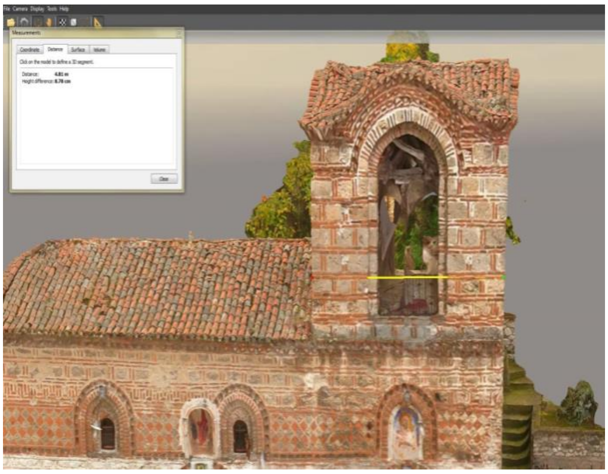

Figure 8. Possibility of direct measurement of details from the recorded 3D model

3. CONCLUSION

- Drones and geodesy are creating an unbreakable bond.
- Data processing and acquisition of spatial data is automated, the quality and domain of the obtained product is increased.
- Due to its power, such data sets provocations and ideas for expanding its application and expanding the domain of cadastral systems, entering into higher levels (4D, 5D ..).
- The existing data within the cadastral system along with the products obtained by drones represent a base for the development of the smart city project.

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