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EDITORIAL TEAM

Editor-in-chief opening remarks

Dear readers,

It is a great honor to introduce you to the new number of the journal Environmental Engineering-Inženjerstvo okoliša published by the Faculty of Geotechnical Engineering, University of Zagreb, Croatia.

The final results are 8 papers, including 2 review papers, 4 original scientific papers and 2 professional papers, with co-authors from 12 different institutions from Croatia and abroad, including co-authors from 6 companies.

The papers covered different issues within the field of environmental engineering: a paper dealing with efficient dam management using SQL and GIS; heavy metal monitoring in surface waters of North-West of Croatia; photocatalytic removal of neonicotinoid insecticide imidacloprid in annular photoreactor; removal of pollutants from abattoir wastewater using a pilot-scale bamboo constructed wetland system in Nigeria; a case study on removal methods for invasive species Amorpha fruticosa at Odransko polje; emission of fine particles (PM2.5) from residential biomass combustion in Croatia; new development strategy alternatives in strategic environmental assessment; and assessment of water quality status in the impact area of the "Piškornica" landfill in Croatia.

In October 2020 the journal signed a license agreement with EBSCO Publishing, Inc. to enter the EBSCO scientific database. The journal will be promoted by the EBSCO Discovery Service (EDS) and in the Central & Eastern European Academic Source (CEEAS), including current Volume.

I would use this opportunity to express my sincere gratitude to the former dean prof. Ranko Biondić for supporting the journal. I`m confident the support of the new dean prof. Hrvoje Meaški will stay at least the same.

At the end, I would like to give my gratitude to all hard-working team members and to our sponsors.

I hope you will enjoy it.

With best regards,

Assoc. Prof. Dr. Aleksandra Anić Vučinić
Editor-in-chief
Department for environmental engineering
Faculty of Geotechnical Engineering
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C O N T E N T

MODERN TECHNOLOGIES AND METHODS OF DATA COLLECTION IN THE FUNCTION OF MAKING BETTER TRAFFIC ANALYSIS OF FORENSIC TRAFFIC EXPERTS

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Abstract: *Even though the European roads are among the safest in the world, the number of road accidents is still a cause for concern. To reduce their number and consequences, many studies are being conducted, including knowledge of the factors that influence the occurrence of accidents. Forensic traffic experts are also part of the treatment of traffic accidents, and they often must base their conclusions on proven incomplete studies of data collected by police officers. In some cases, traffic accident data are still collected in classical ways and with classical measuring equipment. This is often a source of error. This paper defines these errors and offers solutions that are shown primarily through data capture using 3D scanners and photogrammetry. In this way, we can perfectly recreate the situation in the event of a traffic accident through 3D models, thus eliminating many shortcomings of police drawings and records. The article also proposes a central database of traffic accidents as an additional solution to gain a deeper insight into the causes and consequences of traffic accidents.*

Keywords: traffic accidents, forensic experts, traffic accident data errors, 3D laser scanner, photogrammetry, database

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1. INTRODUCTION

The number of vehicles on the roads worldwide is constantly increasing, so there is a greater possibility of accidents. More than 90% of the world's road casualties occur in low- and middle-income countries, although about 54% of the world's vehicles are located there. Drivers between the ages of 15 and 44 are responsible for 48% of all deaths (WHO, no date). In 2020, 18,800 people (European Commission, no date) died in road accidents in the European Union, which is why the European Union is encouraging the establishment of long-term and system-oriented measures taken both within the Union and at the national level.

European roads remain one of the safest globally, with 42 road casualties per million people in the EU, compared to 174 per million worldwide (OECD/ITF, 2020). While the average reduction in road casualties in the EU-27 from 2010 to 2020 was as high as 33%, this percentage is only 10% on average from 2019 to 2020. Of course, some countries have progressed much more than others, such as Malta with 31%, Bulgaria with 26% and Italy and Hungary with 25% (Javna Agencija RS za varnost prometa, 2021).

In Slovenia, we have 555 registered passenger cars per 1,000 population. Their average age is 10.1 years, and all registered vehicles in Slovenia are 1,617,217 (RS, Statistični urad, no date). In 2020, 14,971 traffic accidents occurred in Slovenia (the number is not the most realistic due to the three-month Covid-19 lock-down measures). The highest number of deaths in traffic accidents in 2020 was in the age group over 64 - 16 deaths (the group had 28 deaths in 2018); following the age group from 45 to 54 and 55 to 64 (15 deaths each). Compared to 2019, the most significant increase is in the youngest participants, as six underage participants died last year (3 more than in 2019) (Javna Agencija RS za varnost prometa, no date).

The highest number of traffic accidents in 2020, as in 2018 and 2019, was caused by participants in the age group between 25 and 34, namely 2,328. It is followed by ages between 35 and 44 - 2,317 traffic accidents. Most participants died in traffic accidents caused by perpetrators in the age group between 45 and 54 years of age and between 55 and 64 years of age, with 17 deaths in each age group. There were 14 deceased participants in the age group from 25 to 34 years.

Relative indicators of traffic safety for 2020 are shown as data from the European Commission (Javna Agencija RS za varnost prometa, 2021) and show that in Slovenia, there were 38 deaths per million inhabitants, while in the EU, the average was 43 deaths per million inhabitants (Eurostat, Statistics explained, no date). This places Slovenia in the group of countries with above-average traffic safety in the EU (according to this indicator). However, if we compare our statistics with the best European countries (Norway, Sweden, Malta, Iceland and Switzerland) -

Figure 1, we see that a lot still should be done to achieve road safety in these countries (18-26 fatalities per million inhabitants). In any case, we can say that the situation in Slovenia is significantly better than in 2010 (67 fatalities) or in 2019 (49 fatalities).

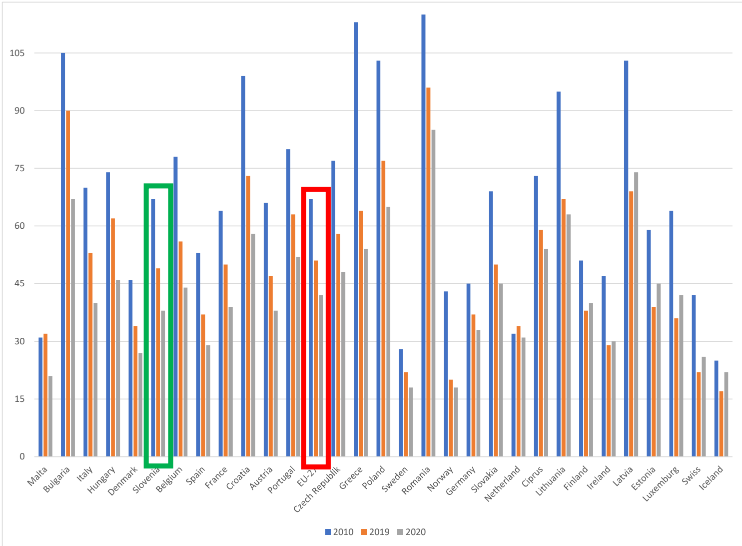

Figure 1. Fatalities per million population in the EU-27

2. TRAFFIC ACCIDENT STATISTICS IN SLOVENIA

The ratio between the number of adults convicted of criminal offences of negligence (PPNMM) and dangerous road traffic (NVCP) with serious body injuries and death and the number of fatalities and severe injuries in traffic accidents in the period 2014-2020 in Slovenia is shown on Figure 2. Data refer to both sexes. We can see that the number of convictions for PPNMM decreases at the expense of convictions for NVCP crime. At the same time, we see that the total number of convictions in 2017-2019 exceeded 350, and in 2020 dropped significantly to 271 (87 PPNMM and 184 NVCP) (RS, Statistični urad, no date).

Following the introduction of the amendment to the Slovenian Criminal Code KZ-1-NPB4 (2012), the crime of NVCP increased sharply compared to PPNMM, and in 2016 for the first time exceeded the acts of PPNMM 52.4% (Fig. 2). Since then, the ratio has been about 2:1, favouring PPNMM.

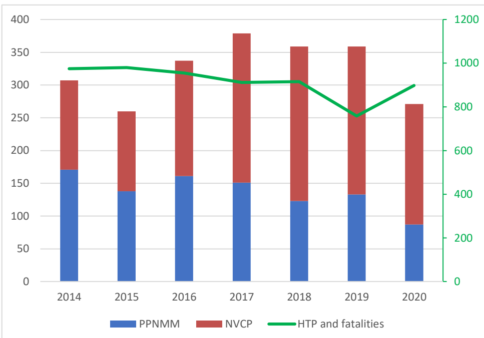

Figure 2. Ratio between the number of adults convicted of PPNMM and NVCP crimes and the number of deaths and severe injuries in traffic accidents in 2014-2020

The main penalties for the PPNMM offence for 2014-2020 and their trends are shown on Figure 3. Imprisonment from 2014 remains the primary measure imposed in the case of the PPNMM. In 2012, this share of prison sentences was only 11.5%. The trend line shows a drastic decline in these penalties from 148 (51.6% of all) to 48 (36.1%) in 2020. A similar but less steep trend has a suspended sentence, which declines from 40.4 % to 34.6% in 2020. In the same period, the fines imposed increased significantly from only 7.3% in 2014 to 29.3% in 2020. These three forms of measures thus remain the main ones and are now pretty much adjusted at about 1/3 each. Other actions (court reprimand, suspended sentence, and preventive measures without sentencing) are almost non-existent in these cases.

The main penalties for the NVCP crime for 2014-2020 and their trends are shown on Figure 4. Here, too, imprisonment since 2014 remains the primary measure. The trend line shows a decrease in these penalties after 2018 to 116 (48.7%) in 2020. Thus, the number of penalties is similar to 2014 (110). A very constant trend is observed in the case of suspended sentences, which averages around 67. However, in this case, there is a trend of increasing fines by more than twice, from 12.0% in 2014 to 28.6% in 2020. In this case, the other measures were negligibly small (one every two years).

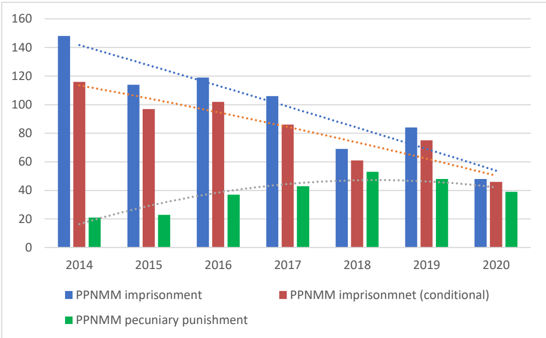

Figure 3. The main penalties for the crime of causing a traffic accident through negligence for the period 2006-2016

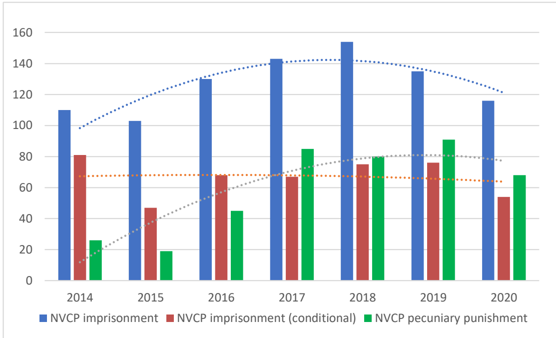

Figure 4. The main penalties for the NVCP offense for the period 2014-2020

Traffic accidents and their consequences in the Republic of Slovenia from 2016 to 2021 are shown in Table 1. 2020 certainly stands out due to the extraordinary epidemiological situation and a few month closures of public life. The table shows that the total number of traffic accidents in Slovenia has decreased. Nevertheless, it is unlikely that we will achieve the goals of the National Road Safety Program for 2022, that by the end of 2022, no more than 35 people per million people will die in traffic accidents and that no more than 230 persons per million inhabitants may be seriously injured.

Table 1. Traffic accidents in the Republic of Slovenia and consequences from 2016 to 2021 (Javna Agencija RS za varnost prometa, 2021)

Year	No. traffic accidents	No. of traffic accidents with injury or fatalities	Consequences (injuries)			Sum of injuries
			fatal	Severe injury	Minor injury	
2016	17931	6495	130	850	7606	8456
2017	17584	6185	104	851	7050	7901
2018	18248	6014	91	821	6867	7688
2019	18861	6025	102	814	6756	7570
2020	14971	4777	80	678	5017	5695
2021	17049	5330	114	784	5654	6438

In the event of an accident with significant material damage, minor and severe body injuries or the fatalities of a participant, the traffic accident ends in court. Table 2 shows the number of cases received in all courts in the Republic of Slovenia from 2016 to 2020, where we see a decline in cases (Slovenija and Pravosodje, 2021). Of these, an average of 6,746 cases (1.03% of all) are related to crimes against public transport safety, which, in addition to PPNMM and NVCP, include endangering special types of public transport and leaving the injured person in an accident without assistance. Still, the latter are in the vast minority. Figure 5 shows the trend in the number of criminal cases in the courts as a whole, compared to road traffic offences. We can see that the number of all criminal offences (Figure 5 - blue line) in the Republic of Slovenia has dropped dramatically since 2014 (by 51.2%), which is, of course, very good. The total number of offences against public transport safety is around 338 cases per year and represents 5% of all violations (Figure 5 - orange line). The largest share of this is NVCP, which is on an upward trend, while PPNMM is on a downward trend.

Table 2. Number of cases in courts and cases related to road traffic in the Republic of Slovenia between 2016-2020

year	2016	2017	2018	2019	2020

All cases	709743	682787	649392	647760	572450
Cases connected to traffic accidents	6687	6252	6098	6036	4814
percentage (%)	0,94	0,92	0,94	0,93	0,84

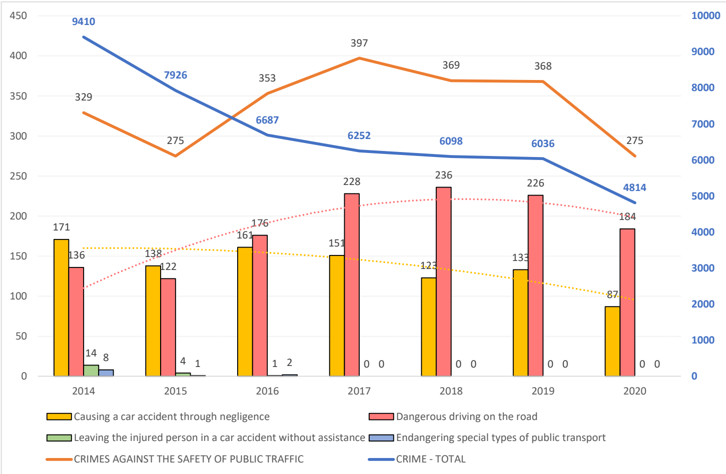

Figure 5. Trends in the number of road transport cases in 2014-2020

In general, the problem of traffic accidents in Slovenia is improving. The improvement of these statistics in Slovenia can be attributed to the following measures:

- new legislation,
- the work of the Ministry of Infrastructure and the Traffic Safety Agency,
- the work of the Councils for Prevention and Education in Road Traffic,
- work in kindergartens, primary and secondary schools with children and students,
- good work of driving schools,
- good work of safe driving schools,
- improved infrastructure,
- improved construction of vehicles,
- good police work,
- work of experts in transport (civil, logistics and traffic engineers, experts, etc.)

Some statistics on traffic accidents are presented in Chapter 2. Traffic accidents around the world are still mainly dealt with in the traditional way: with the help of police officers, measuring tapes and bicycles, and the production of hand sketches. This has certain shortcomings, which will be shown in Chapter 3. Chapter 4 presents some modern measurement methods and technologies that allow better and faster data capturing of traffic accidents and analysis of them even longer after the event.

3. THE WORK OF FORENSIC EXPERTS AND THEIR PROBLEM

Although we have highlighted only traffic accidents with body injury and fatal cases in criminal proceedings in the statistics, the handling of traffic accidents (maybe even the same) can end in court in other proceedings (misdemeanour, litigation and commercial). In many cases, the opinion of a forensic expert is required from time to time or even more than one forensic expert in the same proceedings. This prolongs the duration of the procedure and makes it more expensive. Criminal proceedings are relatively quick, but litigation is long, and its beginnings are usually much further away from the date of the accident than other proceedings. Thus, a forensic expert may have difficulties analysing a traffic accident, as there are no more physical traces on the roadway, and cars are usually already repaired. Thus, the forensic expert must mainly rely on (more or less) quality police records, photo documentation, witness statements and drawings.

Judicial experts are appointed based on a public call by the Minister responsible for justice for a specific professional field and subfield of expert work (ZDeb, 2019). The expert is ordered by a written order of the body conducting the procedure (usually, the expert is given 45 days to prepare an opinion). The order shall state which facts to establish or judge and to whom the expert work should be entrusted. The order is also served to the parties. Before a forensic expert begins work assigned to him by a court or other state body, the forensic expert must carefully examine the scope and type of knowledge and experience required. To prepare an expert opinion, the Ministry of Justice prescribed general and individual guidelines (Ministrstvo za pravosodje, 2014) to prepare an opinion, which the Expert Council approved.

Difficulties in preparing expert opinions are usually identified during the re-inspection phase of the accident or during the opinion itself when comparing photo documentation and a sketch of the accident site and the record. In general, the problems of forensic experts in the field of transport are as follows:

- the police do not perform measurements of the slope of the carriageway (longitudinal and transverse),
- the police do not perform bend radio measurements,
- the accuracy of measurements with a measuring tape or by measuring wheel,
- photo studies are often missing, or images are inferior (black and white photocopies) - especially in litigation, where clients provide pictures.
- the police only perform rectangular measurements, which are often not accurate enough,
- the police do not establish vertical and horizontal band view,
- the certain starting point of measurements does not allow locating the place of collision,
- drawing a sketch in the field and redrawing it in the office is often a source of error,
- drawings are occasionally not to scale (we cannot use it in other programs, we cannot determine distances that are not explicitly quoted and measured),
- the sketch does not specify (measured) all the details drawn,
- the drawing does not show all the fallen parts from the vehicle, traces, etc., visible in the images.

Errors in accident data were well described in the paper (Ahmed et al., 2019), where mistakes were divided into errors in reporting accident data and recording accident data. Although data reporting does not depend so much on technology, much can be done in accident data recording.

Table 3. Percentage of errors in reporting traffic accidents (Ahmed et al. 2019)

Countries with	Percentage of reporting errors: Minor injuries	Severe injuries	Severe injury but no fatalities	Fatalities
high GDP	39 - 82	16 - 52	12 - 84	0 – 31
mid GDP	93 - 98	32,5 - 96	34 - 99	0,5 – 89,5
low GDP	n. a.	n. a.	69 - 80	0 - 61

The average error in the inventory of information related to the location of the accident was 27%, data on the victim 37%, vehicle 16% and circumstances 19%. Among the identified causes of errors in reporting accident data, the police system was highlighted as the most important. A total of 26 causes of mistakes in accident data were addressed, of which 12 were related to reporting and 14 to recording. The authors recommend reforming the police system and raising public awareness to reduce errors in accident data (Ahmed et al. 2019).

Between 2013 and 2021, 50 recent traffic accidents were selected from the personal database of expert opinions. Based on the analysis, we find that in 16 cases (32%), the expert work was challenging due to a combination of the shortcomings listed below (the number of times the problem is repeated is given in parentheses). Among the selected cases were five accidents with material damage, 33 accidents with minor injuries, ten accidents with severe injuries and two fatal accidents. Of these, 41 were heard in civil proceedings and 9 in criminal proceedings.

Identified deficiencies are incorrectly determined data or entered values or could not be determine precisely:

- distances from the place of collision to the stopped vehicle (4x),
- exact location of the collision (12x),
- the sketch made by the police did not cover all the traces visible at the scene of the accident (8x),
- lost details as the drawing were black and white or poorly photocopied (3x),
- details of the accident (when re-examining the scene of the accident), especially in bends and roundabouts, because the tracks, objects, parts of the vehicle or the stopping place of cars were not correctly located (6x),
- there were significant errors in redrawing the sketch of the draftsman at the police station (2x),
- images of the place did not show the situation at the time of the accident (due to the time delay of the arrival of police officers at the scene of the accident and the beginning of the viewing / photographing of the event) (3x),
- sketches are not in scale (7x).

A visit to the scene of a traffic accident by a forensic traffic expert causes delays in the duration of the proceedings and the entire court proceedings are more expensive, but it is necessary if the expert does not have all the required information from the scene of the accident (police work).

4. PROPOSAL TO IMPROVE THE STATE OF IMPLEMENTATION OF TRAFFIC ACCIDENT ANALYSIS

4.1. Use of modern measurement techniques

The use of a 3D scanner and an unmanned aerial vehicle (UAV-drone) is already in everyday practice in some places today, and its advantages are obvious (Kamnik et al. 2020). Laser scanning and photogrammetry with drone images are also used for 3D modelling of outdoor crime (Cunha et al., 2022) and other forensic investigations (Renduchintala et al., 2019; Desmoulin et al. 2022); Authors like Mohd Daud et al. (Mohd Daud et al., 2022) discussed using drones for challenge purposes in recording mass casualties.

There are also investigations of road safety infrastructure (Zhang, 2008; Caroti, Martínez-Espejo et al. 2015; Sarsam et al. 2015; Inzerillo et al. 2018) and road engineering structures (Mandirola et al., 2022) using 3D reconstructions according to traditional or modern routes using 3D modelling and drones. Analyses of traffic flows are already more or less well analysed through drones (Salvo et al. 2014; Garcia-Aunon et al. 2019).

Currently, the Slovenian Police has eight scanners (one traffic police station one), with which they deal with all traffic accidents of the 3rd and 4th category (with fatal outcome or severe injuries). In certain situations, also the 2nd category (with injuries). Given that one scanner covers an extensive area (a total of 111 police stations), it would make sense to consider purchasing additional scanners (e. g. for the needs of motorway police).

4.2. Capturing of images according to photogrammetric principles

Most of the images taken today are taken unsystematically, and it is impossible to make stereo pairs and stereo models from them. Thus, images should be taken according to the basic photogrammetry approaches, and relative orientation should be performed. It is about establishing a similar relative relationship between the shots at the time of the exposure. Stereo-pair are two shots taken from different points of view and partially overlapping by at least 50%. The stereo model is a relatively oriented stereo pair. Thus, we can obtain a 3D model of a traffic accident event, which can always be inspected, additional measurements can be performed, the model can be rotated, the situation can be viewed from different angles, etc. This should be done for all traffic accidents.

Images can be taken from the ground (terrestrial photogrammetry) and/or from the air (aero photogrammetry). That adds a new angle of view to the crash site that may not be visible from the ground. Aerial photogrammetry is now available with very accessible drones for free use for police purposes and without significant restrictions.

The benefits of photogrammetry for data collection in traffic accidents and analysis are discussed by some authors worldwide (Osman & Tahar, 2016; Stáňa et al., 2017; Pérez et al., 2019; Matys et al. 2021; Stehel et al. 2021).

When we have measurements performed in a modern way, many problems disappear. We have opportunities we didn't have before. Figure 6 - Figure 9 shows some possibilities of additional measurement by cloud point or models obtained from scanning data or images: measurements of a longitudinal slope, transverse slope, bend radius, and non-rectangular distances. Of course, there are many more possibilities here, depending on the needs and purpose. The Slovenian police do not use drone traffic data (aero photogrammetry) to capture data. 3D scanning can also be complex in some cases (heavy rain, snow, etc.). We can always take a photo, so in such cases, it is crucial to use the photogrammetric method and obtain a 3D model from the appropriate images.

Figure 6. Longitudinal slope measurement

Figure 7. Transverse slope measurement

Figure 8. Bending radius measurement

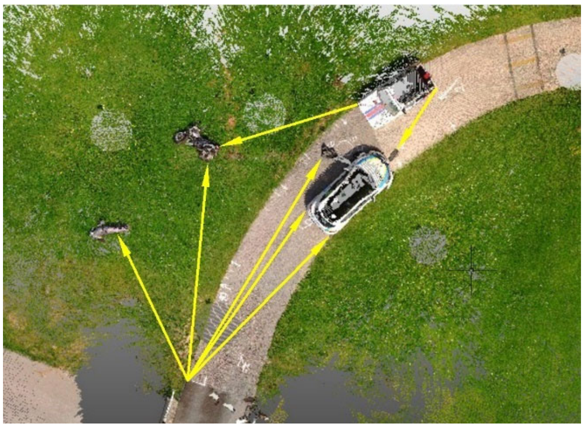

Figure 9. Measurement of non-rectangular distances

4.3. Education of stakeholders involved

With the introduction of new technologies, the education of all stakeholders involved in data acquisition, possible redrawing, data processing, analysis, and reporting must also play a key role. Software packages for image processing and stereo pairs (models) are user-friendly and so called, "Black box" thinking can occur, and over-reliance on the program itself.

It is essential to educate and teach staff who use modern procedures to capture and process data, how to prepare input data well, what are the crucial components of the capturing process, what to pay special attention to, what should be the accuracy of image capturing and where could be sources of error. It is necessary to be aware that insufficient input data result in poor output and, consequently, erroneous conclusions.

4.4. Central database

The primary source of data on traffic accidents today is still primarily the work of the police and statistical office. In any case, it would be necessary to establish a central database, which would be filled in by other stakeholders related to the treatment of traffic accidents (Figure 10).

Additional data sources are mainly insurance companies, which deal with many damage cases that do not reach the police, as the parties manage to agree on their own and when the issue is only minor material damage. In any case, this data would increase/decrease the number of accident black zones and their importance.

One of the most important stakeholders is also road maintenance workers, who have an excellent insight into the state of infrastructure. An essential part of the central database would also be the data of medical personnel, which deals with injuries and the duration of treatment, sick leave, etc.

Research and educational institutions often urgently need input data for the analyses and syntheses that follow from this data. The conclusions could be returned to the central base. Other important stakeholders are the Health Insurance Institute of Slovenia (ZZZS) and the National Institute of Public Health (NIJZ), as they keep data on sick leave, injuries, etc.

The central database should be established by the competent Ministries and regulated through appropriate legislation. At the moment, we see the Traffic Safety Agency as the leading manager of the database.

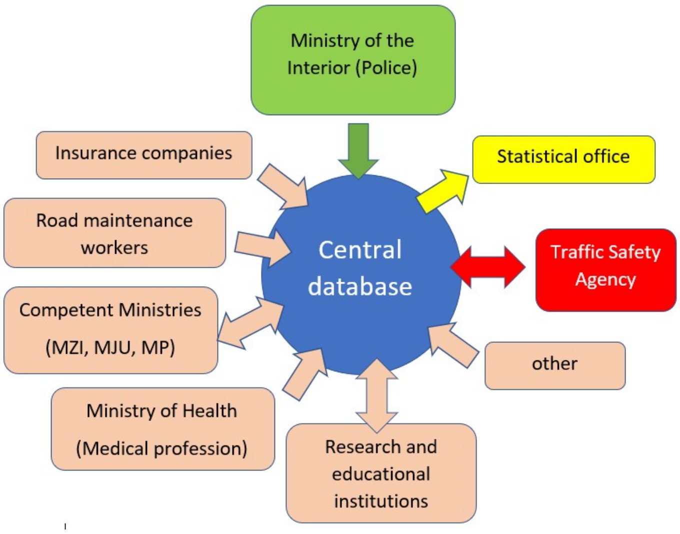

Figure 10. Schematic representation of the establishment of a central database on traffic accidents

5. CONCLUSION

Statistics of traffic accidents worldwide in Europe and Slovenia are relentless, and the numbers remain high. Values have practically halved in recent years at the expense of improved infrastructure and all other measures. Still, any material damage, body injuries and fatal casualties can be a tragedy. However, European roads remain the safest globally, with 42 road deaths per million inhabitants in the EU, compared to 174 deaths per million inhabitants worldwide. In 2020, the number of deaths per million inhabitants in Slovenia due to traffic accidents was 38 (despite the closure of public life).

The number of adults convicted of causing a traffic accident through negligence is declining at the expense of convictions for the crime of dangerous driving. The total number of convictions has been declining since 2017.

Imprisonment since 2014 remains the primary measure imposed in the case of negligent traffic accidents. Still, the trend in the number of such sentences is fortunately negative and fell from 148 (in 2014) to 48 (in 2020). A similar but less steep trend has also imposed a suspended sentence. However, the level of fines imposed is increasing. These are the primary forms of measures and are regulated by proportions of about 1/3 each.

The trend in the number of dangerous driving penalties after 2018 is declining (it was growing until 2018). A constant trend is reflected in the case of suspended sentences, and the trend of increasing fines by more than twice since 2014 is visible.

The number of court cases and issues related to road traffic in the Republic of Slovenia has been declining recently and has almost halved since 2014. The number of criminal offences against public transport safety represents 5% of all criminal offences in the Republic of Slovenia.

The issue of traffic accidents in Slovenia is improving. The improvement of these statistics in Slovenia can be attributed mainly to new legislation, the work of competent services, the improvement of infrastructure, etc.

In many cases of dealing with a traffic accident in court, the opinion of a forensic expert is required from time to time by even more forensic experts in the same proceedings. This prolongs the duration of the procedure and raises the costs. Since it has usually been a long time since the need for an expert opinion and the actual traffic accident, forensic experts can have considerable difficulty gathering additional facts for analysis. Thus, a forensic expert must rely mainly on (more or less) quality police records.

In general, the problems of forensic experts in the field of traffic are related to the lack or even incorrect data of the police, incomplete accident drawings or other errors that occur in capturing and presenting the facts of the accident. According to research, the average number of errors in the inventory of information related to the accident location is 27%, data on the victim 37%, vehicle 16% and circumstances 19%.

Between 2013 and 2021, 50 more recent traffic accidents were selected from our database of processed cases. In 16 cases (32%), expert work was challenging due to one or more shortcomings. Among the selected cases were five accidents with material damage, 33 accidents with minor injuries, ten accidents with severe injuries and two fatal accidents. Of these, 41 were heard in civil proceedings and 9 in criminal proceedings.

Solutions using modern measurement techniques such as 3D laser scanning and photogrammetry (aero and terrestrial) are presented. In this way, measurements, and insights into the situation at the time of the accident can be obtained. This would greatly simplify and improve the work of the forensic traffic expert and speed up and reduce the cost.

It would be excellent for the police to capture images according to the principles of photogrammetry when capturing data in the field. This would enable 3D models to be made by experts who will process their data later, especially in difficult weather conditions).

We also propose appropriate training for all actors who cover accident data to get acquainted with the basic procedures, equipment, technology, and data collection methods in ways that enable better post-processing.

In doing so, it would be necessary to establish a single database not only of the police but also of all other stakeholders who are otherwise involved in dealing with the consequences of traffic accidents or the state of infrastructure. This would also require the necessary resources and regulations and the scope of stakeholders.

The use of modern measurement methods and technology could thus avoid many problems and errors in the collection of traffic accident data, such as: incorrect position measurements, incorrect location of the collision, incomplete collision traces, incorrect scale, missing length and radius measurements and many others.

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STABILITY ANALYSIS OF AN OLD EARTH SAMARKAND DAM IN KAZAKHSTAN UNDER RAPID DRAWDOWN CONDITIONS

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Abstract: *Despite being potential historical sites, old embankment dams are subjected to many stability challenges due to many factors, including a lack of sufficient stability assessment tools by the time the dam was built and changes in embankment material properties induced by natural and human activities. Therefore, with the current advancement in technology is of great importance to investigate the state of old embankment dams under different potential loading conditions. The stability challenges become of more significant concern when the embankment is subjected to a rapid drawdown loading scenario. In this study, the Samarkand dam located in Karaganda province in Kazakhstan which was put into operation in 1941 is investigated in terms of seepage and slope stability with the help of numerical modelling. Both steady and transient (rapid drawdown) flow conditions are taken into consideration. e finite element method-based modelling is achieved using SEEP/W and SLOPE/W of the GeoStudio software. From the analysis results, it was observed that the old dam can be subjected to a potential failure under rapid drawdown conditions as the minimum factor of safety values were decreasing with the increase in the drawdown rates. For instance, the minimum factor of safety from the instantaneous drawdown rate was equivalent to 32.85% less than the factor of safety retrieved from the long-term steady-state conditions. Also, from Analysis of Variance (ANOVA), a p-value of 9.97×10^{-29} was obtained after subjecting the factor of safety values from instantaneous, 5 days, 10 days, and 1 m per day drawdown rates to ANOVA, indicating that the factor of safety differences among the analyzed drawdown rates were statistically significant.*

Keywords: *embankment dam; factor of safety; numerical modelling; rapid drawdown; slope stability.*

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1. INTRODUCTION

Dams are marked as among the significant historic structures. The Jawa Dam in northern Jordan being among the oldest operational dam in the world (Fahlbusch, 2009); whereby, is well-known as the oldest proto-urban development in Jordan, dating from the late 4th millennium BC. Dams can carry a lot of historical information that can be passed from generation to generation (Sharma and Kumar, 2013). Moreover, dams play an important role in the provision of water for domestic, industrial, and irrigation purposes (Altinbilek, 2002; Ho et al., 2017). They are also often used to produce hydroelectric power as well as for river navigation. To be more specific, the domestic uses of water from dams include water for drinking, cooking, bathing, washing, and lawn and garden watering. Nevertheless, dams and their reservoirs provide recreation areas for fishing and boating; while mitigating or reducing floods. These structures can also act as a good material for students to learn more about why dams are built with the associated activities (Hong et al., 2020).

Normally, the operational mechanism of dams is based on the fact that, during times of excess water flow, dams store water in the reservoir; then, they release water at a controlled rate during times of low flow when natural flows are inadequate to meet water demand. Therefore, when designing embankment dams, all these factors have to be taken into account. In the old days, dams were primarily made of earth, wood, or stone (alone or in combination) (Adamo et al., 2020). Nowadays, dams have evolved from just simple and small to advanced, huge, and complex structures parallel to advances in technical achievements and knowledge on the utilization and handling of watercourses (Castillo-Rodríguez et al., 2017). In that matter, the choice of design and materials is also highly influenced by increasing requirements of modern security and supervision.

However, the process of promoting the preservation and gaining public acceptance of a dam as a historical and cultural heritage raises many social issues. It is well known that the older an object is the easier it is accepted as a historical and cultural asset. However, it has also been observed that the smaller the scale and the more traditional (preferably handicraft) an object is, the easier it is accepted as a cultural asset; therefore, at some point, this factor can significantly affect the cultural perspective of old embankment dams. It is also a matter of perception that, cultural environments and objects representing modernization and technological development are often large-scale, complex, and unattractive to the eye, hence challenging our sense of time, history, size, technology, and aesthetics in general (Boyé and Vivo, 2016).

In the literature, dams are marked as historic sites or structures when are 50+ of age (Adamo et al., 2020). The Samarkand reservoir in Kazakhstan is marked as one of the oldest embankment dams in Central Asia that was put into operation in 1941(80 years of operation by 2021) (Toxanbayeva et al., 2021). The reservoir itself has a length of 25 km, and width is 7 km. The height above sea level is 489 m; while the area is 82 km² and the volume is 0.260 km³. Moreover, the Nura River feeds the Samarkand reservoir. The development of hydraulic engineering construction in the Soviet Union, associated with the rapid growth of the country's industrialization, the collectivization of agriculture, and the reconstruction of the national economy, raised the question of the use of such types of dams, which would ensure the possibility of giving the dams a large height and stability and solved the problem of cost reduction construction by making maximum use of local materials.

Despite the potential of old dams as a cultural heritage, their stability is of significant concern because they are highly prone to failure (Dounias, Potts and Vaughan, 1996). The phenomenon can be highly linked to the fact that with time the embankment materials may be weathered (altering the natural conditions of the materials) and the flow characteristics in the catchment can change. It is also a matter of fact that old dams were designed when the technology was less advanced.

Therefore, it is of great importance to investigate different stability factors associated with old embankment dams with time. Numerical modeling is among the useful approaches that can be used to investigate the state of embankment dams (Mkilima, 2021). With the help of technological advancement, the application of numerical modeling for the investigation of slope stability in embankment dams has become more convenient and reliable. In the recent past, there has been significant growth in numeral modeling software, especially for seepage and slope stability including GeoStudio (GeoSlope) and Plaxis (2D and 3D) (Utepov et al., 2021).

In this study, the potential effect of rapid drawdown scenarios on the stability of old dams for the case of Samarkand in Kazakhstan is investigated. The dam has a maximum depth of 12 m and a length of 25 km located in Karaganda province in Kazakhstan that was put into operation in 1941. Both seepage and slope stability with the help of numerical modeling are investigated based on steady and transient (rapid drawdown) flow conditions. The finite element method-based modeling is achieved using SEEP/W and SLOPE/W of the GeoStudio software.

2. MATERIALS AND METHODS

2.1. Case study description

Samarkand is a dam located in the Karaganda region, Kazakhstan with the region font code of Eastern Europe. Its coordinates are 50°5'54" N and 73°0'55" E in DMS (Degrees Minutes Seconds) or 50.0983 and 73.0153 (in decimal degrees). Its UTM position is CR55 and its Joint Operation Graphics reference is NM43-04. Karaganda is the fourth most populous city in Kazakhstan, behind Almaty, Nur-Sultan, and Shymkent. In 2020 the population in Karaganda was estimated to be 497,777 (projected) as well as 459,778 (2009 Census results); 436,864 (1999 Census results). Karaganda is approximately 230 km southeast of Kazakhstan's capital Nur-Sultan (formerly known as Astana).

Karaganda has a humid continental climate with warm summers and very cold winters. Precipitation is moderately low throughout the year, although slightly heavier from May to July. Snow is frequent, though light, in winter. The lowest temperature on record is −42.9 °C, recorded in 1938, and the highest temperature is 40.2 °C (104.4 °F), recorded in 2002. The geology of Kazakhstan includes extensive basement rocks from the Precambrian and widespread Paleozoic rocks, as well as sediments formed in rift basins during the Mesozoic. Small synclines in the Karaganda Foredeep Basin show Deepwater limestone and shale 450 meters thick from the Carboniferous and Permian, as well as 4.5-kilometer-thick coal-bearing molasse. Within the Tengiz Basin, deposits are never more than two kilometers thick and grow thicker to the south. The Chu Basin is filled with undeformed Middle Devonian through Permian red molasse and carbonate deposits. Calc-alkaline magmatism was extensive in the southeast Kazakh Uplands and the Tien Shan Mountains.

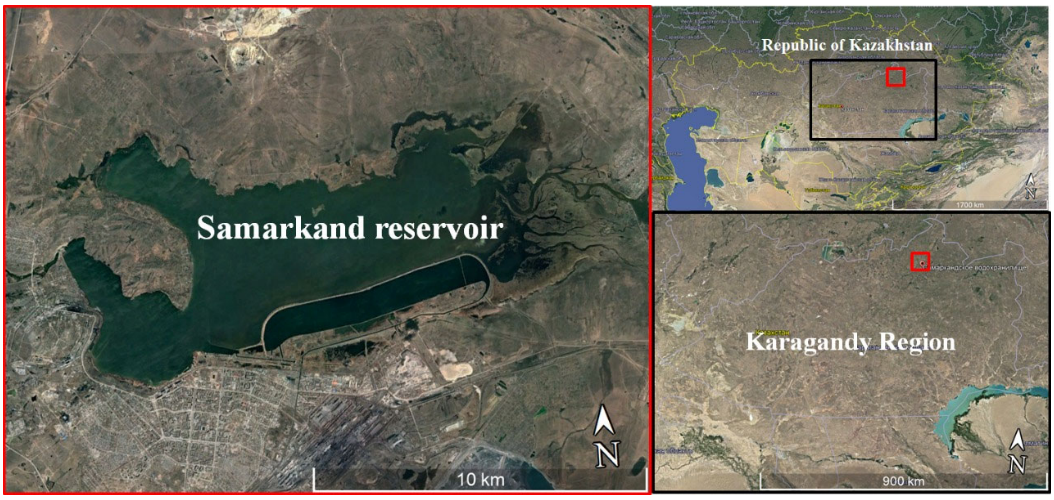


Figure 1. Case study location (Utepov, Mkilima and Abisheva, 2021).

2.2 The historical perspective of the Samarkand dam

The construction of the Samarkand hydroelectric complex was done in 5 years, from 1934. When the construction started, people became the main labor force; it was with their hands that the dam was constructed because the first excavator appeared on the construction site only in 1936. Mainly, during the time, the main labor force was the prisoners of KarLAG, two departments of which were specially transferred closer to construction, to the village of Samarkand. However, it should also be noted that the Samarkand dam is not the only artificial dam on Nura, but it is the largest of these artificial reservoirs. From 1934, the construction process was completed in 1939, which turned out to be arid and therefore the dam was able to be under full operation in 1941, which for this reason is mistakenly considered the year of completion of its construction. The dam erected on Nura was 20 meters high and 300 meters wide. The process of filing an area of 8000 hectares with water lasted a lot - 22 years, until 1961 when the reservoir mirror was formed.

After the construction of the Samarkand dam, it became the most significant artificial reservoir in Central Kazakhstan. According to the Kazakh Academy of Sciences, the total length of the reservoir was 20 kilometers, the width - was 6.5 kilometers, and the maximum depth - was 17 meters.

Then later in 1982, a new hydroelectric complex started to be constructed and was delayed for various reasons. In 1988, the facility was put into operation, but its technical re-equipment and bringing into line with modern standards became possible today when the construction was transferred to the balance of the state. The old dam is currently associated with a number of geotechnical issues, making the operation of the hydroelectric complex of more significance. However, the fact that people used to live on the site of the dam has been producing a lot of mysterious rumors, to the extent that people believe that there is an old cemetery at the bottom of the reservoir. However, local historians cannot confirm this information, since there is no official data on any burials in this area.

2.3 General modelling process

The potential influence of the rapid drawdown scenarios on the stability of the embankment dam was investigated with the help of the finite element method. The other parameters in the analyses were kept constant while changing the drawdown rates. The embankment geometry (as shown in Figure 2) is composed of four different zones with zones 1a and 1b being similar. Generally, the investigation was categorized into five different cases based on the drawdown rate: steady-state, instantaneous drawdown, 5 days drawdown, 10 days drawdown, and 1m drawdown rate stability factors were investigated at the end of the modeling process in all the investigated cases. In this study, the instantaneous drawdown was considered the most extreme condition (worst scenario). Moreover, the analyses were accomplished using the SEEP/W (Arshad, Babar and Javed, 2016)s mainly for seepage analysis, and SLOPE/W is mainly for stability analysis. The modeling processes in the two sub-units of the GeoStudio used slip surfaces, pore-water pressure conditions, soil properties, and loading conditions as inputs.

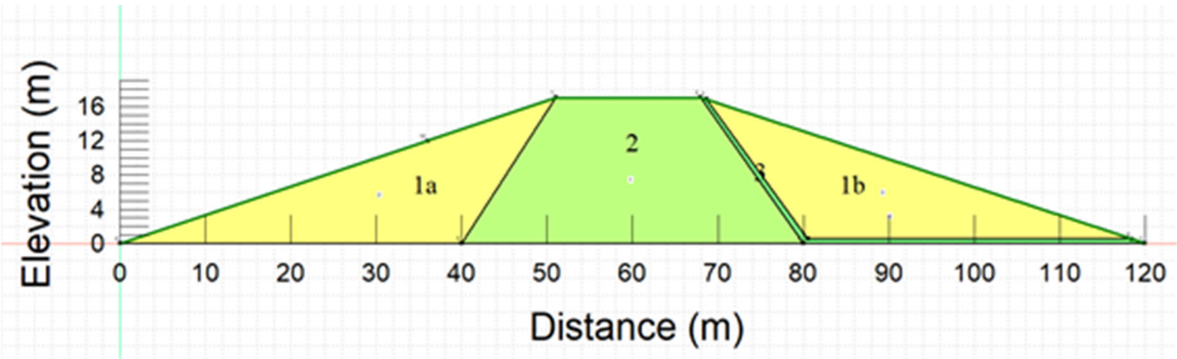


Figure 2. Embankment geometry.

2.4 Seepage analysis through the embankment

Before the simulation of the transient conditions based on the drawdown rates, the model was subjected to a long-term steady-state simulation using the Steady-state analysis method. The transient modeling used the seepage-induced pore-pressures generated from the long-term steady-state. The boundary condition approach was used to specify the extent of the water level variations during the rapid drawdown process (as shown in Figure 3). Moreover, in the study, the transient seepage analyses were used as parents to the slope stability analyses.

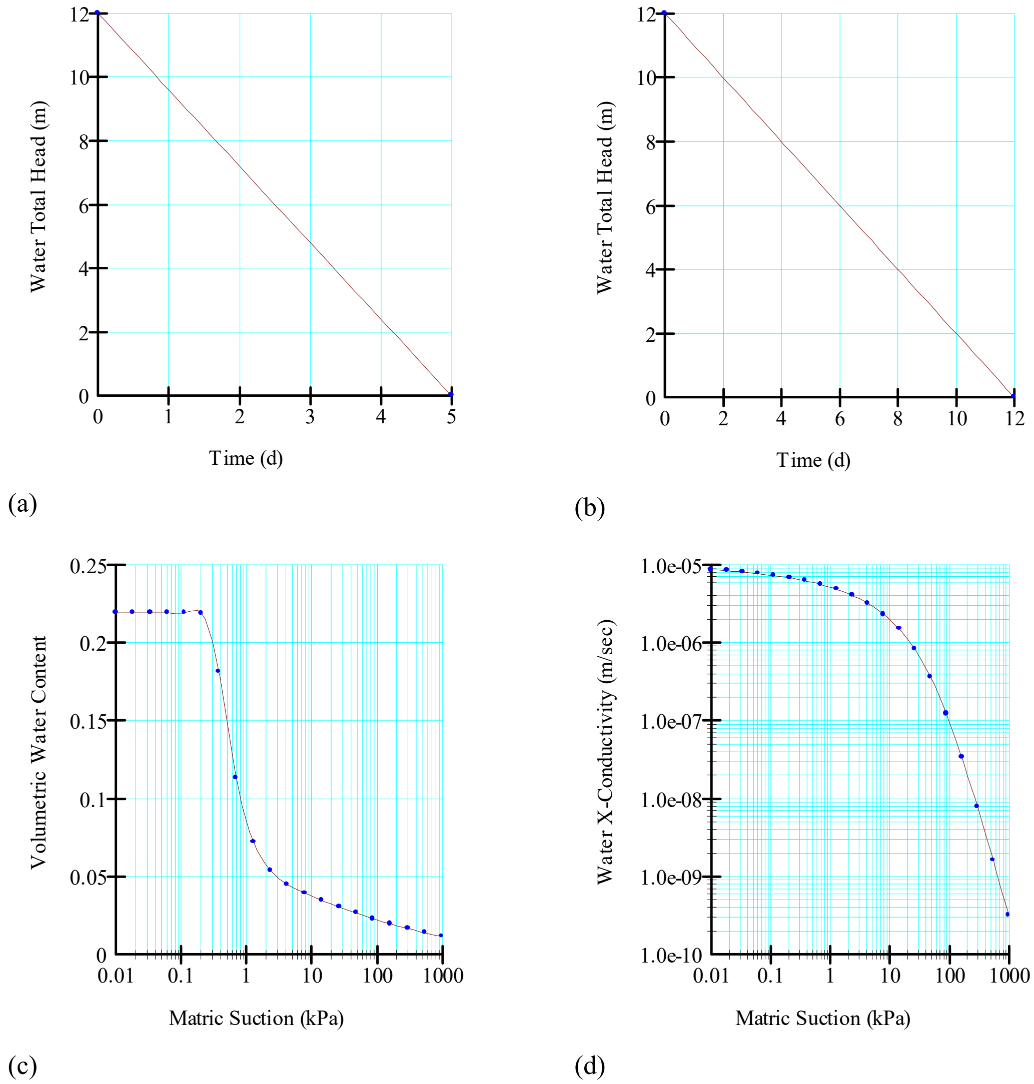


Figure 3. Some of the defined functions: (a) the boundary condition for 5 days drawdown rate (b) the boundary condition for 1 m per day drawdown rate (c) volumetric water content function from zone 1(d) hydraulic conductivity function from zone 1.

2.5 Slope stability analysis

On the other hand, the help of the SLOPE/W of the GeoStudio accomplished the investigation of the embankment slope stability. The Morgenstern–Price (El-Ramly, Morgenstern and Cruden, 2002) analysis method under the general limit equilibrium (GLE) (Lam and Fredlund, 1993) was used in the slope stability modeling. To be more specific, the Morgenstern–Price is a general method of slices that works based on limit equilibrium with the sustaining equilibrium of forces and moments acting on individual blocks. To create the blocks the soil above the slip surface has to be divided by dividing planes (Atashband, 2015). It is also important to be noted that, the interslice shear forces used in the general limit equilibrium methodology are dealt with in an equation developed by Morgenstern and Price (Morgenstern and Price, 1965) (Equation 1).

$$X = E\lambda f(x) \qquad (1)$$

Whereby: *f(x)* represents a function, λ represents the percentage (in decimal form) of the function used, *E* represents the interslice normal force, and X represents the interslice shear force.

2.6 Material characteristics

The dam embankment is divided into different zones based on the material properties; zone 1 (a and b) is more of coarse materials mixed with fine materials (mainly silt and clay) and liquid limit (w_L) ranging from 25% up to 45%. Zone 2 (core) is composed of cohesive material, and fine-grained material (clay). While Zone 3 is more of non-cohesive soil, and filter material (sand and gravel). Table 1 provides a summary of the material characteristics.

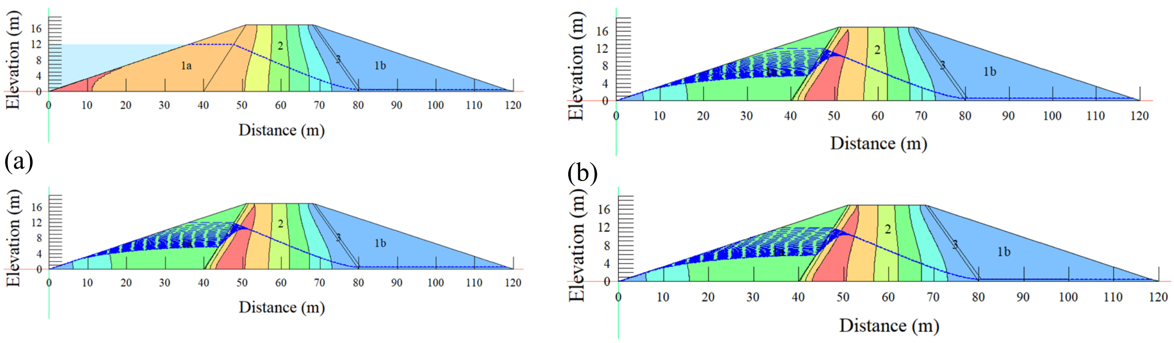
Table 1. Material properties of the embankment

PARAMETER	ZONE		
	Zone 1a, b	Zone 2	Zone 3
Saturated hydraulic conductivity (k_{sat}), m/s	$5 \cdot 10^{-5}$	10^{-8}	10^{-4}
Diameter at passing 10% (mm)	0.1	0.002	0.2
Diameter at passing 60% (mm)	40	0.05	0.8
Liquid limit (%)	25 to 45	50	
Unit weight (kN/m^3)	20.5	20	18.5
Saturated water content (%)	29.6	36.8	40.1
Internal angle of friction (degree)	40	28	38
Cohesion (kPa)	-	15	-

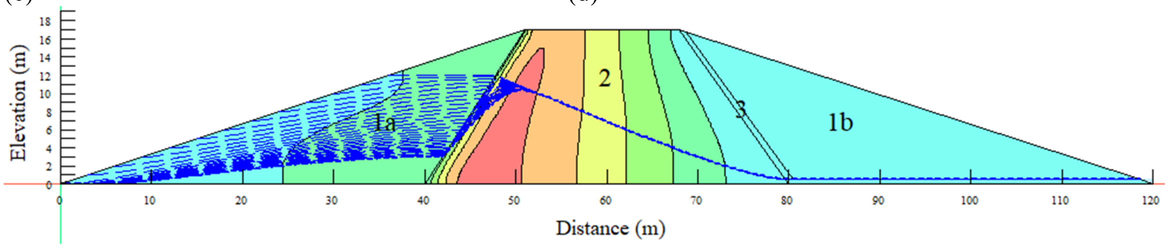
3. RESULTS AND DISCUSSION

3.1 Seepage analysis

The numerical modeling was successfully executed; from Figure 4 it can be observed that the seepage within the embankment was safely carried away through zone 1a and zone 2. The general setup shows that the embankment was properly designed to not allow seepage along the downstream face of the embankment. The phenomenon was similar to all the investigated drawdown cases. Generally, based on the phreatic lines, the seepage within the embankment can be observed to be evenly distributed (more of linear flow), while due to change in soil properties in zone 2 a more parabolic flow can be observed. In the instantaneous drawdown case, it can be observed that most of the phreatic lines are concentrated somewhere close to the foundation of the embankment. The distribution of phreatic lines becomes more evenly when the drawdown rate is reduced from fast to slow.



(c) (d)



(e)

Figure 4. Seepage analysis (a) long-term steady-state (b) instantaneous drawdown (c) 5 days drawdown (d) 10 days drawdown (e) 1m per day drawdown.

Normally, embankment dams are characterized by seepage as the impounded water seeks paths of least resistance through the dam and its foundation. However, seepage must be controlled to prevent erosion of the embankment (Omofunmi et al., 2017). If the seepage forces are relatively large enough within the embankment, there is a high chance that soil will be eroded affecting the stability of the embankment with time. It should also be noted that the seepage control requirement is highly dependent on the quantity, content, and location of the seepage problem. Moreover, reducing the extent of the seepage problem when the embankment is already constructed is difficult and expensive; and it is in most cases not attempted unless the seepage has been threatening the stability of the embankment. During the process of solving the seepage problems in embankment dams, regular monitoring is significantly essential to detect seepage and prevent a potential dam failure. The monitoring activities should include having a clear knowledge of the dam's history; this helps to determine the condition of the seepage (Singh Saluja ZHCET, Mohammad Athar ZHCET and Sarfaraz Ansari ZHCET, 2018).

3.2 Slope stability

Apart from the seepage analysis, the model embankment was also subjected to the slope stability analysis. It is also worth noting that, slope stability analysis is a crucial factor to take into account while managing various mining operations or civil engineering projects. In general, is a measurement of a slope's resistance to failure due to collapse or sliding, whether it be natural or man-made (Utepov et al., 2022). Figure 5 shows that a factor of safety of 2.344 was obtained when the embankment was subjected to the long-term steady-state reservoir conditions. Under long-term steady-state conditions, the retrieved factor of safety value is relatively high and can be regarded as safe for embankment stability. However, subjecting the embankment to the rapid drawdown situation is equally crucial in order to study how the embankment responds in this scenario.

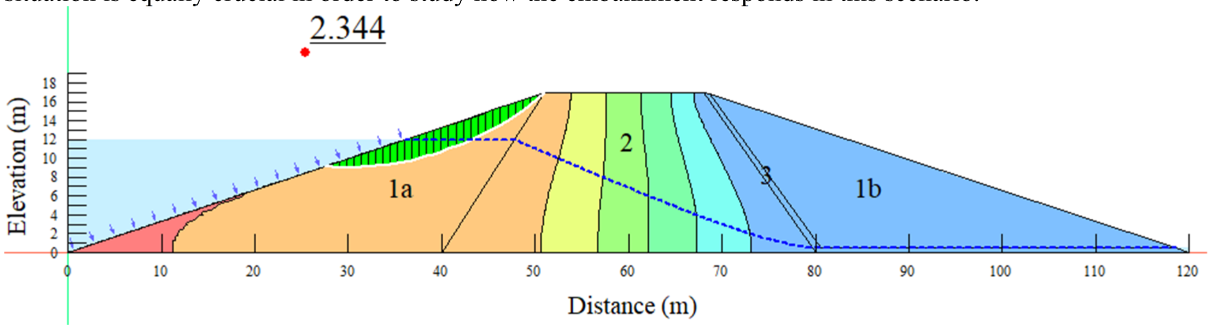


Figure 5. The long-term steady-state factor of safety.

Firstly, the embankment was subjected to the long-term steady-state slope stability analysis; whereby, a factor of safety of 2.344 was achieved. A steady-state flow condition is one in which the pressure at any location in the reservoir remains constant across time. It is also worth noting that, the long-term reservoir steady state plays a significant role in the embankment stability. Figure 6 presents the results when the embankment was subjected to the 1 m per day drawdown rate. The embankment began to lose stability during the first four days and began to restore stability on day five, as shown in the Figure. A minimal factor of safety of 2.149 was also obtained when the embankment was subjected to the 1 m per day drawdown rate; the minimum factor of safety value was attained on the fourth day of the drawdown. The retrieved factor of safety from the 1 m per day drawdown rate is equivalent to 8.32% less than the one retrieved from the long-term steady-state condition.

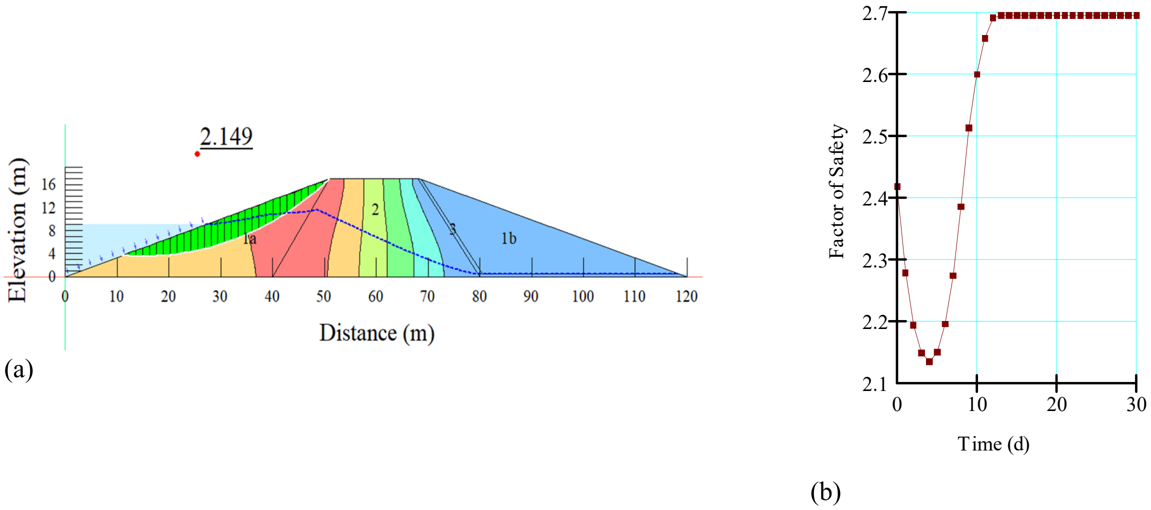


Figure 6. Drawdown (1 m per day drawdown rate); (a) embankment (b) graph of the factor of safety values.

Figure 7 presents the results when the embankment was subjected to the 10 days drawdown rate, it can be observed that the embankment was losing stability within the nine first days of the drawdown. Whereby, a minimum factor of safety of 1.804 was achieved from the 9th day of the drawdown. Moreover, it can be observed that the embankment started regaining stability from the 10th day. Additionally, the minimal factor of safety value retrieved when the embankment was subjected to a drawdown rate of 10 days is equal to a decline of 23.04% from the factor of safety value retrieved under long-term steady-state conditions. The factor of safety value shows further that despite the high factor of safety value from the long-term steady condition, the minimum factor of safety value can decrease significantly after subjecting the embankment to rapid drawdown conditions. A similar phenomenon has also been observed in other studies in the literature (A. A. Khattab, 2010; A. Irinyemi, Lombardi and M. Ahmad, 2021).

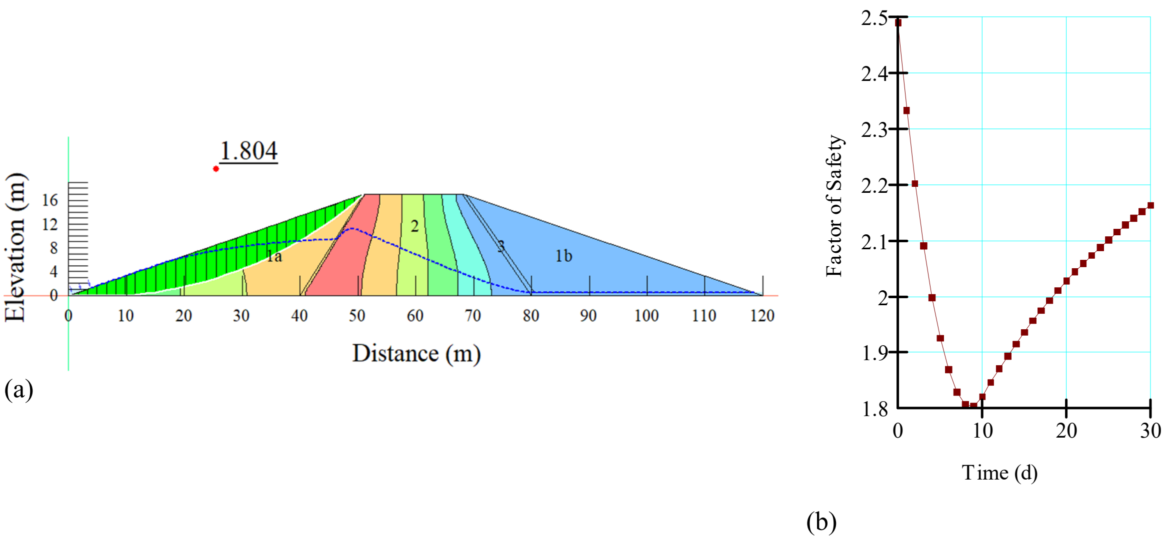


Figure 7. Drawdown (10 days drawdown rate); (a) embankment (b) graph of the factor of safety values.

After the 10 days, the rate was then reduced to 5 days to investigate further the effect of a potential rapid drawdown on the embankment stability. Figure 8 presents the results from the 5 days drawdown rate, and it can be observed that the embankment was losing stability within the five days of the drawdown process; whereby, it started regaining stability from the 5th to 6th day. Also, it can be observed that the minimum factor of safety of 1.706 was obtained within the 5th day of the reservoir draining. Also, when the embankment was subjected to the 5 days drawdown rate, the retrieved minimum factor of safety value is equivalent to a 27.22% decrease if compared to the factor of safety value retrieved from the long-term steady-state condition.

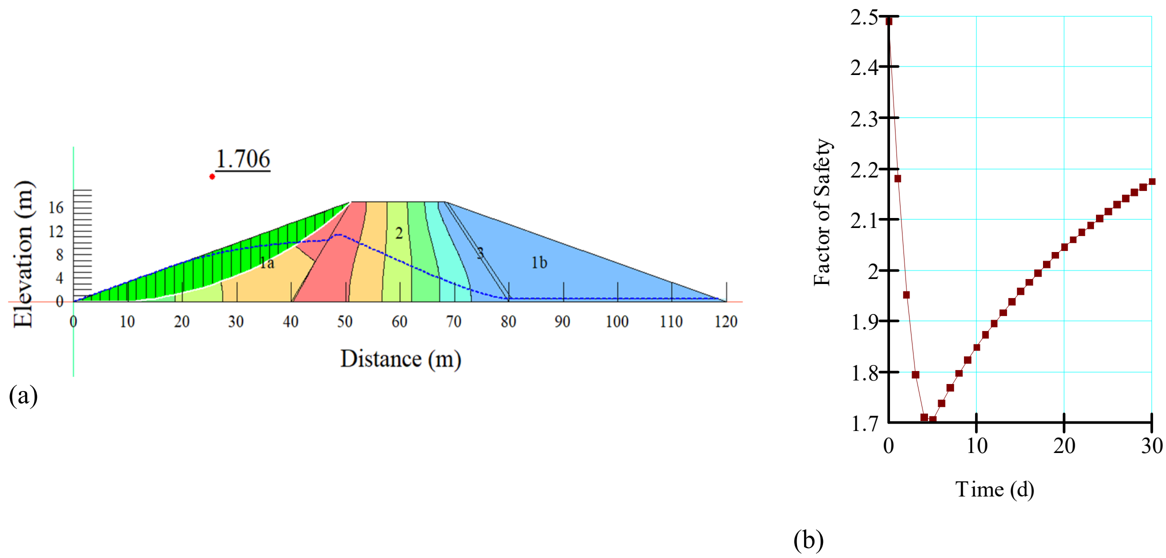


Figure 8. Drawdown (5 days drawdown rate); (a) embankment (b) graph of the factor of safety values.

Figure 8 presents the results when the embankment was subjected to the worst scenario of rapid drawdown (instantaneous), and it can be observed that the embankment lost stability from approximately 2.5 factors of safety to 1.574 within the same day of drawdown. Moreover, it can be observed that the embankment started regaining stability within the same day; however, was not able to reach the 2.5 initial factor of safety which is an indication of a potential failure. The obtained factor of safety from the instantaneous drawdown rate is equivalent to 32.85% less than the factor of safety retrieved from the long-term steady-state conditions.

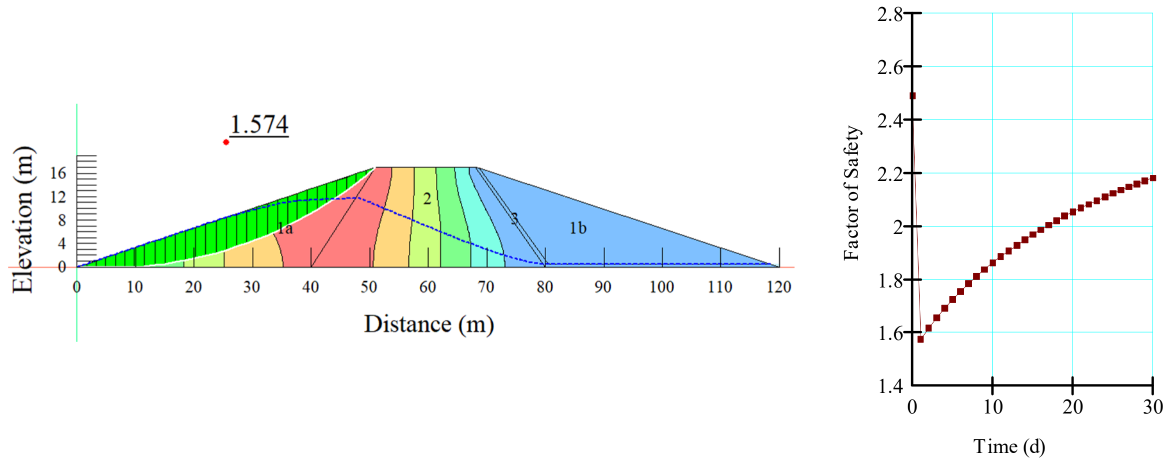


Figure 8. Instantaneous drawdown; (a) embankment (b) graph of the factor of safety values.

In the literature, it has been observed that for a static two-dimensional (2D) a minimum factor of safety of 1.3 is acceptable for temporary or low-risk slopes and 1.5 for permanent slopes (Stark and Ruffing, 2017). However, in most cases, when a factor of safety is below 1 then is considered a total embankment failure.

3.3 Single Factor Analysis of Variance (ANOVA)

Table 2 shows that a p-value of 9.97×10^{-29} was obtained after subjecting the factor of safety values from instantaneous, 5 days, 10 days, and 1 m per day drawdown rates to ANOVA, indicating that the factor of safety differences among the analyzed drawdown rates are statistically significant. It should be noted that a statistically significant p-value is less than 0.05 (usually 0.05). It provides significant evidence against the null hypothesis, as the null hypothesis has a less than 5% chance of being right (and the results are random) (Stoker, Tian and Kim, 2020). The findings also show that a drawdown rate has a substantial impact on an embankment dam's slope stability.

Table 2. Results from ANOVA

SUMMARY						
Groups	Count	Sum	Average	Variance		
Instantaneous	31	60.79289	1.961061	0.040298		
5 days	31	61.64857	1.988664	0.030041		
10 days	31	62.65467	2.021118	0.024648		
1 m per day	31	77.26121	2.492297	0.002294		
ANOVA						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	5.915494	3	1.971831	81.07681	9.97× 10-29	2.680168
Within Groups	2.918464	120	0.024321			
Total	8.833958	123				

4. CONCLUSIONS

The potential effect of rapid drawdown scenarios on the stability of old dams for the case of Samarkand in Kazakhstan has been investigated. The dam has a maximum depth of 12 m and a length of 25 km located in Karaganda province in Kazakhstan that was put into operation in 1941. Both seepage and slope stability with the help of numerical modelling were investigated based on steady and transient (rapid drawdown) flow conditions. The finite element method-based modelling is achieved using SEEP/W and SLOPE/W of the GeoStudio software. The embankment was first subjected to a long-term steady-state slope stability analysis, which resulted in a factor of safety of 2.344. The pressure at any point in the reservoir remains constant over time in a steady-state flow scenario. It's also worth noting that the reservoir's long-term steady state has a big impact on embankment stability. When the embankment was subjected to a 1 m per drawdown rate, a minimum factor of safety of 2.149 was obtained; the minimum factor of safety value was reached on the fourth day of the drawdown. The factor of safety recovered from the 1 m per day drawdown rate is 8.32 percent lower than the one retrieved from the long-term steady state. Moreover, the factor of safety determined from the instantaneous drawdown rate is 32.85% lower than the factor of safety obtained from long-term steady-state conditions. The results derived in this study revealed further that, it is significantly important to investigate the stability of old embankment dams taking into account different drawdown rates as the factor of safety reduces with the increase in the drawdown rate.

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Authors contribution: Conceptualization, A.Z., and T.M.; methodology, A.Z., and T.M.; software, T.M.; validation, A.Z.; formal analysis, T.M.; investigation, resources, and data curation, T.M., and A.Z.; writing—original draft preparation, T.M.; writing—review and editing, A.Z., and T.M.; visualization, T.M.; supervision, project administration, and funding acquisition, A.Z.; All authors have read and agreed to the published version of the manuscript.

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THE TECHNIQUE FOR EXTRAPOLATION OF ROCK MASS INITIAL PARAMETERS DURING THE CONSTRUCTION OF THE TUNNEL

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Abstract: *It is important to perform research to the degree that it is adequate to identify the features of the terrain composition, before, during, and after the building of facilities since predicting the behaviour of rock mass during tunnel construction is a complicated engineering challenge. Engineering research works in laboratories and in the field are of different scope and methodology during testing. In this paper, the established interdependencies of some of the basic parameters obtained during the testing of rock mass are presented: Edyn = f(Vp), Edyn = f(RMR) i Edyn = f(Q). Also, the relations between the engineering systems of rock mass classification and seismic primary waves are derived. RMR = f(Vp), Q = f(Vp). The relations were based on the examination of the rock mass for the construction needs of the tunnel on the Nis-Merdare highway. The results obtained in this study can be applied in environments that have similar lithological and structural characteristics.*
Keywords: *Classification, Extrapolation, Geotechnical model, Physical model, Rock*

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1. INTRODUCTION

Despite the fact that numerical modelling is becoming more prevalent in all aspects of geotechnics, the fundamental conclusions are still reliant on in situ field experiments and laboratory samples. However, the data from several tests do not produce the same conclusions, primarily because one approach differs significantly from the others and also because the material is complicated and heterogeneous. For the designing purposes of underground structures, in addition to the direct application of test results, some of the numerous classifications of rock masses are used regularly. It is necessary to show the granite mass's inherent heterogeneity and the degree of cracking of the rock mass. How to extrapolate the parameters from the test zone to the entire surface (volume), which is important for the investigation of the interaction of the rock mass structure and the object (construction), is one of the fundamental issues. One of the first in Europe who tried to find a solution was Kujundžić (1977) who was working on of extrapolation for the purpose of building large dams, and over time, numerous other authors began to do so.

From a technical point of view, describing the rock mass and its condition during testing is not easy. According to the first classification developed for the needs of tunnel design and construction (Terzaghi 1946), the rock mass was divided into 9 descriptive, ie quantitative categories. However, there was a need to present the classification of rock mass qualitatively (in numbers), and over time, many other classifications have developed, among which the most common in the world: RMR - Rock Mass Rating system (Bieniawski 1973; 1989); RSR - Rock Structure Rating; Q system - Rock Mass Quality (Barton, Lien & Lunde 1974; 1980); RMi - Rock mass index, modified BQ, a multiparameter classification system ERMR - Excavation Rock Mass Rating, as well as increasingly represented GSI - Geological Strength Index (Hoek 1998). The possibilities of integrating approaches for extrapolation of parameters during tunnel construction, which often represent a problem, are presented in this paper The proposed methodology is based on a combination of empirical method, rock mass classification and geophysical measurements in the field. The analyses are based on the results of research on several tunnels in the southern part of Serbia (**Figure 1**). This highway represents a very important road for the further development of the entire western part of the Balkans. According to the Seismic Hazard Maps for the Western Balkans, this area where the highway route is planned is subject to tectonic changes and that is one of the important reasons why the classification should be done in a quality way (Gulerce et al. 2017).

2. METHODS

A highly significant feature of the paperwork for numerous infrastructure projects and geotechnical studies should now include the categorization of rock mass systems as a requirements are to gather. A number of rock mass categorization methods have emerged during the past 50 years, with RMR, Q, and GSI seeing the most widespread application in ordinary routine. A huge variety of studies provide geologists and engineers the chance to evaluate different rock masses. However, for better analysis and comparison, a strong link between these system categories is required. On the basis of statistical analysis of field data, several prominent authors have in the past offered empirical data and a connection between the RMR and Q systems (**Table 1**). Since both of these qualitative classification techniques are based on the examination of a number of factors, it is possible to demonstrate the dependency of the parameters of each approach separately.

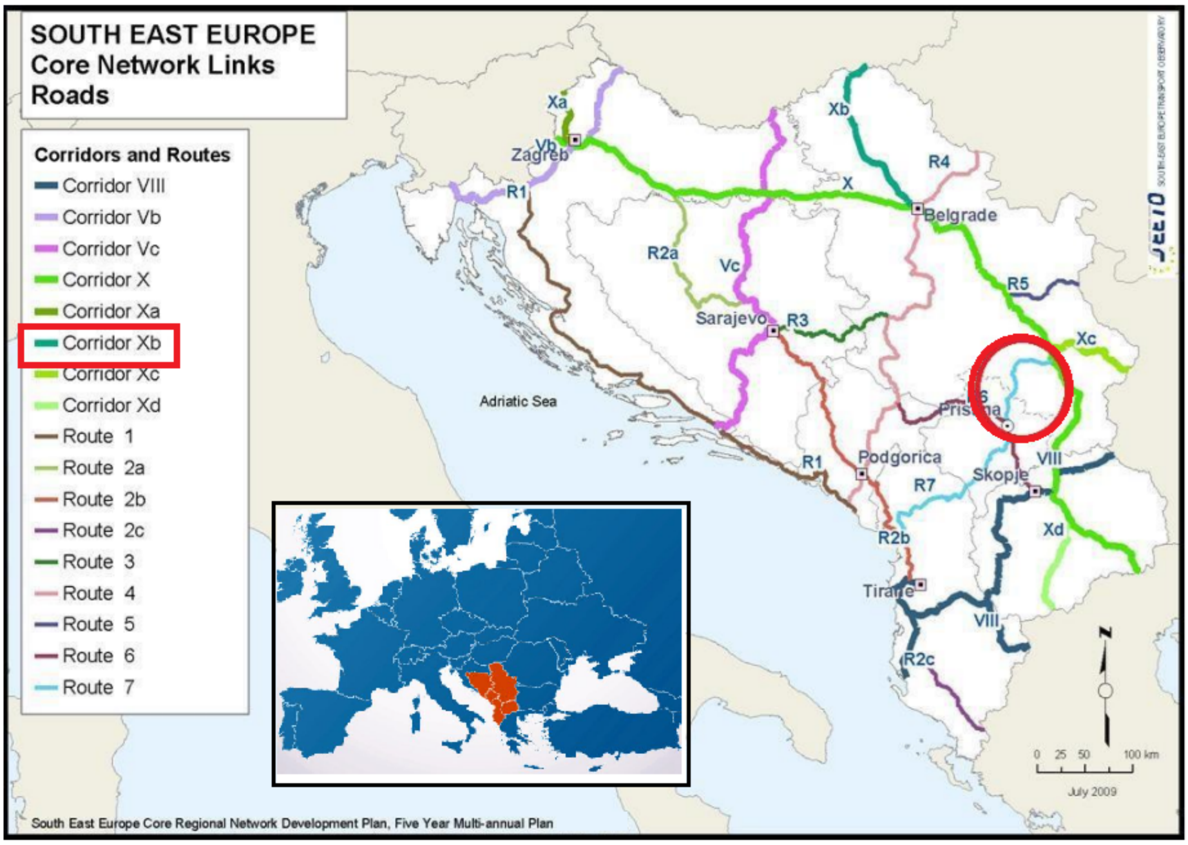

Figure 1. Map of the main road network in the Western Balkans (source SEETO MAP)

Table 1. Equations of existing correlations of RMR and Q methods for rock mass classification (modified according to Sayeed & Khanna)

AUTHORS	CORRELATION
Bieniawski (1976)	RMR = 9 ln Q + 44
Rutledge and Preston (1978)	RMR = 5, 9 ln Q + 43
Moreno (1980)	RMR = 5.4 ln Q + 55.2
Cameron - Clarke and Budavari (1981)	RMR = 51ln Q + 60.8
Abad et al. (1984)	RMR = 10.5 ln Q + 41.8
Jovanovski (2001)	RMR= 9.38 lnQ+45.15

A streamlined technique for classifying rock mass strength is called the Geological Strength Index (GSI). The GSI value is based on an evaluation of the rock mass's structure, the characteristics of the intact rock, the characteristics of the discontinuity surface, as well as the circumstances resulting from the geometry of the intact rock parts and their behavior in response to the rock mass's changing stress state. The interdependencies between the GSI and RMR categorization systems in some of the most significant studies are displayed in **Table 2**.

An alternate approach, or evaluation based on empirical correlations for a variety of characteristics, is frequently utilized when examining the rock mass. This is frequently true for both the categorization that is the focus of this work and for establishing the rock mass deformation modulus, which is crucial information for engineering projects (Khabbazi et al. 2013).

Table 2. Equations of existing correlations of RMR and GSI methods for rock mass classification

AUTHORS	CORRELATION
Hoek and Brown (1997)	RMR_{89} = GSI + 5
Osgoui and Ünal (2005)	RMR_{89} = 20ln(GSI/6)2
Singh and Tamrakar (2013)	RMR_{89} = 1.36GSI + 5.90
Ali et al. (2014)	RMR_{89} = 1.01GSI + 4.95
Zhang et al. (2019)	RMR89 = 0.827GSI + 15.394
Somodi et al. (2021)	GSI = 0.876 RMR_{89} + 0.935

With the development of technology, a technique for figuring out a rock mass's propreties has been created that doesn't need excavation and sampling. For the purposes of obtaining these data, geophysical methods and parameters are most often used to obtain the dynamic characteristics of rock masses based on the measured velocities of longitudinal (Vp) and transverse (Vs) seismic waves. it was inevitable that the emergence of new methods led to the creation of new connections between the obtained results. Numerous examples indicate that seismic refraction data in surface layers or deeper cross tomography can be extrapolated using one or more correlations between Q and Vp. At the beginning of the 20th century, based on data from solid rock projects during tunnel construction in several countries, the relationship between RMR, Q and Vp was proposed by several authors (Jovanovski 2001; Barton 2002), where Vp is the propagation speed of longitudinal waves (**Equations 1-4**):

$$\text{RMR} \approx 0.0161\,\text{Vp} + 1.5\ (\text{Vp in m/s}) \qquad (1)$$
$$\text{Vp} \approx 0.545\ln Q + 2.6\ \ (\text{Vp in km/s}) \qquad (2)$$
$$\text{Vp} \approx 3{,}5 + \log Q \quad \text{depth to } 25\text{m}\,(\text{Vp in km/s}) \qquad (3)$$
$$\text{Vp} \approx 5{,}0 + 0{,}5\log Q \ \ \text{depth to } 500\text{m}\ \ (\text{Vp in km/s}) \qquad (4)$$

The results obtained by geophysical surveys largely depend on the lithological structure of the terrain. The extrapolation method is mainly based on the following assumptions given by Kujundžić (1977):

1. Parallel static and dynamic testing directly in the field with flat jacks and geophysical methods are needed, as a basis for obtaining sets of values for deformability of rock mass and values of velocity of longitudinal seismic waves.

2. Determining the value of the velocity of longitudinal seismic waves for the area of interaction between the rock mass and the object (tunnel).

3. Formation of direct and indirect analytical connection between the modulus of deformation and elasticity with the values of the velocity of longitudinal waves (Vp) and the modulus of dynamic elasticity (Edyn).

4. Extrapolation of parameters using formed regression curves from the test area to the entire volume of the rock mass involved in the interaction of the rock mass and the object (tunnel).

One of the basic problems in building subterranean structures within a rock mass is determining the rock's strength and deformability for the purposes of study and design. For many different techniques of classifying rock masses, the strength and deformation modulus of the rock mass serve as the fundamental and essential factors. The rock is usually a discontinuous, heterogeneous and anisotropic environment. Therefore, the behavior of the rock mass as a whole cannot be depicted by laboratory testing on core samples or field tests. Representative tests of rock mass strength and deformability by test loads in situ are rarely practically or economically possible. The development of empirical models linking the static modulus of deformation, the dynamic modulus of deformation, and the conditions of rock mass quality went through a number of stages (primarily RMR and Q). **Figure 2** shows a visual illustration of the relationship between the static modulus of deformation and the aforementioned techniques. This study demonstrates the relationship between the dynamic modulus of deformation and the RMR and Q classification systems, as well as the Vp and Vs seismic wave velocities. Also, Barton in his work (Barton 2002) showed that the dynamic modulus can be calculated using the wave velocities Vp and Vs in the classic elastic small strain using the **Equation 5**:

$$E_{dyu} = \gamma V_S^2 \frac{3(V_p/V_s)^2}{(V_p/V_s)^2 - 1} \qquad (5)$$

whereby γ - volume weight of wall mass.

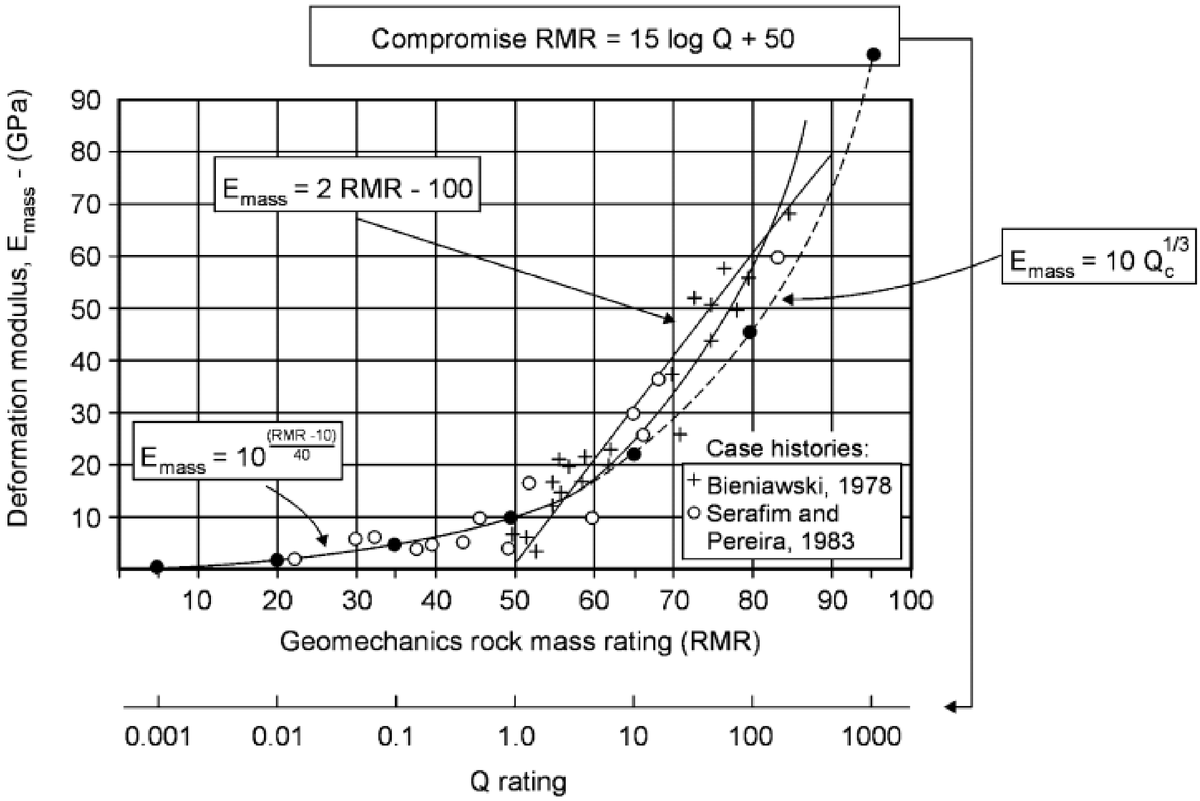

Figure 2. Static deformation modulus Emass; Q and RMR and some empirical inter-relationships (*Barton 2002*)

Based on results from triaxial rock mass tests, the Hoek-Brown rock mass strength criteria is regarded as an empirical criterion. The software programs were created based on the generic Hoek-Brown criteria of fracture, which in a very straightforward manner enables to acquire an accurate assessment of the characteristics of rock mass, both for very excellent and for very weak rock masses. In order to establish geological zones in the next stage of research and model development, the extrapolation problem is primarily created for major constructions by combining static and dynamic testing and the creation of relevant engineering data (EGS and EGM). There are more and more instances when models of rock masses are created by taking into account all geological, geophysical, and geotechnical survey findings and assessing longitudinal elastic wave velocities (Vp), small models, and cross sections by discontinuity characteristics (Nourani et al. 2017).

The proposed methodology can be briefly defined as an empirical-static-dynamic extrapolation methodology. This means that all known methods for determining the deformability and shear strength of rock masses can be used and combined to extrapolate parameters for the whole area. The prerequisite for using this methodology is the following (Zafirovski et al. 2012):

1. To have sufficient data for rock mass classification that are reliable.
2. To have sufficient test data for deformability with static tests.
3. The area of the entire engineering facility (in this case the tunnel) should be covered by geophysical seismic surveys.

Before selecting some test areas, we select one or more properties that will be relevant when compared to other parts. These regions, also known as quasi-homogeneous zones, stand in for the fundamental and defining components of the geological model. Some characteristics or qualities are constant across this zone but can vary greatly outside of it. Spatial restrictions, which are governed by a number of crucially significant characteristics, determine each zone. The tests must be carried out in a way that will provide reliable data for geotechnical modeling of the natural geological environment of the whole area along the tunnel. Given that a significant number of characteristics are required for the characterisation of a particular rock mass, it is simple to draw the conclusion that information on the uniformity of the whole working environment may be acquired with just a limited (insufficient) number of tests and samples. It should be noted that the process of extrapolation is interrelated with the process of geotechnical terrain modeling. Obviously, the models must meet two requirements: to simulate real terrain conditions as best they can, but to be as simple as possible (Pavlović, 1996).

3. RESULTS AND DISCUSSION

Based on the mentioned methods and comparisons, in this paper, the data collected during the testing for the needs of the construction of several tunnels designed along the Nis-Merdare highway are processed. For the purpose of processing the parameters, the following methodology is used (Zafirovski et al. 2012):

1. Collection of data from the results of massive rock tests (laboratory and field tests) - results of strength, deformation, discontinuity and other parameters.
2. Specific laboratory and field tests for specific purposes.
3. Statistical analysis and comparison of data collected from the literature and data collected by research and tests performed for the purposes of this article.

All the results of geological, geotechnical and geophysical investigations were used to establish a physical model through RMR, Q and GSI classification. The exception is the Božurna tunnel, where the terrain is predominantly marly clay, where correlations were made according to other parameters because RMR classification could not be done, except for one small segment (Rakić et al. 2017a; 2017b). **Figure 3** shows the correlation of RMR and Q classification on tunnels in these areas.

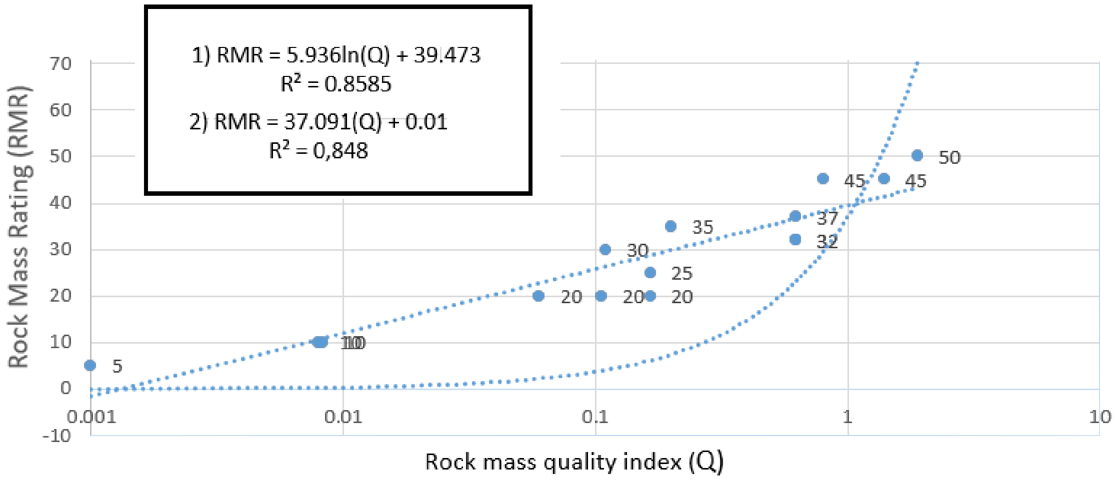

Figure 3. Correlations between rock mass rating (RMR) and Rock mass quality index (Q): 1) Logarithmic, 2) Linear

Various physical models defined by GSI values based on the HB method (Hoek & Brown 2018) were used for analytical models and prediction of shear strength and deformability parameters of rock mass. The GSI value is also used to classify terrain as a working environment (Chaniotis et al. 2017). Some typical GSI values for the main lithological types along the analyzed cross section in the Bozurna and Visnik tunnels are given in **Figure 4**.

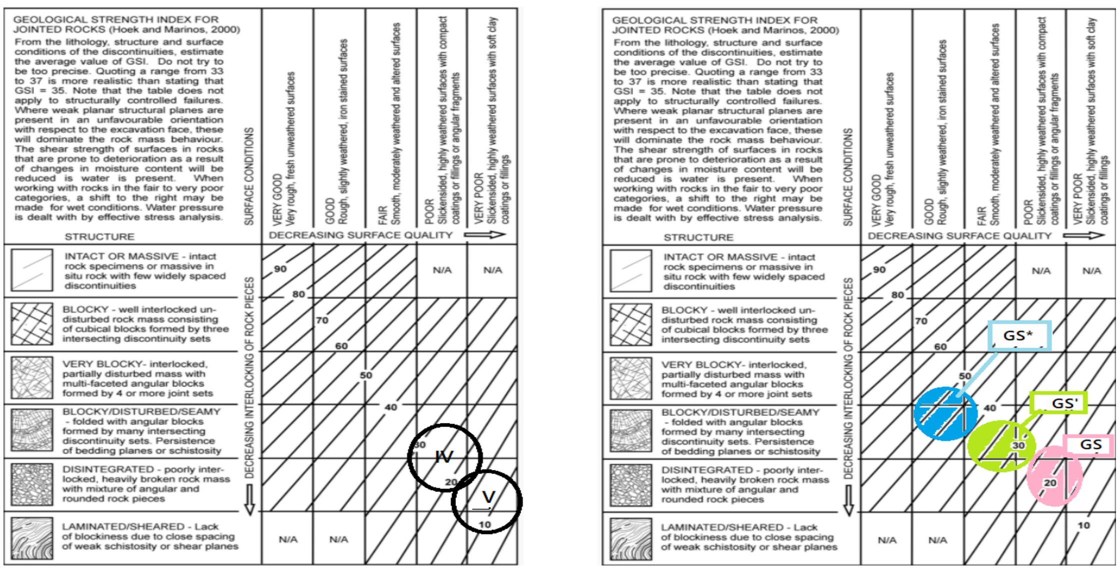

Figure 4. Range of GSI values for different zones of tunnel Bozurna and tunnel Visnik

Figure 5 and **Figure 6** illustrate regression models between longitudinal elastic wave velocities and rock mass quality as determined by the RMR and Q systems. For the tunnels in this segment, zones may be categorized as follows based on the average value of longitudinal elastic wave velocities (results do not apply for the Bozurna tunnel):
- Surface layer with values: Vp < 200-750 m/s, Vs < 80-280 m/s 1 to 4 meters thick;
- Subsurface zone, which would correspond to the decomposed altered rock masses to the level of soil debris with values: Vp < 800-1580 m/s i Vs = 300-590 m/s, 8 to 11 meters thick;
- Quite degraded gneisses with values: Vp = 1600-1900 m/s; Vs = 600-700 m/s
- Degraded cracked gneisses with values: Vp = 1900-2200 m/s; Vs = 700-800 m/s.
By examining the data, it can be shown that the base rock mass does not have a high longitudinal wave propagation velocity up to the test depth. Other classifications of rock masses and the expected conditions for tunnel construction can be implicitly determined based on the known relationships between the quality of the rock mass and Vp (Barton et al. 2002; Jovanovski 2001).

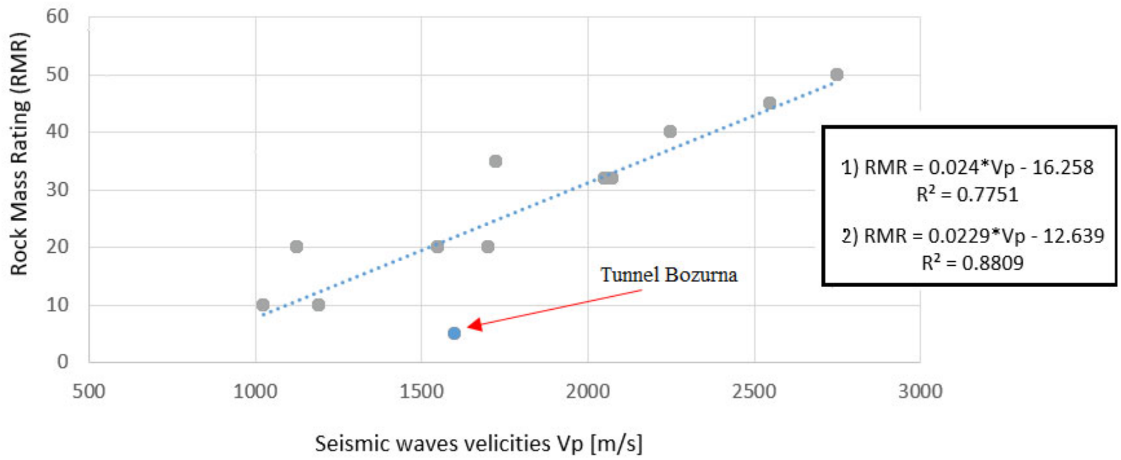

Figure 5. Correlations between rock mass rating (RMR) and longitudinal seismic wave velicities(Vp): 1) All Tunnels 2) All Tunnels without Bozurnain in marls and soil rock types

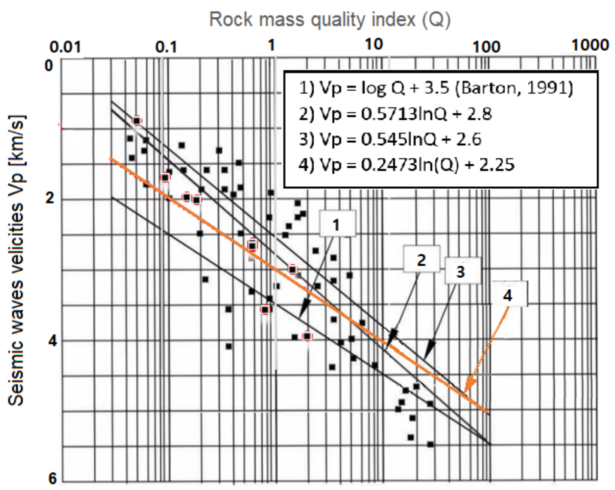

Figure 6. Correlative dependences between rock mass quality index (Q) and longitudinal seismic wave velocities (Vp)): 1) for areas from Norway, 2) more areas than Macedonia, 3) tunnels from the highway Demir Kapija - Smokvica (Jovanovski 2001), 4) tunnels from the highway Niš-Priština

The fact that the wave velocity Vs findings decrease with increasing values suggests that this approach is not the most accurate in high pressure areas and that the results for these regions are widely dispersed. **Figure 7** and **Figure 8** show a few regression models between the dynamic modulus of elasticity and values derived from the categorization systems RMR and Q, as well as the basis of the velocity of longitudinal elastic waves.

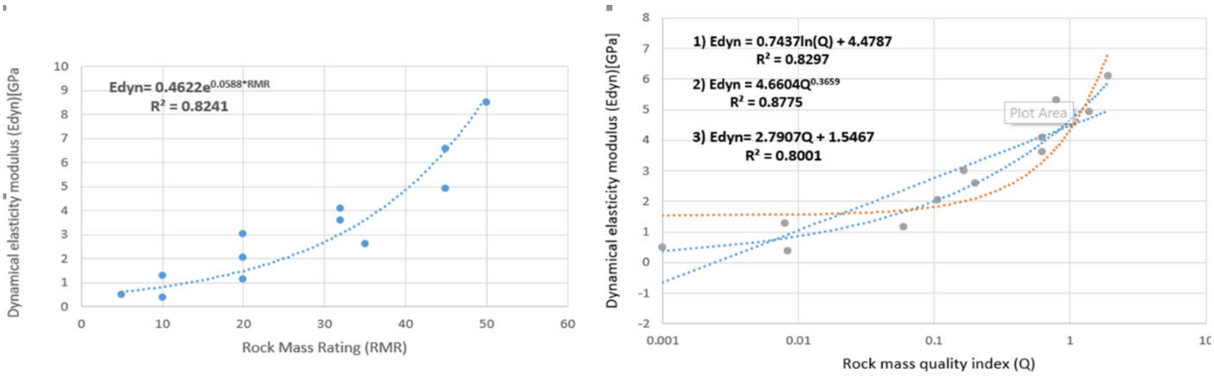

Figure 7. Correlative dependences between: (left) quality of rock mass by RMR and dynamical elasticity modulus (Edyn) and (right) Rock mass quality index (Q) and Edyn

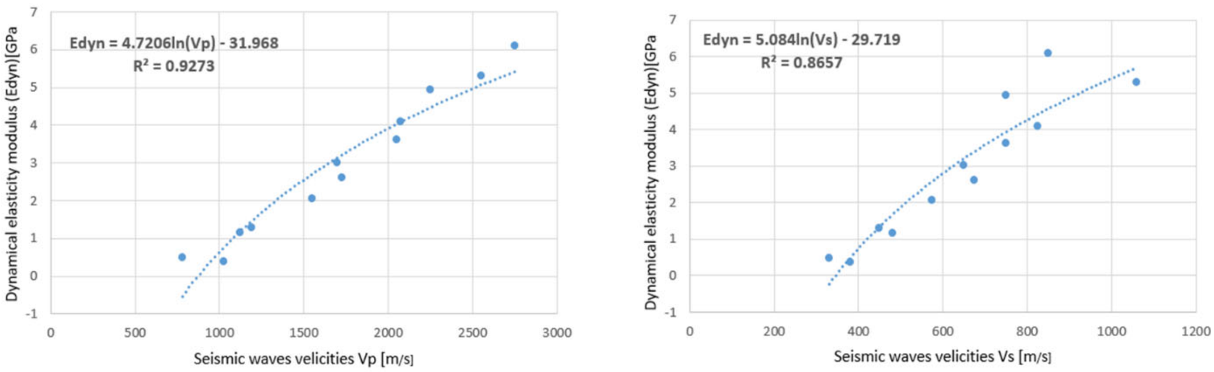

Figure 8. Correlative dependences between (left) seismic wave velocities (Vp) and dynamical elasticity modulus (Edyn) and (right) seismic wave velocities (Vs) and Edyn

When all tunnels are taken into consideration and the models are reviewed, it is discovered that the studied parameters have a significant link, as shown by the coefficients of determination (R2). Lower values of RMR and Vp refer to the category of very weak to weak rock masses (RMR = 10-30 RMR and Vp mainly from 1000-1800 m/s). Degraded and cracked gneiss corresponds to the value of the class of parameters in the range of RMR = 30–40 and Vp of 2100–2900 m/s, whereas higher evaluation values were achieved in the event of excellent rock mass. With such correlations and known seismic wave values, it is possible to extrapolate the input parameters using the empirical-static-dynamic methodology approach of parameter combination in order to carry out numerical analyses for each quasi-homogeneous zone throughout the tunnel.

4. CONCLUSIONS

In the creation of geotechnical models, the empirical-static-dynamic approach for data extrapolation is described. The suggested approach has to be examined in the interim for potential applicability at other sites and other facilities in other geological contexts in order to verify. However, considering that it is virtually difficult to finish researching this scientific subject in a single publication, this also creates prospects for more study. The phases of study and design must coincide with the modeling process. In the beginning, simpler methods are frequently applied. The outcomes of this kind of first models for complex things may point to the need for new data and permit reinterpretation of current data, both of which have an impact on the model's improvement or generate fresh concepts for novel models. We might infer from the foregoing that there are many of possibilities for more study in this area. The goal is to validate and enhance the methods described in this article for different types of building structures as well as for rock mass during the construction of tunnels.

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MICROPLASTICS ASSESSMENT IN THE KRKA RIVER ESTUARY SURFACE WATER

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Abstract: *Microplastics (MPs), commonly defined as particles less than 5 mm, are a persistent ubiquitous anthropogenic contaminant that can be found in every environment, making it a global environmental, health, and socioeconomic problem. Due to their high surface area, MPs adsorb toxic pollutants that become bioavailable to organisms upon ingestion as they are often mistaken for food leading to biomagnification (Bule et al., 2020). The sampling area represents the lower part of the Krka River Estuary and is under direct anthropogenic influence from the city of Šibenik runoff waters, nautical and communal ports, city harbor, tourism, mariculture, and fishing. Estuaries and harbors have been recognized as hotspots and transfer pathways for MPs primarily because of the vicinity of the urban environment that emits contaminants from various sources (Miller et al., 2021). The main focus of this research was to determine MPs size, shape, color, surface area, and abundance in surface water using volume-reduced samples collected by a net. Laboratory protocol included sieving, wet peroxidation (H2O2), density separation (saturated NaCl solution), sonication, and filtration. Filter papers were then visually inspected for MPs. Image processing and measurements were carried out with ImageJ/Fiji open-source software.*
Keywords: *microplastics (MPs), Krka River estuary, surface water, ImageJ/Fiji*

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1. INTRODUCTION

Microplastics (MPs) are plastic particles (synthetic polymers) smaller than 5.0 mm in size. The lower limit is still not specified, but often the mesh size (300 µm) of neuston or manta nets is considered, which are used for sampling (Masura et al., 2015). MPs come from a variety of sources, which can be classified into two groups: primary and secondary MPs (Miller et al., 2021). Primary MPs are purposefully manufactured as pellets for plastic production, abrasive blasting (sandblasting), paints, adhesives, detergents, and microbeads incorporated into personal care products (face scrubs, toothpaste, bath products, etc.) (Miller et al., 2021). They can be released into the environment intentionally as part of regular usage of the product, via spillage, sewage discharge, runoff, or by domestic and industrial effluents (Razeghi et al., 2021). Whereas secondary MPs occur because of the fragmentation of larger plastic particles or synthetic fibers already found in the environment caused by UV photodegradation, mechanical abrasion, chemical breakdown, or biodegradation. They are more abundant in the marine environment than primary MPs (Miller et al., 2021; Razeghi et al., 2021). Several pathways of secondary MPs entering the marine environment have been proposed (Bailey et al., 2021; Freeman et al., 2020): washed off the land by rain or translocated by wind (atmospheric deposition), via treated or untreated wastewater discharged into waterways, via effluent from municipal wastewater treatment plants (WWTPs), via sewage sludge used in agriculture as fertilizer, via tearing of plastic components used in WWTPs, boating and fishing activities, etc.
MPs have a high affinity for toxic pollutants, such as heavy metals, persistent organic pollutants (POPs), polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PBCs), chemical additives, and plasticizers (phthalates), due to their large surface area to volume ratio (He et al., 2021; Razeghi et al., 2021). In addition, MPs can easily be ingested by marine biota, as they are often mistaken for food (Bule et al., 2020). Thus, organisms that ingest such MPs are a threat to the whole food web, including humans (Defontaine et al., 2020).
Estuaries worldwide have been suggested as hotspots for MPs contamination and dispersion (Piehl et al., 2021), although MPs movement in estuarine environments is not yet fully understood, despite growing research. It is suggested that the MPs distribution highly depends on complex estuarine hydrodynamics, bathymetry, intense currents, and harbor activities (Defontaine et al., 2020; Miller et al., 2021). The sampling area represents the lower part of the Krka River Estuary, with limited water exchange and is directly subjected to anthropogenic influence from the city of Šibenik. This urbanized estuary receives MPs from various sources and activities, including urban runoff waters, nautical and communal ports, city harbor, tourism, mariculture, and fishing. No previous study regarding MPs abundance, size, shape, and color was done in this area prior to this research. Therefore, the main

goal of this research is to quantify and characterize the types of plastics affecting the area. It is crucial to assess the abundance of MPs particles to implement prevention measures against MPs contamination.

2. MATERIALS AND METHODS

All methods and protocols used were adapted from the National Oceanic and Atmospheric Administration (NOAA) (Masura et al., 2015), and from the multinational BASEMAN project, which is funded under the EU Joint Programme Initiative (JPI) Ocean (Gago et al., 2019).

2.1. Quality assurance and quality control (QA/QC)

Due to their ubiquitous nature, MP particles could easily contaminate samples that we are working with, which could lead to overestimations of the abundance of MPs in the sample. Given that, it is crucial to avoid any cross-contamination by implementing several contamination minimization procedures, as we did, such as: always wearing a clean 100% cotton laboratory coat and nitrile gloves; avoiding wearing synthetic clothing even underneath the coat, especially fleece; closing doors and windows to minimize air movement in the laboratory; cleaning all equipment and working stations with 70% ethanol and rinsing it 3 times with Mili-Q water; washing glassware with 10% HNO3 and rinsing it 3 times with Mili-Q water; covering all equipment and samples with aluminum foil; inspect all Petri dishes, filters, and forceps under stereomicroscope; using non-plastic material (steel, glass, aluminum); work in a fume hood; pre-filtering all working solutions and reagents with LLG Syringe Filters SPHEROS, PTFE (pore size: 0.22 µm); running field, laboratory and procedural blanks.

2.2. Microplastics sampling

Surface water samples were taken from the lower part of the Krka River estuary, mainly in Šibenik bay (43°43.245'N, 15°54.144'E), in March 2022. The average vessel speed was 1.7 knots and the duration time for towing was 20 minutes. Volume-reduced samples were obtained from the first 40 cm of water surface with a “Net for Microplastic Sampling” (Hydro-Bios, Apparatebau GmbH, Germany; mesh size: 300 µm; net aperture: 0.28 m^2 [width 70 cm, height 40 cm, length 260 cm]) deployed behind the vessel. The volume of water that passed through the net was calculated with a flow meter (Mechanical Flow Meter, Hydro-Bios, Apparatebau GmbH, Germany) positioned at the net rim, according to the given manual by the manufacturer. After towing, the net was rinsed from the outside with Mili-Q water from a pressure container to avoid sample contamination. All sampled MP particles were gathered in the collecting glass jar with a lid from the cod end. The samples were refrigerated at +4°C until further laboratory processing.

2.3. Sieving

Obtained samples from glass jars were wet sieved through a series of stacked sieves (4 mm, 2 mm, 1 mm, 250 µm, 125 µm, 63 µm), thoroughly rinsed with Mili-Q water to collect all MP particles and transferred to a new clean and marked glass jar. Multiple metal sieves were used for easier visual inspection.

2.4. Organic matter removal

For organic matter removal, Fenton’s reagent (a mixture of 0.05 M Fe (II) sulfate (7.5 g of FeSO4*7H2O (from Gram-Mol d.o.o.) in 500 ml of Mili-Q water and 3 ml of concentrated sulfuric acid (from Acros Organics) with a 30% H2O2 solution (from Gram-Mol d.o.o.)) was used. 40 ml of Fenton’s reagent was added to each beaker and heated on a “hot plate” at 75°C for 2h. Some samples had higher amounts of organic matter, so for complete removal, the second addition of 40 ml of Fenton’s reagent was necessary.

2.5. Density separation

A saturated salt solution (1.2 g/cm^3) was prepared by dissolving 360 g of NaCl in 1000 ml Mili-Q water and placing it on a heated magnetic stirrer for 30 minutes to fully dissolve. The solution was filtered over glass microfibre filters (LGG Labware; pore size 1.6 µm; filter diameter Ø 47 mm) placed on a filtration system (MF31, Rocker Scientific) connected to a vacuum pump (Büchi® V-500). 100 ml of saline solution and the sample were poured into a clean beaker, put on a magnetic stirrer for 2 minutes and sonicated for 15 minutes (Sonorex Super RK 255 H, Bandelin). The solution was left to sediment for at least 2h whilst covered with aluminum foil to avoid airborne contamination. The supernatant containing MPs was then transferred to a clean beaker. The walls of a density separator were thoroughly rinsed with Mili-Q water to transfer all MP particles. This step was repeated 3 times to increase the recovery rate of plastic particles.

2.6. Filtration

All samples and solutions were filtered over glass microfibre filters (LGG Labware; pore size 1.6 µm; filter diameter Ø 47 mm) placed on a filtration system (MF31, Rocker Scientific) connected to a vacuum pump (Büchi® V-500). The funnel walls were thoroughly rinsed with Mili-Q water to transfer all MP particles to filters.

2.7. Visual inspection & quantification of microplastics

Each fragment was visually inspected and photographed through a stereomicroscope (Nikon SMZ745T) equipped with Bresser MikroCam PRO HDMI 5 MP using multiple magnifications ranging from 10-50x (eyepiece: Nikon C-W10xB/22). For the acquisition of images, MikroCamLabII version 4.7.15283 (Bresser, GmbH) software was used. Using ImageJ/Fiji (Schindelin et al., 2012), images containing MPs were measured, determining Maximum Feret's diameter (mm) and surface area (mm^2). For each image, a calibration scale was set. Total plastic abundance (items/m^3; items/m^2), plastic surface area (mm^2), sampling area (m^2), sampling volume (m^3) were calculated, alongside the number of particles per sample.
Furthermore, MP particles were classified based on type (fiber, filament, fragment, pellet, microbead, film, foam), color (white, black, transparent, blue, red, green, pink, violet, yellow, orange, brown, grey, or multicolor) and size (> 5 mm; 2-5 mm; 1-2 mm; 0.5-1 mm; 0.3-0.5 mm; <0.3 mm).
Certain criteria for MP recognition were followed to discern them from organic matter: MP particles must not have visible cellular or organic structures; fibers should be equally thick throughout their entire length; and particles should exhibit clear and homogeneous color throughout (Cutroneo et al., 2020). Only such particles were considered for further processing.

3. RESULTS AND DISCUSSION

Total of 507 particles were visually detected and considered as MPs from the sampled surface waters with a mean abundance of 0.730 items/m3 and 0.292 items/m2, respectively. The maximal abundance (1.364 items/m3, 0.545 items/m2) was recorded in the proximity of the Mandalina marina, gradually decreasing as the sampling proceeded further from the marina, with a minimal abundance of 0.310 items/m3 and 0.124 items/m2. This indicates that the highest concentrations of MPs were directly linked with anthropogenic influences associated with activities from the nearby marina.
MPs were found in different shapes, sizes, and colors. Several images of collected MPs in surface water from the Krka River Estuary are shown in Figure 1. Fragments (58.38%) were the dominant shape, followed by foams (14.40%), filaments (10.06%), fibers (8.28%), microbeads (3.94%), films (3.55%) and pellets (1.38%) (Figure 2.). Fragments usually originate from the breakdown of larger plastic particles (Bošković et al., 2022), fibers and filaments are usually derived from clothes, fabrics and fishing gear, microbeads from cosmetic products (Fan et al., 2021), films from packaging, bags or wrapping material and foams are probably due to the degradation of domestic packaging and pristine polystyrene (PS) foam (Fiore et al., 2022).

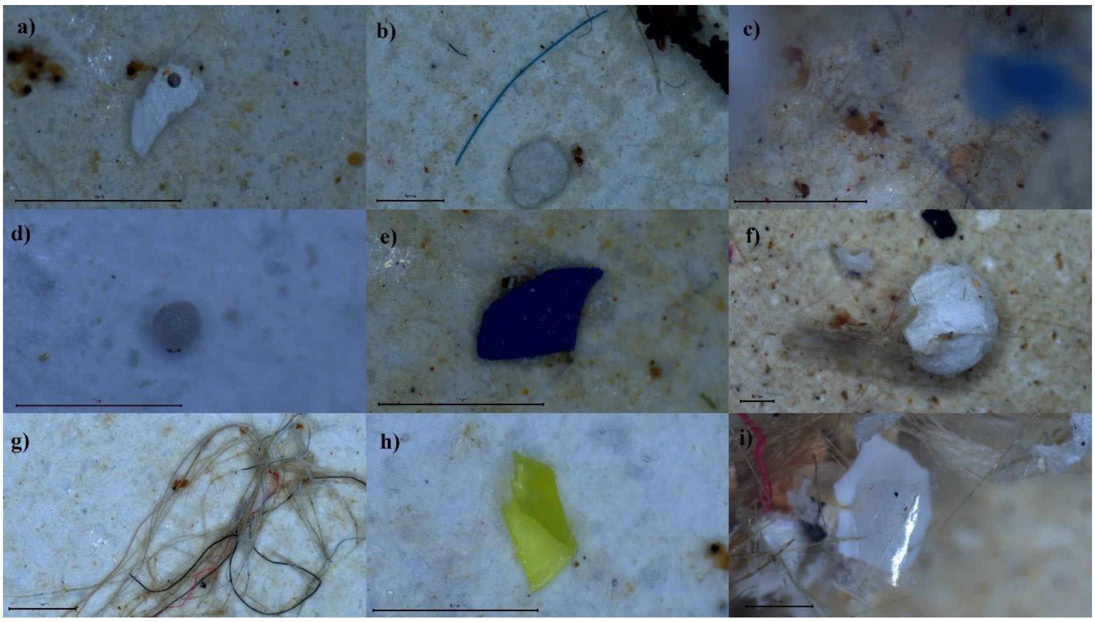

Figure 1. Images of MPs visually identified by Nikon SMZ745T stereomicroscope: a), e), h) fragments; b) fiber; c) microbeads; d) pellet; f) foam; g) filaments; i) film.

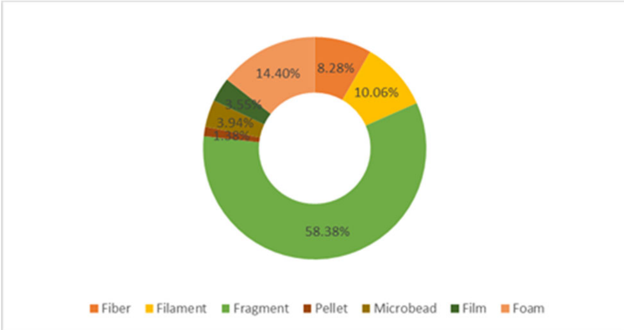

Figure 2. Distribution of surface water MPs by shape.

Based on color (**Figure 3**.), the most abundant were blue (26.43%) > transparent (20.91%) > white (20.71%) > red (18.74%) > black (3.35%) > orange and multiple colors (2.76%) > yellow (1.58%) > green (1.18%) > brown (0.79%) > gray (0.59%) > pink (0.20%) and no purple MPs. Most fibers were blue (52.38%), followed by black (14.29%) and red (14.29%). Filaments were mostly transparent (49.02%), blue (21.57%) and white (7.84%); fragments blue (33.78%), red (29.05%), transparent (13.85%); pellets white (71.43%) and transparent (28.57%); microbeads white (85%) and transparent (15%); films transparent (94.44%) and black (5.56%); foam white (56.16%), transparent (17.81%) and orange (15.07%) as can be seen in **Table 1**.

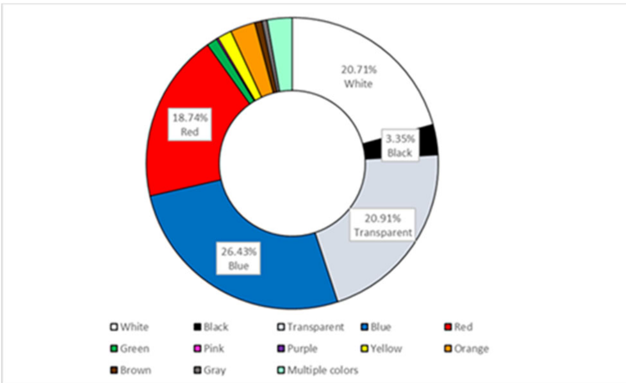

Figure 3. Distribution of surface water MPs by colour.

Table 1. Distribution of MPs by shape and colour.

		Fiber	Filament	Fragment	Pellet	Microbead	Film	Foam
	Total (n)	(%)						
White	105	2.38	7.84	12.50	71.43	85.00	0.00	56.16
Black	17	14.29	3.92	2.36	0.00	0.00	5.56	1.37
Transparent	106	11.90	49.02	13.85	28.57	15.00	94.44	17.81
Blue	134	52.38	21.57	33.78	0.00	0.00	0.00	1.37
Red	95	14.29	3.92	29.05	0.00	0.00	0.00	1.37
Green	6	2.38	3.92	0.68	0.00	0.00	0.00	1.37
Pink	1	2.38	0.00	0.00	0.00	0.00	0.00	0.00
Purple	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Yellow	8	0.00	1.96	2.36	0.00	0.00	0.00	0.00
Orange	14	0.00	0.00	1.01	0.00	0.00	0.00	15.07
Brown	4	0.00	5.88	0.34	0.00	0.00	0.00	0.00
Gray	3	0.00	0.00	1.01	0.00	0.00	0.00	0.00
Multiple colours	14	0.00	1.96	3.04	0.00	0.00	0.00	5.48
	507	42	51	296	7	20	18	73

The size distribution among sampled MPs is shown in Figure 4. MPs were divided into 6 size categories: > 5 mm, 2-5 mm, 1-2 mm, 0.5-1 mm, 0.3-0.5 mm and <0.3 mm according to BASEMAN Project standardized protocol for monitoring microplastics in seawater (Gago et al., 2019). Maximum Feret's diameter was measured for size determination. MPs in the size category 0.5-1 mm (30.18%) were the most abundant across all samples, following by sizes 0.3-0.5 mm (21.89%), 1-2 mm (20.71%), 2-5 mm (13.61%), <0.3 mm (11.44%) and >5 mm (2.37%). Used mesh size (300 µm) often causes underestimation of the real abundance of MPs because of the loss of smaller particles (Cutroneo et al., 2020). Different sizes, shapes and colors of MPs could indicate different sources and degradation rates of plastic particles (Hidalgo-Ruz et al., 2012). Even though all samples were sieved through a 4 mm sieve, the reason why we got particles greater than that lies in the elongated shape of particles that got through perpendicular with regards to the sieve.

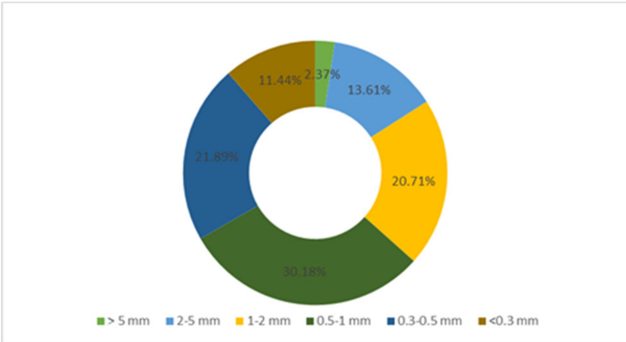

Figure 4. Distribution of MPs by size.

4. CONCLUSION

A total of 507 plastic particles were found in the lower part of Krka River estuary's surface water. All particles were classified into 7 shape categories. The most abundant shape were fragments, followed by foams, filaments, fibers and to a less extent microbeads, films, and pellets. Blue, transparent, white, and red were the most dominant colors. According to maximum Feret's diameter used in size determination, MPs in the size category 0.5-1 mm (30.18%) were the most abundant. Various shapes, colors and sizes could indicate various sources and different degradation rates of plastic particles. Our results showed the highest abundance of MPs in the vicinity of marina Mandalina, which was expected because of high anthropogenic pressure. We have provided useful basis for further research to improve sampling and processing techniques, considering the whole water column, not only the surface water. Given that, an overall picture of MPs abundance in certain area could be assessed.

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CLIMATE CHANGE, DISASTER RISK REDUCTION AND RESILIENCE

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Abstract: *Climate change increases the risks of instability in all its forms, and significantly affects the frequency and intensity of natural threats. In the last two decades, 90 percent of the world's major disasters were caused by events such as heat waves, floods, and weather-related droughts. The 2019 Disaster Risk Assessment for the Republic of Croatia for 10 out of 15 simple risks determined that climate change affected their occurrence. Climate change also affects complex risks, especially in urban areas. Therefore, when assessing the impact of climate change on the environment, it is necessary to consider the impact they have on disaster risks. Disaster risk reduction and climate change adaptation have a common area of interest, partly overlapping, and activities to strengthen resilience and to prepare a response system require joint efforts and cooperation.*
Keywords: *disaster risk reduction, climate change, risks, resilience, disaster*

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1. INTRODUCTION

From 1995 to 2015, 90 percent of recorded major disasters in the world (floods, storms, heatwaves and droughts) were linked to climate change. Climate change affected the frequency, intensity and duration of threats depending on weather conditions. According to the National Risk Assessment from 2019, climate change affects the occurrence of 10 out of 15 simple risks in Croatia. They affect: plant diseases, animal diseases, extreme temperatures, epidemics and pandemics, floods, open fires, snow and ice, droughts, land salinization and landslides (Disaster Risk Reduction Portal, 2019).

The response to the increased number of disasters in the world is the Sendai Framework for Disaster Risk Reduction, which links risk management, as well as reduction of risks to sustainable development. The goal is to prevent the emergence of new risks, reduce existing risks from disasters and manage the remaining risk, which will contribute to strengthening resilience (Sess: 2014-2015). This holistic approach is not limited to disaster management but implies continuous risk reduction.

Disaster risk reduction and climate change adaptation have a common area of interest. There are differences between these areas, but also convergence. Bringing together these areas and striving to achieve the same goal is most evident in focusing on increased climate-related dangers, climatic extremes such as floods, storms, landslides, droughts and others. Disaster risk reduction clearly emphasized the effects of climate on the increase of the risk of certain threats. There is a joint and multidisciplinary approach in searching for solutions and the development of horizontal and vertical cooperation with stakeholders. Climate-related disasters are impossible to analyze and discuss without taking into consideration climate change. However, it is not enough to focus only on activities after the disaster during the recovery and reconstruction phase. It is also important to act in the field of prevention, preparedness and mitigation which is the strongest link between disaster risk reduction and adaptation to climate change.

2. VISION AND STRATEGY

2.1. What is resilience

Measures and activities undertaken in the area of disaster risk reduction are linked to strategies aimed at strengthening resilience, a concept that has become key to sustainable development. Resilience at national and all other levels aims to ensure that shocks, stresses and dangerous events do not lead to a long-term gap in development, economic growth and progress. The concept of resilience has integrated various fields and is referred to in all recent international agreements related to disaster risk reduction as well as climate change adaptation. In Croatia as well, the Strategy for Adaptation to Climate Change in the Republic of Croatia for the period to 2040 with a view to 2070 (hereinafter: Strategy for Adaptation to Climate Change) has a development vision of "the Republic of Croatia resistant to climate change". The goal. i.e. resilience, is planned to be achieved by reducing the vulnerability of natural systems and society to the negative impacts of climate change and by strengthening the ability to recover from these impacts (Adaptation Strategy 2020). The adoption of the Disaster Risk Management Strategy until 2030 with the vision of "Croatia more resilient to disasters" is also in the process.

The concept of resilience has its drawbacks. One of the biggest objections is the difficulty of measuring results. Critics emphasize the insufficient concreteness of the concept of resilience and the existence of multiple concepts and definitions (I. Sudmeier-Rieux 2014). The United Nations defined the term for the field of civil protection. Resilience means the ability of a system, community or society exposed to hazards to timely and effectively resist, absorb, adapt and recover from the effects of hazards, including the preservation and restoration of essential basic structures and functions. The community's ability to recover in relation to any hazard or event is determined by the degree to which it is equipped with resources and the ability to organize before and during the need (United Nations 2016). Resilience means functioning without compromising long-term prospects for sustainable development, peace and security, human rights and well-being for all. The focus is on the capacity, that is, the capabilities of the community, and not so much on vulnerability, as was the case before. Terminology agreed at United Nations level defines capacity as the combination of all strengths, attributes and resources available in a community, society or organization to manage and reduce risk and strengthen resilience. Capacity thus defined may include infrastructure, institutions, know-how, and collective attributes such as social relations, leadership and management.

Capacity building is one way to reduce short-term and long-term disaster risks. In addition to the capacity for disaster response, it is important to strengthen the capacity for ecosystem management, the capacity for a higher level of self-organization, as well as the capacity for all areas that lead to disaster risk reduction and strengthening resilience. By strengthening capacity, we can reduce vulnerability, the increased sensitivity of an individual, community, property or system to the effects of threats (United Nations 2016). Vulnerability can be determined by physical, social, economic and environmental factors or processes.

2.2. European strategies and visions

The European strategic long-term vision for a prosperous, modern, competitive and climate-neutral economy presented by the European Commission at the end of 2018 places Croatia in three regions with regard to climate exposure. These are: Mediterranean, mountain and continental regions (European Commission 2018). This complex situation can increase the spectrum and number of risks in our area.

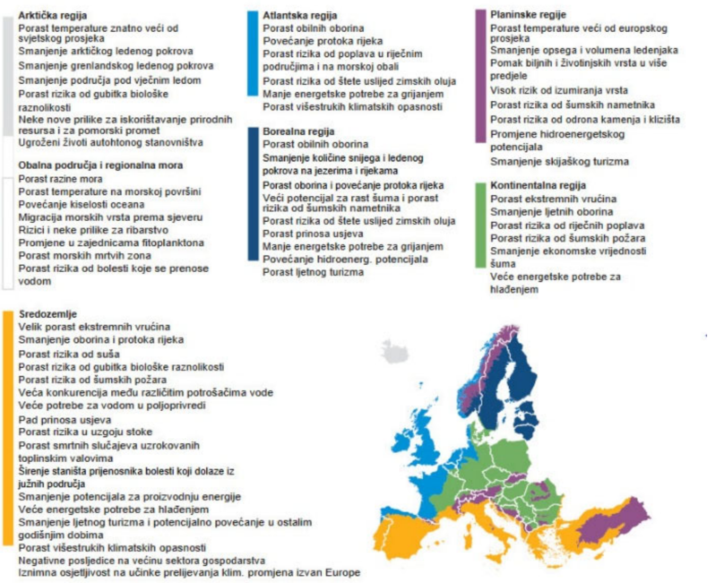

Figure 1. Consequences of climate change in Europe (Source: European Commission 2018)

The European Green Deal offers solutions to save the endangered environment and eliminate increased threats from natural disasters. Unlike the new EU climate change adaptation strategy, adaptation or disaster resilience are mentioned less. However, this does not reduce its impact on changes, and the Deal itself is called a growth strategy that will transform the European economy into a resource-efficient and competitive one by 2050 at the latest. It envisages the complete elimination of net greenhouse gas emissions because economic growth will no longer be linked to the use of resources that have led to climate change (European Commission 2019). Conservation and restoration of ecosystems and biodiversity mitigate natural threats. That is why the European Green Deal aims to strengthen the foundations for sustainable investments, and better integrate climate and environmental risks into the financial system, which will thus help increase resilience.

Creating a climate-resilient Europe – the EU's new Climate adaptation strategy aims to improve adaptive capacity and reduce vulnerability to climate impacts. It emphasizes the importance of knowledge about climate impacts and resilience, and the need for more and better data on climate-related risks and losses, which are important for making informed decisions. Data on climate-related risks and losses must include public and private losses due to climate change impacts such as loss of life, damage to infrastructure or commercial activities, as well as crisis response and recovery costs (Creating a Resilient Europe, 2021). The concept of resilience is mentioned more than 60 times in this strategy.

2.3. Croatian strategies for adaptation to climate change and disaster risk management

The strategy of adaptation to climate change in the Republic of Croatia for the period to 2040 with a view to 2070, as part of the assessment of the impact of climate change and vulnerability, also addresses the area of disaster risk reduction. It was pointed out that climate change can increase the probability of a disaster and increase its intensity. The main expected impacts with high or medium vulnerability are: landslides, floods, extreme temperatures, open fires, droughts, epidemics / pandemics and complex risks, especially in urban areas (Adaptation Strategy, 2020). The presentation of the impact and challenges of adaptation from this strategy in the area of disaster risk reduction has been supplemented and partially amended in the Disaster Risk Management Strategy until 2030.

The impacts and challenges of adaptation for the area of disaster risk reduction include "the exposure of the built environment and the probability of damage or loss due to a certain level of threat", and "increase in the frequency and intensity of floods and droughts" was also added. Issues related to construction and exposure of the built environment play a major role in disaster risk reduction. In addition, corrections were made to possible responses to reduce high vulnerability (**Table 1**).

Table 1. Adapted presentation of the impacts and challenges of adaptation to climate change in the field of disaster risk management (Source: Climate Change Adaptation Strategy in the Republic of Croatia for the period to 2040 with a view to 2070 (adapted))

Impacts and challenges causing high vulnerability	**Possible responses to reduce high vulnerability**
■ open space fires due to extended periods of high solar radiation and extended periods of high air temperature and longer dry periods ■ exposure of the built environment and the likelihood of damage or loss due to a given level of threat ■ increase in the frequency and intensity of floods and droughts ■ epidemics and pandemics, due to the way the disease is transmitted or the characteristics of the pathogen of the disease ■ increase in the extent of the health and socio-economic burden of the community due to the impact of risks caused by climate change	■ strengthening the competencies of key stakeholders in risk management related to climate change ■ strengthening the capacity to respond to major accidents and disasters ■ determination of multisectoral guidelines for actions related to climate change ■ expansion of the risk monitoring and assessment system using tools for monitoring risk indicators related to climate change ■ effective recovery from the consequences of major accidents and disasters ■ reducing community burdens after exposure to climate change-related threats

The management dealt with by the Disaster Risk Management Strategy is a complex process including national, regional and local levels of government and organizations operating at a horizontal level (civil society associations, companies, etc.). Disaster risk management means the application of policies and strategies that can be aimed at preventing emerging risks, reducing existing ones and managing residual risks. It also implies a contribution to strengthening resilience and reducing losses from disasters (United Nations 2016).

Climate change has influenced the greater acceptance of prospective and corrective risk management. Prospective risk management deals with activities and efforts to avoid the development of new or increased disaster risks and focuses on addressing risks that could develop if risk reduction policies are not put in place. On the other hand, corrective risk management deals with activities and efforts to remove or reduce existing risks. Although we start from how risks can be influenced and effectively reduced, in the case of climate change, the process is long-term. Therefore, in addition to the, compensatory risk management including activities to strengthen both the social and economic resilience of individuals and societies is necessary due to facing a risk that cannot be effectively reduced. It applies to residual risk and includes preparedness, response and recovery activities and combines different financing instruments.

3. STRENGTHENING FINANCIAL RESISTANCE TO DISASTERS

3.1. Financial damages

Due to weather and climate extremes, damages in the 27 EU member states exceeded 487 billion euros in the last 40 years. This is significantly more than what the EU spends over two years on all its policies and programs. Germany, Italy and France had the highest costs caused by damages and Denmark, Austria and Luxemburg the biggest loss per capita.

From 2005 to 2014, Croatia was among the leading countries in the European Economic Area in terms of damages from natural disasters in relation to gross domestic product. According to the estimates of the NatCatService database, Croatia, Bulgaria, Romania and Latvia lead the way in terms of damages from natural disasters in relation to their GDP in the European Union (**Figure 2**). These are the data that European institutions rely on, which in general are not satisfied with the collection and availability of data on disasters.

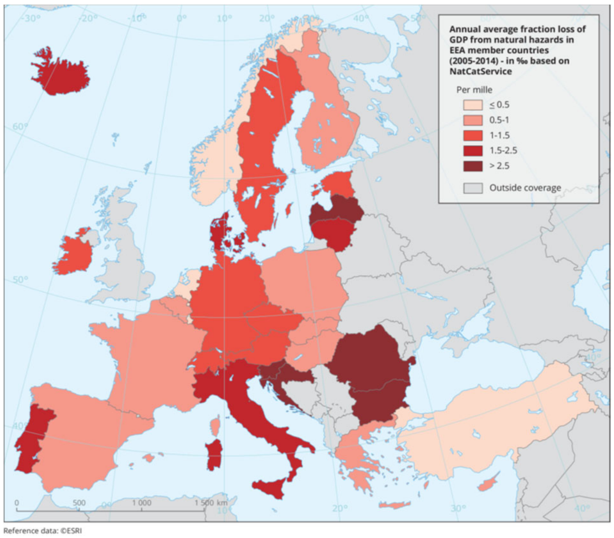

Figure 2. Average annual losses from natural threats for the countries of the European Economic Area from 2005 to 2014 (Source: https://www.eea.europa.eu)

The Register of reported damages from 2010 to 2018 maintained by the Ministry of Finance of the Republic of Croatia shows that the total amount of damages due to natural disasters in Croatia exceeded HRK 21 billion (EUR 2.8 billion). More than half of the amount was damage caused by droughts, floods and precipitation, and fires (**Figure 3**).

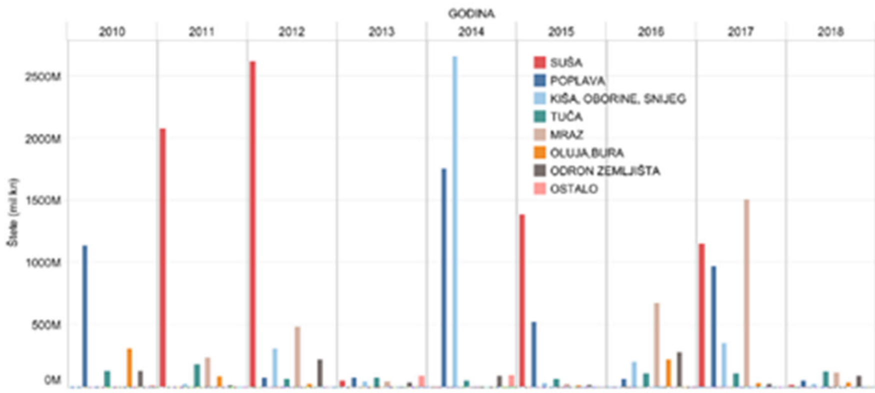

Figure 3. Damages due to natural disasters from 2010 to 2018 (Source: Register of reported damages of the Ministry of Finance of the Republic of Croatia)

The most damage due to natural disasters from 2010 to 2018 was reported by Primorje-Gorski Kotar County, Osijek-Baranja County, Virovitica-Podravina County and Vukovar-Srijem County (**Figure 4**.).

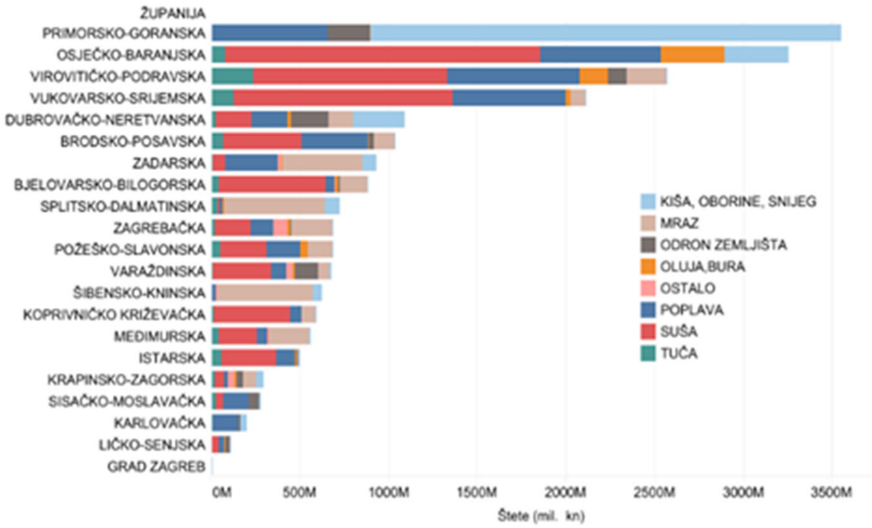

Figure 4. Damage from natural disasters by county from 2010 to 2018. (Source: Register of reported damages of the Ministry of Finance of the Republic of Croatia)

According to the data of the Register of reported damages, in 2011, Croatia had over two billion kuna damages (around EUR 265 million) due to droughts, and in 2012 as much as 2.6 billion kuna (around EUR 347 million). In relation to the number of inhabitants and GDP, the damage had more severe consequences than the catastrophic droughts in some developed European countries a few years later. Osijek-Baranja County, Vukovar-Srijem County and Virovitica-Podravina County suffered the most, i.e. the counties of the continental part of the country with developed agriculture.

Damage monitoring is important for correcting disaster and climate change policies, and also useful for both disaster risk assessment and strengthening financial resilience.

3.2. Strengthening resilience

Forecasts of climate indicators for the Mediterranean are worse than forecasts at the global level for most values. Climate experts for the Mediterranean region predict during the 21st century the following: increase in temperature, decrease in summer precipitation, increase in drought periods, both greater frequency and intensity of extreme events, increase in sea level and coastal flooding, as well as sea acidification due to increased amounts of carbon dioxide (Galeotti, 2020). Without mitigation of climate change, i.e. with expected warming of 3°C by the end of the century, forest fires and pest epidemics would be more frequent and severe. Due to the increased loss of biomass, the amount of carbon in the atmosphere would increase. The increase in warming would be accompanied by the reduced availability of water resources, which could reach 40% in the southern regions of Europe, and the lack of water and drought would affect agriculture, energy production and water supply. Mortality due to extreme heat would increase as much as 30 times (90,000 people per year compared to the current 3,000). Crop yields would fall by more than 10% in southern Europe, losses from river floods would increase sixfold. The increase in the risk of fire is greater in the lower latitudes of Europe. The PESETA IV study, which was carried out to better understand the consequences of climate change for the European Union, pointed out significant differences in risks between the north and south of Europe. Increasing global warming will bring more suffering to southern Europe due to high temperatures and water availability. Without mitigating climate change, human exposure to heat waves will increase 40 to 50 times in southern Europe, and about 30 times in other parts of the continent (Feyen, Ciscar, Gosling, Ibarreta, & Soria, 2020).

Therefore, strengthening resilience for Croatia as a country in the south of the European continent is more challenging. Models for four European regions – Mediterranean, Atlantic, Continental and Boreal show that the south of Europe can expect the most severe consequences due to droughts. The estimate of annual damages in euros at an average temperature increase of 1.5°C, 2°C and 3°C compared to the base year 2015 is shown in Figure 5. Vertical lines indicate climate uncertainty.

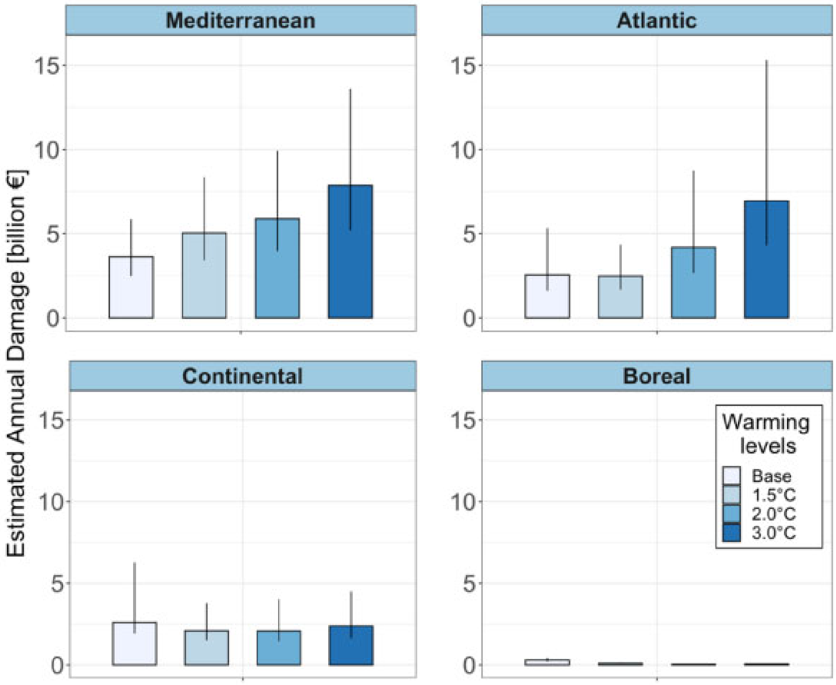

Figure 5. Annual damage due to droughts in billions of euros
(Source: JRC, Global warming and drought impacts in the EU)

As a country that belongs to both the Mediterranean and Continental region, Croatia can also expect: increase in extreme heat, decrease in summer precipitation, increase in the risk of river floods, increase in the risk of forest fires, decrease in the economic value of forests and increase in energy needs for cooling (European Commission 2018).

Due to the floods in 2014, according to data from the Ministry of Finance, Croatia suffered more than HRK 1.7 billion in damages (more than EUR 232 million). The PESETA IV study developed four adaptation strategies to reduce damages from river floods. These are: strengthening of the embankment system, construction of retention areas for flood water storage, measures to reduce damage to buildings and relocation to areas safe from floods (**Table 2**). For Croatia, as well as for most European countries, the most expensive thing is to do nothing in adapting to climate change.

Table 2. PESETA IV analysis results of four adaptation strategies to reduce damage from river floods at the EU level (Source: Climate Change Impacts and Adaptation in Europe, JRC PESETA IV final report (EUR 30180EN))

Savings / Adaptation strategies	Return of investment (per 1 EUR)	Reduction of economic damage (%)	Reduction of damage to the population (%)
Strengthening of the embankment system	2 – 2,9	41 - 68	41 - 65
Construction of retention areas	2,9 – 3,5	64 - 82	63 - 81
Measures to reduce damage to buildings	5,2	50	0
Relocation to areas safe from floods	1,2	17	16

Forest fires cost the European Union about 2 billion euros annually, and damage is beginning to be recorded in northern and central Europe as well. Since 1980, fires in Europe have burned more than 190,000 square kilometers of forest, which is the size of two Portugals. The record year in terms of damage in Europe was 2018, and in Croatia 2017. At that time, 67,343 hectares of forests were destroyed in 104 fires in our country. The acquisition of a new monitoring and notification system enabled a faster response, and the result is visible from the data for 2019 (**Figure 6**), when, despite the greater number of fires, the size of the burned area is significantly smaller, and thus the damage.

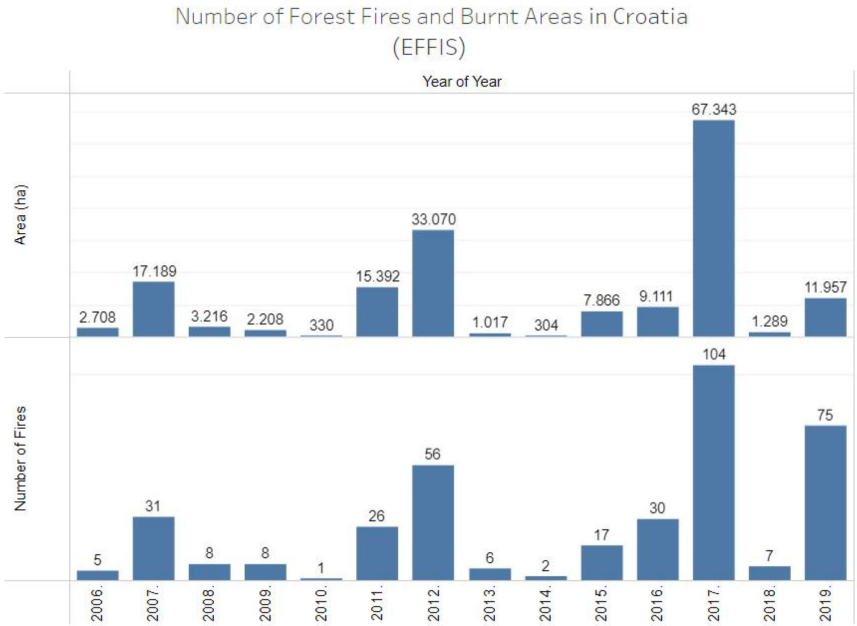

Figure 6. Number of fires and burnt areas

Disaster risk reduction and climate change adaptation are two practices that address increased disaster risk. Disaster risk reduction seeks to reduce the risk of natural and man-made disasters by reducing the exposure and vulnerability of people and property and increasing preparedness for such events, while climate change adaptation seeks to adjust reduce the potential negative effects of climate change on society in terms of climate extremes and gradual climate change. Despite their similarities, disaster risk reduction and climate change adaptation are strictly separated by institutional and administrative boundaries, although this does not exclude cooperation and information exchange.

Activities related to disasters and their consequences in Croatia are mainly EU-funded, and the country itself has very small reserves, mostly insufficient to repair damages caused by very high exposure to disasters (International Bank for Reconstruction and Development / The World Bank, 2021). As stated in the new EU strategy for adapting to climate change, resilience to the risks of climate change and natural disasters must be included in national fiscal frameworks. In addition to increasing the rate of household catastrophe insurance or public property insurance, this could significantly improve the management of insufficient finances in the face of future global warming.

Climate change adaptation measures do not make sufficient use of synergies with the field of disaster risk reduction. Better coordination at the national level could achieve better alignment of practices, norms, guidelines, goals, resources, and knowledge. Increased and improved communication and collaboration between those involved in climate change adaptation and disaster risk reduction enhances the learning process. Currently, climate change adaptation and disaster risk reduction use and apply the same terms, but still their meaning can be different, which confuses laymen and representatives of other professions. Linking knowledge enables better understanding, easier recognition, and research of overlapping areas, and would certainly have positive financial effects.

4. CONCLUSION

In the past decade, Croatia was faced with natural threats that caused enormous material damage. Risk assessments have established that, under the influence of climate change, threats have become more frequent and more intense. Building resilience is therefore an imperative for action highlighted in key development strategies. The forecasts of climate indicators for the Mediterranean, according to several experts, are worse for most of the observed values, and it is necessary to act intensively to mitigate climate change and reduce the risk of disasters. Our goal is common – to reduce the suffering of people, threats to their health, and to preserve both public and private property, preserve cultural assets and protect critical infrastructure. The path to that goal leads through environmental preservation, changes in the economy, but also through changing awareness of how the world around us is very vulnerable.

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THE IMPACT OF CLIMATE POLICY AND CLIMATE CHANGE ON $PM_{2.5}$ EMISSION FROM RESIDENTIAL WOOD COMBUSTION

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Abstract: *Residential wood combustion is the dominant source of particulate matter $PM_{2.5}$ in the Republic of Croatia. Although the wood biomass is considered a green, sustainable energy source, at the same time the inhalation of $PM_{2.5}$ particles from residential wood combustion, is associated with harmful effects on human health. The paper analyzes the variability of $PM_{2.5}$ emission regarding three factors, which are closely related to climate policy and climate change. The first factor is related to the introduction of new, more environmentally friendly wood biomass combustion technologies. The second factor relates to the consumption of wood biomass depending on climate variability. The third factor refers to the implementation of measures for energy renovation of family houses. The aim of this paper is to distinguish the contribution of individual factors, both on the historical $PM_{2.5}$ emissions from residential wood combustion, and on the emission projections up to the year 2050.*

Keywords: $PM_{2.5}$ emission variability, residential wood combustion, climate policy, climate change

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1. INTRODUCTION

Energy and climate policies and strategies increasing the use and boosted of renewable energy sources. The bioenergy from wood combustion considered a green and sustainable but has an impact on environment (UNFCCC, 2015; WBA, 2016; European Council, 2019). Particularly, the inhalation of $PM_{2.5}$ particles from residential wood combustion, is associated with harmful effects on human health (Air Quality Expert Group, 2017; WHO, 2015; WHO, 2021). In the Republic of Croatia, the residential wood combustion is the key source of many air pollutant emissions (Ministry of Economy and Sustainable Development, 2021; EMEP CEIP, 2022) with the impact on the local air quality considering $PM_{2.5}$, PM_{10} and benzo(a)pyrene (BaP) (Ministry of Economy and Sustainable Development, 2020; UN ECE, 2019). This paper starts with an overview on the policies concerning the use of the bioenergy from biomass, scope of the fuelwood combustion in households, resulting air pollution, specifically $PM_{2.5}$ emission and emission projection and impact of it on human health. The paper analyses the impact of selected three factors on $PM_{2.5}$ emission from household heating appliances on wood biomass as following: the introduction of new, more environmentally friendly wood biomass combustion technologies replacing the old, inefficient technologies with high particulates emission, the consumption of wood biomass depending on climate variability, and the implementation of measures for energy renovation of family houses. Finally, the conclusion discusses the results are presented.

2. POLICIES, WOOD BIOMASS AND $PM_{2.5}$ EMISSION

Energy and climate policies and strategies envisage increasing the use of renewable energy sources (RES), including wood biomass, as an important means for the energy sector to achieve environmental, economic, and social goals of sustainable development (Andersen, Allen and Domingo, 2021; UNFCCC, 2015; WBA, 2016). The application of RES is a key component of mitigating climate change and for achieving the international obligations of the European Union and member states under the Paris Agreement (UNFCCC, 2015). Biomass fuels were also included in the European Commission's strategy to achieve its climate and energy goals by 2020 (20% reduction in greenhouse gas emissions, 20% final energy consumption from RES and a 20% increase in energy efficiency) (WHO, 2015). For example, in the year 2018 the share of solid biomass in total Final Energy Consumption in the Residential sector was 16.3 % in the EU, and the Republic of Croatia achieved a share of 44.9 % (Eurostat a (n.d.)). By implementing RES, Europe has replaced part of its energy production from non-renewable sources (especially from fossil fuels) and managed to reduce greenhouse gas (GHG) emissions. The further goal of the EU's goal is to achieve climate neutrality by 2050 delivering on its commitments under the international Paris Agreement (European Council, 2019). The EU’s strategy for reaching its 2050 climate goal is The European Green Deal. This requires current greenhouse gas emission levels to decrease substantially in the next decades. As an intermediate step towards climate neutrality, the EU has raised its 2030 climate ambition, committing to cutting emissions by at least 55% (compared to 1990) by 2030. The 'Fit for 55' legislative package will turn the EU's ambition into reality and strengthen the EU's position as a global climate leader. 'Fit for 55' package will additionally boost the development of renewable energy sources in the EU, especially through the implementation of the revised Renewable Energy Directive (RED). However, not all sources of renewable energy have the same environmental impacts. Energy from wood biomass combustion, in particular causes air pollution and impacts health (Air Quality Expert Group, 2017). Increased usage of energy from wood biomass can pose a challenge for EU Member States in meeting EU air quality standards, defined by current framework used to control ambient concentrations of air pollution in the EU - Ambient Air Quality Directive & daughter Directive 2004/107/EC, and their emission reduction commitments for air pollutants set out under the National Emission reduction Commitment Directive (NEC Directive) along with the parties of the United Nations Economic Commission for Europe (UNECE) Convention on Long Range Transboundary Air Pollution (Convention LRTAP) and belonging the 1999 Gothenburg Protocol to Abate Acidification, Eutrophication and Ground-level Ozone (Gothenburg Protocol) (Environmental Protection UK, n.d.). The Republic of Croatia, as EU Member State and the party of UNECE Convention LRTAP, is required to regularly compile and report official estimates of their emissions and projected (future) emissions for GHGs and air pollutants. The mandatory reporting of projections plays an important part in the policy process: it is designed to provide MS, the European Commission, and other stakeholders with a reliable early indication of the expected trend of future emissions, and thus with information on whether implementation of national and EU-wide policies and measures is helping countries meet their emission commitments. The set of projections scenarios that MS have been required to report fall into the two categories: 1) projections scenario 'with measures' (WM) - means projections of anthropogenic GHG or air pollutant emissions by sources that encompass the effects of currently implemented or adopted policies and measures, and 2) projections scenario 'with additional measures' (WAM) - means projections of anthropogenic GHG or air pollutant emissions by sources that encompass the effects of policies and measures which have been adopted and implemented, as well as planned policies that are judged to have a realistic chance to be adopted and implemented in the future. The officially reported emission estimations (EMEP CEIP, 2022) and project emission estimation for two scenarios (WM and WAM) (EMEP CEIP, 2021) for pollutant $PM_{2.5}$ are used in this paper for analysis and results presentation. The burning of wood biomass in household heating appliances is responsible for the majority of particulate matter emissions in Europe (EIONET, 2021; WHO, 2015; Environmental Action Germany, 2015; Carrington D, 2021). Ambient (outdoor) air pollution in cities and rural areas is estimated to cause 4.2 million premature deaths worldwide in 2016 and is the result of exposure to $PM_{2.5}$ particles, which cause cardiovascular and respiratory diseases and cancer (WHO, 2021). At EU27+UK level in 2016 as stated in ETC/ATNI Report 6/2020 (EIONET, 2021), it is estimated that the interrelationship between the increase in emissions due to biomass use and the reduction in emissions due to all other RES growth is responsible for around 9,200 premature deaths and 97,000 years of life lost. As such, the increase in solid biomass heating alone (particularly due to high particulate emissions from domestic stoves) is estimated to be responsible for an increase of around 10,700 premature deaths and 113,000 years of life lost in 2016. Official reported data (Ministry of Economy and Sustainable Development, 2021) show that in the Republic of Croatia, wood biomass burning in households is a key source of emissions of many pollutants, and $PM_{2.5}$ is one of them (**Figure 1**). In 2020, wood biomass in Croatia accounted for 63.3% of the total consumption of all energy sources in household heating appliances, and it dominates throughout the entire historical trend since 1990 (EMEP CEIP, 2022). The increase in the use of wood biomass in household heating appliances is associated with an increase in the concentration of $PM_{2.5}$, especially during the winter heating season (EIONET, 2021; Air Quality Expert Group, 2017; WHO, 2015).

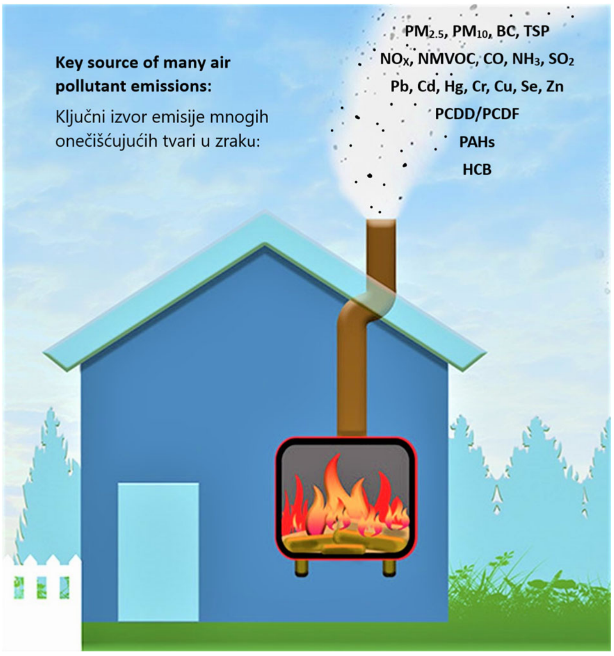

Figure 1. Residential wood combustion as a key source of many air pollutants emissions

According to Croatian strategic and planning documents (OG 25, 2020; OG 63, 2021; Ministry of Economy and Sustainable Development, 2020; OG 46, 2020; OG 140, 2020) it is expected that the consumption of wood biomass will increase until 2030, and then decrease due to boost of energy home renovation. Compared to 2018, the consumption of energy from biomass in households is expected to increase by 6% in WM and 4% in WAM scenario until 2030. Due to boost of energy home renovation, it is expected that consumption of wood biomass will decrease by 46% in WM and 53% in WAM scenarios until 2050. WM scenario assumes energy renovation rate of 0.75 % per year, and 20 % of total old wood heating appliances replacement by 2030. WAM scenario assumes energy renovation rate of 1.3 % per year, and 41.7 % of total old wood heating appliances replacement by 2030. There is no change in technology share after 2030 in both scenarios (Ministry of Economy and Sustainable Development, 2021; CEIP EMEP, 2021).

3. OBJECTIVE OF THE WORK AND METHODOLOGY

Objective of the work is distinguishing the impact of influencing factors on $PM_{2.5}$ emission and emission projections from household wood biomass burning. Factors that affect the amount of $PM_{2.5}$ emission from wood biomass combustion in residential heating appliances and, consequently, the level of $PM_{2.5}$ concentration in the air are following:

- amount (and type) of fuelwood - number of households that use it as an energy source
- climate conditions
- combustion technology
- operational settings maintenance of heating appliance and its age
- fuel quality (depending on storing practice, waste co-firing)
- implementation of energy efficiency measures

Among previously mentioned influencing factors, three of them, closely related to climate policy and climate change, were selected:

- Factor #1: Introduction of new, more environmentally friendly wood biomass combustion technologies,
- Factor #2: Wood biomass consumption variability depending on interannual climate variability, and
- Factor #3: Decreasing wood consumption due to improving the energy efficiency of family houses.

By analysing the variability of the emission of $PM_{2.5}$ regarding three selected influencing factors, it will be determined which of them has the greatest influence on $PM_{2.5}$ emission, that is, which of them contribute the most to its reduction.

The impact of each factor was analysed separately. The reference year for the analyses is 2018, the most recent year in the officially submitted emissions projections. The observed timeframe included the base year 2018 and regard this the historical period (1990 – 2020), and the projection period (after 2020 up to 2050). All results are expressed as a difference from baseline year 2018. The input data were biomass energy consumption in households and share of biomass combustion technologies for two scenarios WM and WAM, all presented in **Figure 2**.

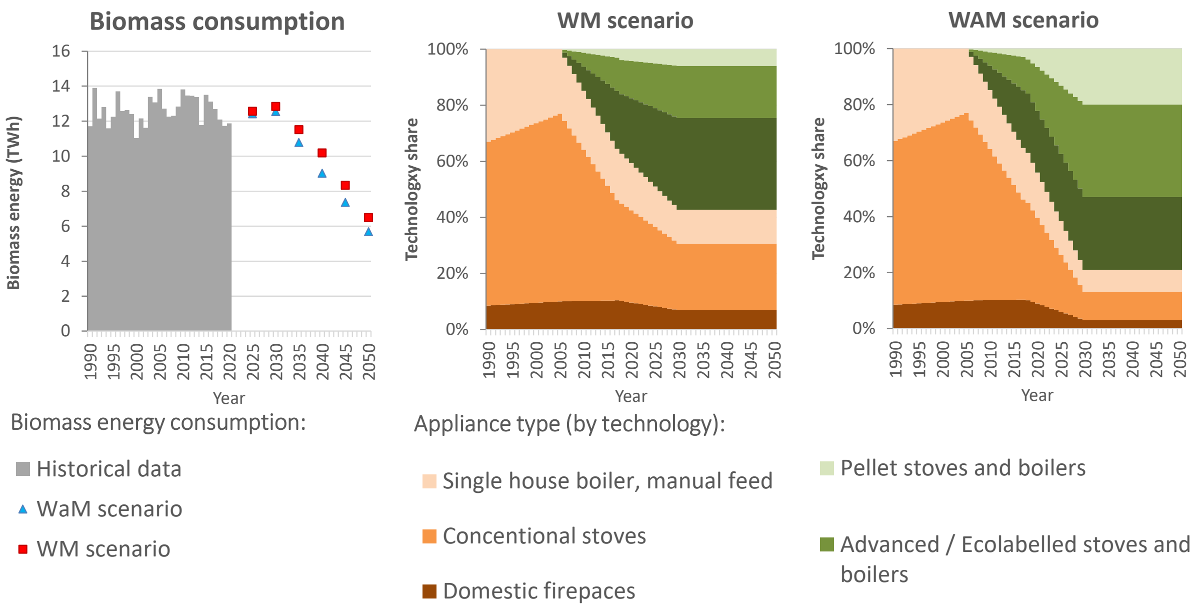

Figure 2. Biomass energy consumption in households and share of biomass combustion technologies for historic period (1990 - 2020) and projection period (after 2020) for the WM and WAM scenarios

Emission factors showed in *Figure 3* present the range of $PM_{2.5}$ emission from various type of biomass burning appliances used in households. It can be seen that pellet stoves and boilers have approximately ten times lower $PM_{2.5}$ emission than conventional alliances (conventional stoves and single house boilers).

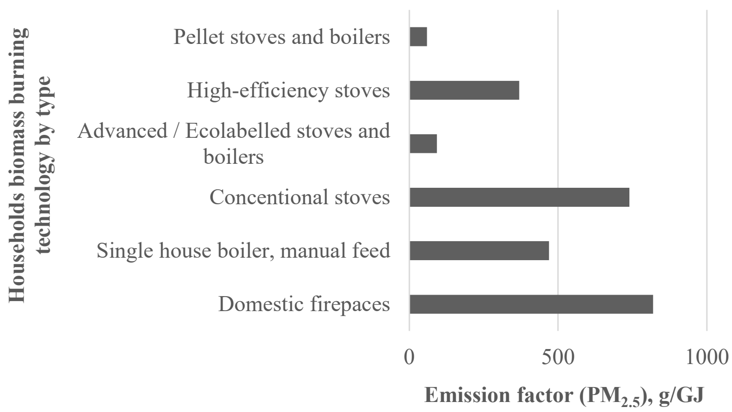

Figure 3. $PM_{2.5}$ emission factors for different wood biomass appliances used in households

4. RESULTS AND DISCUSSION

The impact of wood biomass combustion technology (Factor #1) and climate variability (Factor #2) on $PM_{2.5}$ emission and emission projections from household biomass heating appliances are presented on **Figure 4**.

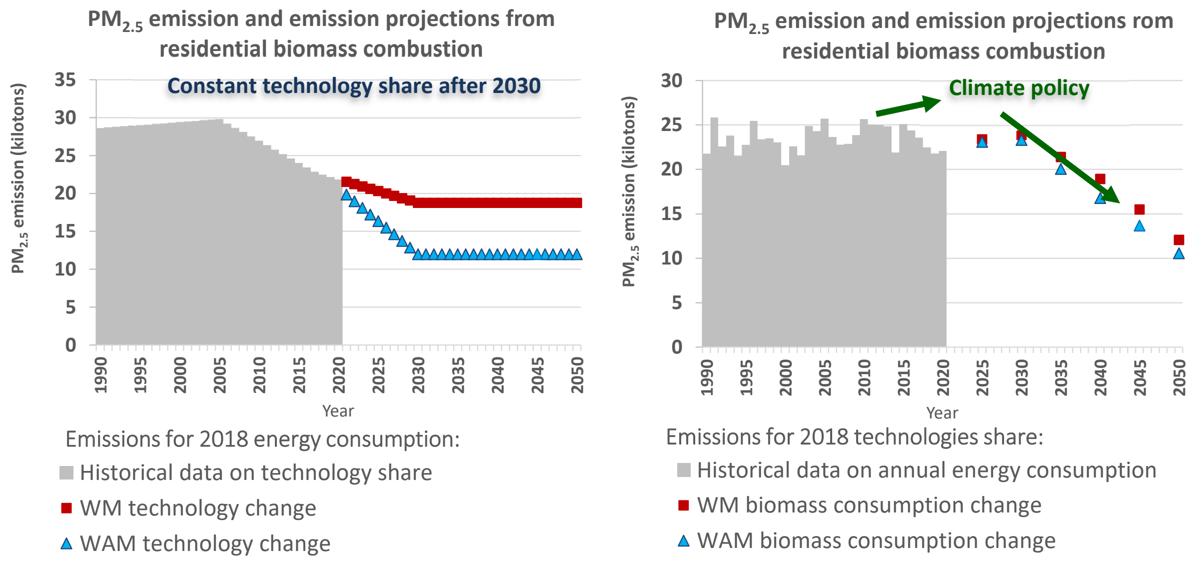

Figure 4. Impact of wood biomass combustion technology (left) and climate variability (right) on $PM_{2.5}$ emission and emission projections from household fireplaces on wood biomass for the historical period and scenarios WM and WAM

The implementation of the climate polices, which is expected increased use of firewood in households by 2030, will consequently result in higher $PM_{2.5}$ emission. The results of the sensitivity analysis regarding Factor #1, show that within the historical period, due to a greater share of old combustion technologies, $PM_{2.5}$ emission could be up to 25% higher than in 2018 (**Figure 4 (left)**). Regarding Factor #2, the sensitivity analyse shows that $PM_{2.5}$ emission difference may go between -10 % to +13 % due to variability of the biomass energy consumption (**Figure 4 (right)**). **Figure 5 (left)** compares the historic trends variability of heating-degree days (HDD) (EUROSTAT b, n.d.) and biomass energy consumption in households. HDD variability goes between -12 % and +35 %, while the biomass consumption variability goes between -9 % and +15 %. The discrepancy between variability of HDD and biomass consumption indicates an increase in biomass consumption in households, which is in line with climate policies. According to climate projections for 2030 and 2040, HDD is expected to decrease by 2.3% and 4.7%, respectively, compared to 2018 (Ministry of Economy and Sustainable Development, 2021).

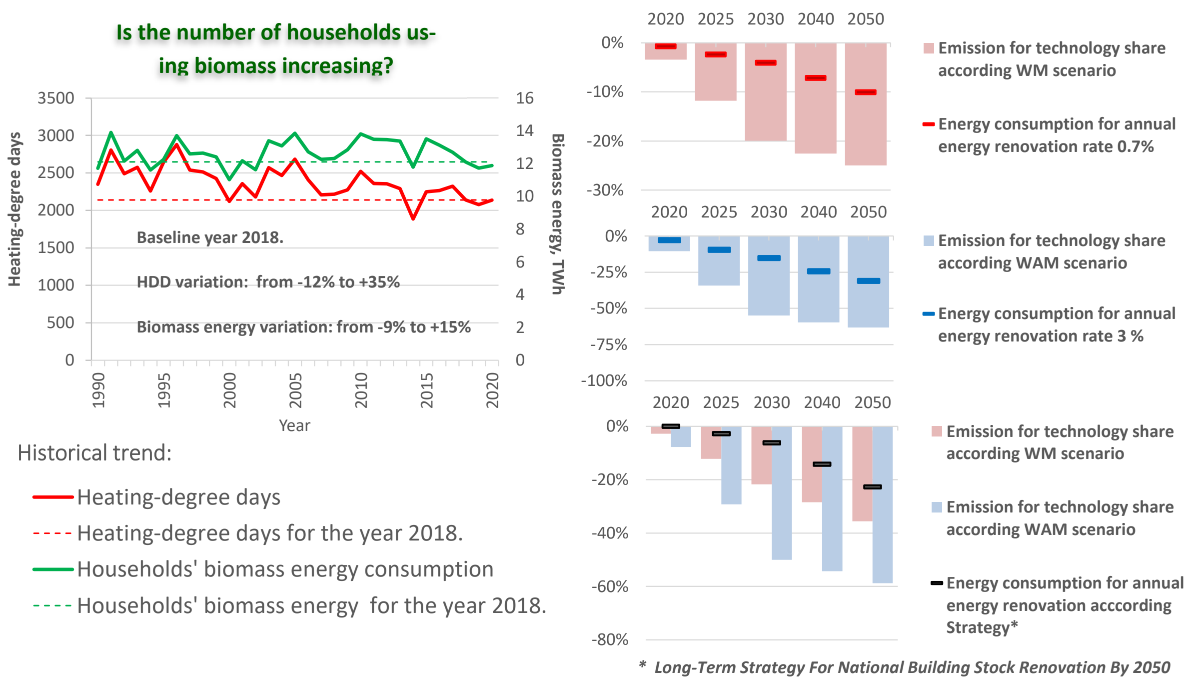

Figure 5. Heating-degree days and biomass energy consumption for the historic period (left) and the impact of energy renovation and technology improvement on $PM_{2.5}$ emission decrease (4 scenarios) (right)

The impact of improving the energy efficiency of family houses (Factor #3) is analysed for three different renovation rates: 1) constant energy renovation rate of 0.7 % per year, 2) constant energy renovation rate of 3 % per year, and 3) linear change of energy renovation rate from 1 % in 2020 to 3 % in 2030). For the sensitivity analysis of Factor #3 following scenarios were used: conservative, optimistic, moderate conservative and moderate optimistic one and results are presented in *Figure 5 (right)*. The conservative scenario (**Figure 5** *(right), upper graph*), which includes WM biomass technology change scenario and energy renovation rate of 0.7 % per year, may result with -22 % reduction of $PM_{2.5}$ emission in 2030 when comparing to base year 2018. The optimistic scenario (**Figure 5** *(right), middle graph*), which includes WAM biomass technology change scenario and energy renovation rate of 3 % per year, may result with -56 % reduction of $PM_{2.5}$ emission in 2030 when comparing to 2018. The moderate conservative scenario (**Figure 5** *(right), lower graph, red*), which includes WM biomass technology change scenario and linear change energy renovation rate from 1 % to 3 % per year, may result with -24 % reduction of $PM_{2.5}$ emission in 2030 when comparing to 2018, while conservative optimistic scenario (**Figure 5** *(right), lower graph, blue*) with the same linear change energy renovation rate, and with WAM biomass technology change may bring -51 % reduction. The year 2030 is chosen to indicate how energy and climate policies may have impacted $PM_{2.5}$ emission in this decade.

5. CONCLUSIONS

This paper analyses the impact of three influencing factors on $PM_{2.5}$ emission from household heating appliances using wood biomass which are closely related to climate policy and climate change. The first factor refers to introduction of new, more environmentally friendly wood biomass combustion technologies replacing the old. The second factor is related to the climate variability which effects consumption of wood biomass. The third factor refers to the implementation of energy renovation of family houses.

With energy renovation rates of family houses according to the Long-term strategy [22], and widespread use of eco-friendly biomass appliances, a reduction in $PM_{2.5}$ emissions between 24 % (WM scenario) and 51% (WAM scenario) could be expected up to 2030.

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ENVIRONMENTAL IMPACT ASSESSMENT CASE STUDY OF THE CONSTRUCTION OF A MAIN GAS PIPELINE, SECTION SVETI NIKOLE-VELES

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Abstract:

The Republic of North Macedonia undertakes intensive activities aimed at replacing fuels - fossil fuels with renewable energy sources and natural gas, to monitor the modern trends of exit from the energy crisis and environmental protection. Under the efforts of the National Gasification System in the country, i.e. the development of the existing gas infrastructure, the project for construction of the gas pipeline section Sveti Nikole – Veles was developed. The route of the gas pipeline starts east of the city of Sveti Nikole and ends south of the city of Veles with characteristics: DN 200, Ø 8" and length of 27.67 km.

The Environmental Impact Assessment process is intended to serve as a primary input for the decision-making process by Macedonian authorities and the IFI in charge (EBRD in this case), which have to approve the Project before its implementation. The decision-making process includes the preparation of all documentation in accordance with the EBRD's Performance Requirement (PR), The National Legislation, and Good International Practice (GIP).

This EIA study identifies the potential negative impacts on the media in the environment from the relevant stages of the project i.e. pre-construction, construction, operations, and decommissioning and reinstatement, and proposes measures for their reduction or mitigation, i.e. improvement of the environment in the Environmental and Social Management Plan.

Keywords: *1st Environmental Impact Assessment (EIA), 2nd gas infrastructure, 3rd potential negative impacts, 4th mitigation measures, 5th decision-making process*

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1. INTRODUCTION

This Study has been prepared in accordance with national Environmental Impact Assessment (EIA) procedures and environmental standards, EU Environmental Impact Assessment (EIA) procedures and environmental standards, and in accordance with the EBRD Performance Requirements (PRs).

In the event that international funding is required for a particular project, the screening phase should be used to categorize the project so as to guide the subsequent EIA process. As this Project involves the funding of isolated sections of the pipeline, which are a greenfield facility, the EBRD has preliminarily assigned it a Category A, and has commissioned an Environmental and Social (E&S) Assessment of the Project. The ESIA process is based on environmental baseline data at an appropriate level of detail. An EIA should be seen as a process that starts at the Conceptual Design Stage of the Project and continues throughout project construction, operation, and decommissioning. It covers all relevant known direct and indirect environmental impacts and risks and foresees appropriate mitigation measures in relevant stages within the Project.

2. OBJECTIVE

An Environmental Impact Assessment (EIA) should be seen as a process that starts at the Conceptual Design Stage of the Project and continues throughout project construction, operation, and decommissioning.

During this process, several deliverables were prepared to guide the activities of the specific stage. During the scoping process potential environmental and social impacts were identified and possible alternatives to the project were evaluated. All reasonable alternatives were assessed according to their impact on the physical, biological and social environment, as well as existing cultural heritage. During the scoping phase, the content and scope of work in this EIA Study and the specialist studies, such as the Biodiversity Impact Assessment Study and Heritage Impact Assessment Study, for the selected final route of the gas pipeline section were determined. The stakeholders were informed about the planning of a Detailed Design and the development of the EIA, and they were also involved within the decision-making process. At the end of the scoping process, as a result of baseline data gathering, the Baseline Report was prepared which is part of the EIA Study. After the scoping process, the possible positive and negative impacts on the environment and society were analyzed and estimated, and the significant impacts from the project implementation were identified. At the end of the EIA process, mitigation measures were proposed that aim to remedy or compensate for the predicted adverse impacts of this Project.

All mitigation measures are towards fulfilling the recommendations of The European Green Deal which responds to these challenges. It is a new growth strategy that aims to transform the EU into a fair and prosperous society, with a modern, resource-efficient, and competitive economy where there are no net emissions of greenhouse gases in 2050 and where economic growth is decoupled from resource use.

3. METHODOLOGY

Applied approach and methodology for EIA Study preparation was as follows:

1. Baseline data gathering. It includes the Screening phase (desktop survey, field survey, and reporting stage) and Scoping phase. The Baseline Report considers the findings of the screening and scoping phases.
2. EIA process
3. Mitigation measures

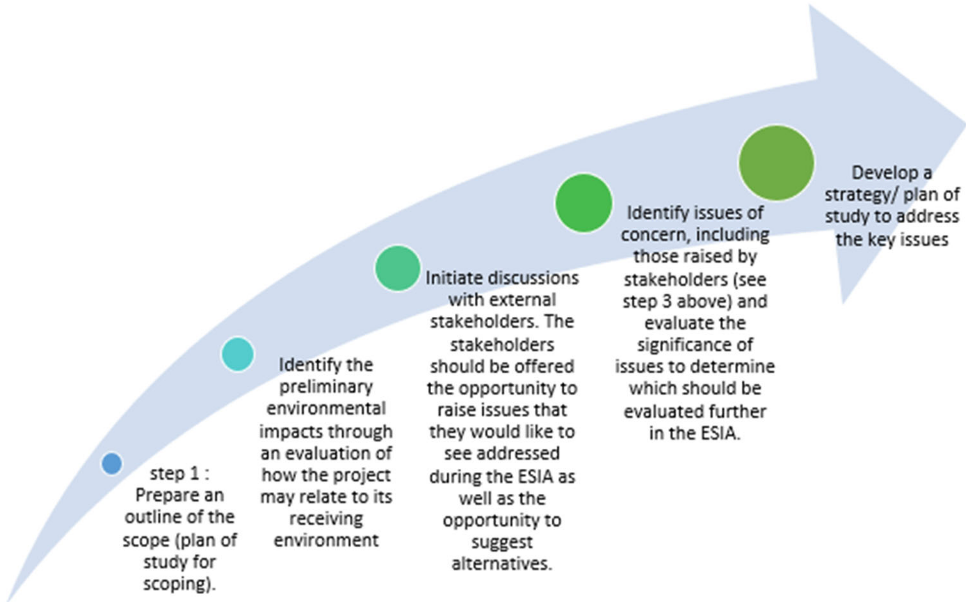

Figure 1. Steps in the scoping phase

The analysis of the environmental impacts and the impacts of the social environment takes into account potential changes in the bio-physical and socio-economic environment (given in the basic data, such as environmental media, demographic characteristics, the data relating to the health aspects of the population that lives and works in the project area, educational facilities, infrastructure, etc.), which may result from the proposed project activities. The level of change determines the significance of the change, which is assessed in terms of type of impact, reversibility, geographic extent, time when the impact occurs, duration, likelihood of occurrence, and intensity or magnitude. The overall rating refers mainly to the changes that are considered significant.

4. TECHNICAL DESCRIPTION

The route of the pipeline begins east of Sveti Nikole and north of the village Erdzelija as attachment after BS2 of the existing pipeline LOT 1 Klechovce Kavadarci continued the south-east of the region of Veles, where ends with Block Station, receptions cleaner station and MMRS Veles.

At the beginning, the Block Station (BS2) was selected at the location of the existing valve block on the gas pipeline DN500 LOT 1 Klechovce - Negotino, which Block Station was constructed specifically for the main gas pipeline in question. Besides the Block Station, at the beginning of the gas pipeline there is an Initial Cleaning Station Sveti Nikole, also at the end of the gas pipeline and in front of MMRS Veles, a Receiving Cleaning Station Veles is planned.

The project will include the following design facilities:

- Main gas pipeline DN 200, Ø 8" with a length of 27.67 km;
- Initial Cleaning Station Sveti Nikole at the beginning of the gas pipeline (km 0);
- Receiving Cleaning Station Veles at the end of the gas pipeline (km 27.5);
- From the gas pipeline, connections are predicted towards Sveti Nikole - DN 80 with a length of 387 m (km 6.39);
- The linear Block Station DN200 is predicted at km 27.5 (BS Veles);
- Block Station DN80 is predicted at the connection to Sveti Nikole;
- Cathodic protection system;
- Main measuring-regulation stations: MMRS Veles (25.000 – m^3/h), MMRS Sveti Nikole (8.000 – m^3/h).

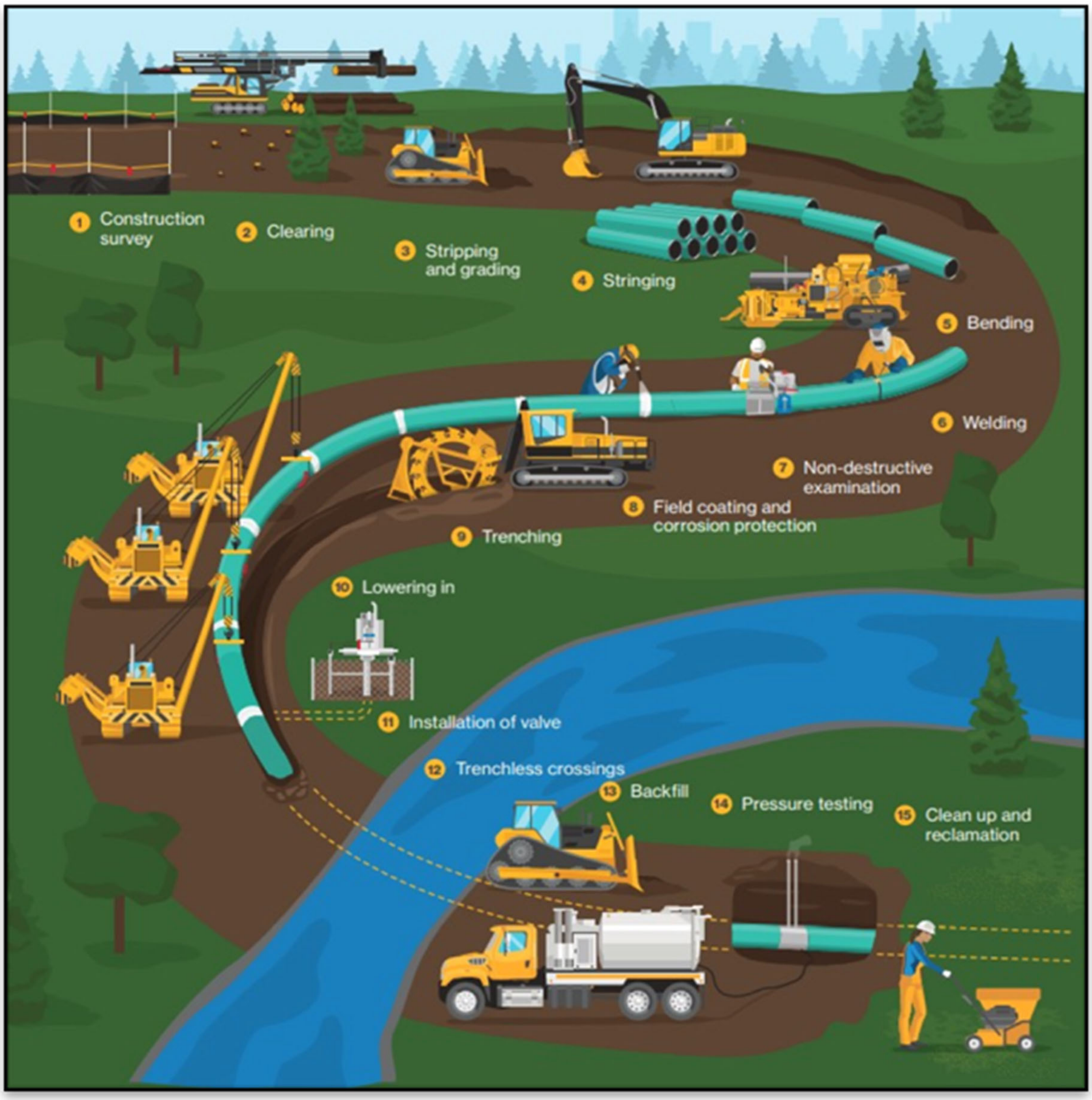

Figure 2. Gas pipeline construction phases

Figure 3. Map of the wider area of the main gas pipeline, Section Sveti Nikole-Veles

5. ENVIRONMENTAL IMPACTS ASSESSMENT AND MITIGATION MEASURES

5.1. Methodology and criteria for impact assessment and proposing mitigation measures

The structure of this chapter is focusing on the potential impacts for each project phase for the following components:

- Soil,
- Surface and groundwater,
- Air,
- Climate change,
- Waste generation,
- Noise and vibration,
- Biodiversity,
- Cultural heritage, and
- Cumulative impacts.

The impact analysis is done for two phases of the project activities:

- The construction phase of the gas pipeline section (which includes the preparatory and constructive phase), and
- The operational phase of the gas pipeline section (or operational phase).

The analysis of the environmental impacts and the impacts of the social environment takes into account potential changes in the bio-physical and socio-economic environment (given in the basic data, such as environmental media, demographic characteristics, the data relating to the health aspects of the population that lives and works in the project area, educational facilities, infrastructure, etc.), which may result from the proposed project activities. The level of change determines the significance of the change, which is assessed in terms of type of impact, reversibility, geographic extent, time when the impact occurs, duration, likelihood of occurrence, and intensity or magnitude. The overall rating refers mainly to the changes that are considered significant.

All identified impacts from the project during the designing and construction phase were taken into consideration in compliance with current standards and using best practice techniques, thus reducing the potential impacts in the construction and operational phase.

Mitigation measures aim to remedy or compensate for the predicted adverse impacts of the Project, and are in response to legal requirements. Mitigation is both a very important principle and practice. It means that the Investor (NER) will do its best to reduce, neutralize and repair the impact of its activities on people and the natural environment. All mitigation efforts should, however, focus first on how to avoid environmental impacts in the initial stages of planning. This has much greater beneficial effect than remedial action later.

5.2. Assessed potential impacts on soil and proposed mitigation measures

Table 1. Soil - Construction phase

Assessed potential impacts
The potential impacts on soil during the gas pipeline construction phase are as follows: - *Change in the soil quality as a result of the introduction (emission) of pollutants that could impair the soil quality;* - *Possible contamination of soil can result in a pollution of ground and surface water through infiltration of pollutants or through their washing from the soil surface by atmospheric water;* - *During the preparation of the terrain, a thorough clearing of the route will be performed, which includes mechanical treatment / excavation of the soil;* - *Destruction of surface fertile soil.* *The significance of the impacts on the soils as a result of possible emissions that could impair the soil quality and destruction of surface fertile soil caused during the construction phase is* ***low to moderate.***
Proposed mitigation measures
In the construction phase, in order to reduce the impacts caused by changes in soil quality as a result of pollution, to take the following measures: - *Careful planning of construction works in order to reduce the negative effects and ensure the prevention of soil pollution;* - *The excavated material, if possible, to be reused in the construction, or to be used as a layer for covering the trenches intended for the pipeline pipes. Excess material to be disposed of at a designated location / landfill designated by the Competent Authority;* - *To make the maximum possible reduction of the size of the construction sites, in order to minimize the land that suffers a negative impact, in order to reduce the destruction of the surface fertile soil;* - *Safe storage of building materials;* - *Vehicles and construction machinery are maintained in good condition to prevent unwanted leaks of fuels, oils and other pollutants;* - *Prohibits servicing of vehicles and machinery along the route of the pipeline. In case of emergency spills of fuels, oils and other harmful substances is mandatory prompt action, remediation of polluted areas and reinstatement in order to protect the soil;* - *In case of leakage of fuels, oils and other pollutants, the contaminated soil layer should be covered with absorbents, collected and disposed of and treated as hazardous waste. The Contractor to conclude a contract with a company authorized for handling hazardous waste that will take it from the site and will act further with it;* - *Refueling should be done in specially designated places away from watercourses. If this is not possible, provide portable tankers for refueling;* - *In case of a breakdown of machinery and transport vehicles, fuels, oils and other pollutants not directly discharged to the ground, but it needs to adequately collect in appropriate containers and removed from the construction site;* - *Placing mobile toilets in certain places on the site and concluding a contract with a licensed company that will install and clean;* - *Construction debris should be regularly removed from the construction site and disposed of at an appropriate landfill.;* - *Proper waste management, as provided in the appropriate subchapter (measures to improve waste management);* - *Thorough cleaning of the construction site and its rehabilitation after the construction works are completed.* *The Measures for prevention of erosion and landslides, as well as the protection of the embankments on watercourses, are given in the technical description, in the separate chapter - A set of erosion protection measures, as follows:* *I. <u>Measures to prevent erosion and landslides</u>* - *For securing the inner side of incisions from drained wastewater and prevention from water concentrated in them, it is required to construct drainage canals and the soil trenches need to have a cross section of not less than 0.02. Drainage canals intersected by the gas pipeline must be reinforced with crushed stone, as well as stone-filled drainage sites;* - *The protection of the inclined plane obtained by making the incision needs to be protected as soon as possible, which would prevent possible erosion caused by surface water;* - *The passages of the gas pipeline through ravines and ditches should be filled with mineral soil with appropriate consolidation, the leveled surface should be reinforced by sowing a permanent layer of plant soil. Within the boundaries of parts of active erosion of gorges and ravines should be performed protection of the incline surface by sowing grass. Within the boundaries of certain parts, appropriate partitions are constructed that prevent the occurrence of undermining of the ground, i.e. the occurrence of erosion;* *II. <u>Protection of embankments on watercourses</u>* - *When overcoming water obstacles, it is necessary to protect embankments as follows:* • *at the bottom of the riverbed:*   - *Laying gabions*   - *Filled with stone. The choice of size and weight of the stone should depend on the speed of the water* • *protection on the outside of embankments and slopes above the level protected by stone filling must be carried out with soil and plant it to grasslands;* *Riverbeds of permanent and occasional water flows, streams, canals and ditches with water velocities greater than 0.6-0.7 m/s need to be renewed and strengthened after the construction works.*

Table 2. Soil - Operational phase

Assessed potential impacts
In normal operation of the pipeline is not expected to have impacts on soil. If defects occur in the underground part of the pipeline, the reconstruction activities will be the same as the construction activities in the construction phase. *In such a case, during the intervention of fault repair of underground facilities can lead to unwanted spillage of oils, fats and fuels from construction machinery and transport vehicles to be used on soils. In this case, a quick reaction is needed, which would collect all the toxic substances, which would not allow them to enter the soil, and thus the groundwater.* *The significance of the impacts on soils as a result of possible soil emissions caused during the exploitation phase is* ***low.***
Proposed mitigation measures
In case of leakage or damage to the underground part of the pipeline, reconstruction works will be performed to repair or replace the damaged part of the pipeline. These reconstruction works are the same as construction works in the construction phase and accordingly, such impacts on the soil will be created. It is necessary to take appropriate measures as in the construction phase.

5.3. Assessed potential impacts on surface and groundwater and proposed mitigation measures

Table 3. Surface and groundwater - Construction phase

Assessed potential impacts
The potential impact on water (surface water and groundwater) during the gas pipeline construction phase is change in the surface and groundwater water quality as a result of pollution with pollutants. *The significance of the impacts on water due to emissions in surface water or soil and indirectly in groundwater, caused in the construction phase is* ***low to moderate.***
Proposed mitigation measures
For the purposes of reducing the impact on the quality of the surface and groundwater as a result of the pollution caused by various pollutants, it is necessary to undertake the following measures: - *To set up mobile toilets in certain places on the site and to conclude a contract with a licensed company that will install and clean them;* - *To stop construction activities in case of unwanted spills of oils, fats and fuels on the soils, sprinkle with sand and remove of the contaminated soil layer, in order not to infiltrate the contaminants in the soil and reach the groundwater. Contaminated soil layer to be treated as hazardous waste;* - *To use the technical water for the sprayers for dust reduction with appropriate quality and sufficient quantity;* - *Washing of construction machinery should be done at a suitable location, outside the construction site;* - *Refueling in trucks and construction machinery, oil replacement and other things related to truck maintenance and machinery is prohibited in an area of 50 m on both sides of watercourses to which the route of the pipeline is approached or bridged;* - *Implementing measures to improve waste management;* - *The Contractor to provide water quality measurements, before and during the construction phase;* - *Crossing under rivers will be done by digging the bed of the watercourse, taking into account the results of geological investigations. The project elevation of the upper edge of the pipeline is more than 1.50 m below the river bottom;* - *If during the construction of the gas pipeline under the rivers is necessary to temporarily divert the rivers of Svetinikolska River and Sariderska River to carry out dry excavation, in order to prevent soaking and cleaning of the pipes, there will be a change in the hydrological regime, the erosive processes and turbidity of rivers, and the migration of river fauna (fish of other freshwater species) will be disrupted;* - *To prevent turbidity of the surface watercourses under which the route will pass, it will be necessary to install straw bales that will serve as a filter for purification of wastewater from digging;* - *When overcoming water obstacles, it is necessary to protect embankments as follows:* • *at the bottom of the riverbed:* - *Laying gabions* - *Filled with stone. The choice of size and weight of the stone should depend on the speed of the water* • *protection on the outside of embankments and slopes above the level protected by stone filling must be carried out with soil and plant it to grasslands;* - *Riverbeds of permanent and occasional water flows, streams, canals and ditches with water velocities greater than 0.6-0.7 m/s need to be renewed and strengthened after the construction works;* - *If the flow of the riverbed is diverted, it can be done with the help of dams or with the use of pumps. In both cases it is necessary:* - *Works to be performed in the summer and on dry days* - *Previously to get approval from authorities* - *The duration of deviations should be limited to the shortest possible time so as not to disturb the aquatic ecosystem and the migration of species across the river;* - *Riverbeds of permanent and occasional water flows, streams, canals and ditches with water velocities greater than 0.6-0.7 m/s need to be renewed and strengthened after the construction works;* - *In situations where the pipeline section crossess the small water channels the Constructor should install concrete pipe culverts for smooth water permeability during the construction and for movement of construction machinery. After the completition of the construction works these concrete pipe culverts should be removed from the site;* - *To perform the hydro test, the Contractor must:*

- *Provide water of adequate quality (in accordance with current standards). Potable water is widely accepted as hydro test water for steel pipes, provided the water is not recycled for other hydrotest and limited time of residence water within pipeline and vessel under test;* - *If the Contractor cannot provide sufficient amount of potable water for the hydro test, then the water that will be used for hydro test must be chemically treated to ensure its adequate quality. It is recommended to use as cleanest water as possible - demineralized, steam condensate, or potable treated;* - *In order to minimize the water intake, it is necessary the Contractor to use appropriate amount of water (the required quantities to be calculated and defined within the Procedures for Construction);* - *The Contractor is required to conduct a wastewater quality examination and, depending on the result, primarily to ensure its reuse for the same purpose, or, if necessary, to treat it first to ensure adequate water quality for conducting a hydro test, and then to ensure its reuse. The Contractor should provide wastewater quality examination, and if it is necessary to treat the wastewater its treatment as well, by an accredited laboratory.*

Table 4. Surface and groundwater - Operational phase

Assessed potential impacts
During the operational phase of the gas pipeline system, impacts on surface and groundwater are not expected, except in case of accident / pipeline failure. In such a case, during the intervention to eliminate the defect of the underground facilities, there may be an unwanted spill of oils, fats and fuels from the construction machinery and transport vehicles that will be used, on the soils and indirectly in the groundwater. In this case, a quick reaction is needed, which would include collection of all the toxic substances, in order not to enter the soil, and thus in the groundwater as well. *The significance of impacts on water as a result of possible emissions into soil and indirectly underground water caused in the exploitation phase is* ***low to moderate.***
Proposed mitigation measures
During the regular operation of the gas pipeline system, no impacts on surface and groundwater are expected. If during an accident/defect of the pipeline, there is an unwanted leakage of oils, fats and fuels from the construction machinery and transport vehicles that will be used, then in order to protect the soil and groundwater from potential contamination, the following measure should be applied: *To stop construction activities in case of unwanted spills of oils, fats and fuels on the soils, sprinkle with sand and remove of the contaminated soil layer, in order not to infiltrate the contaminants in the soil and reach the groundwater. Contaminated soil layer to be treated as hazardous waste.*

5.4. Assessed potential impacts on air and proposed mitigation measures

Table 5. Air - Construction phase

Assessed potential impacts
The potential impacts on the air during the gas pipeline section construction phase are as follows: - *Occurrence of fugitive dust emissions from clearing the terrain and cleaning of greenery (trees and shrubs), loading and transport of waste;* - *Occurrence of fugitive dust emission during loading and unloading of construction materials, soil waste;* - *Exhaust emissions from construction machinery and transport vehicles.* *The significance of the effect - air pollution due to emission of pollutants caused by construction activity is* ***low to moderate.***
Proposed mitigation measures
The following measures, proposed for the purposes of mitigating the environmental impact, can reduce the air pollution during the construction phase of the gas pipeline: *Measures for exhaust gas reduction:* - *Use of proper construction machinery and transport vehicles with the declared emission of exhaust gases determined during their homologation;* - *Use of standardized fuels for mechanization and shutdown of mechanization engines when not in use.* *Dust reduction measures:* - *During dry periods to carry out spraying locations susceptible to emissions of fugitive dust with technical water. For this purpose, use sprayers that do not contain chemicals, and are water-based;* - *Limiting the speed of vehicles on the construction site;* - *Vehicles that will transport aggregate material and excavated soil to be permanently covered;* - *Route planning, loading and unloading factors are of great importance in reducing fuel consumption and exhaust emissions and fugitive dust emissions.*

Table 6. Air - Operational phase

Assessed potential impacts
All the possible emissions and impacts that may occur during the operational phase of the gas pipeline section are in case of malfunctions and accidents of pipeline component as follows: - *Operational emission: air emissions from normal or planned operating activities where small volumes of natural gas is possible to be released to the atmosphere from the gas network components;* - *Fugitive emissions:* 1. *Fugitive emissions from permeation of pipelines;*

2. Fugitive emissions due to connections (flanges, pipe equipment, valves, joints, seals, etc.). - *Vented emissions which are usually identified during commissioning, decommissioning, renewal and maintenance of pipeline systems, regular emissions of technical devices and emissions from start-stop operations;* - *Regular emissions of technical devices i.e., from combustion of gas in boilers located in the Main measuring - regulation station (MMRS).* *The significance of the impact on air due to emission of pollutants caused in the phase of construction is* ***low to moderate.***
Proposed mitigation measures
In the phase of normal operation of the pipeline does not expect negative impacts on air. Only in case of leakage or damage to the underground part of the pipeline, reconstruction works will be performed to repair or replace the damaged part of the pipeline, which are the same as the construction works in the constructive phase. *Measures that should be taken into account to reduce fugitive emissions along the pipeline in operational phase refer to:* - *The selected equipment and design of the compressor station and metering stations to be in compliant with Best Available Techniques (BAT);* - *Make sure that valves and flanges are installed correctly;* - *Establish and follow a valve and flanges preventive maintenance program;* - *Replace old, outdated valves and flanges;* - *Install low emissions valve packing;* - *Install monitoring system for leaks;* - *Replace high-bleed pneumatic devices with low-bleed ones;* - *Implement a directed inspection and maintenance (DI&M) program at compressor stations.*

5.5. Assessed potential impacts on climate change and proposed mitigation measures

Table 7. Climate change - Construction phase

Assessed potential impacts
The potential impacts on the climate change during the construction phase of the gas pipeline section are as follows: - *Impact on the local microclimate;* - *Greenhouse gas emission from the operation of the construction machinery, equipment and transport vehicles;* - *Greenhouse gases from waste biomass.* *The significance of the impacts on climate change during the construction phase of the gas pipeline section is* ***insignificant to low.***
Proposed mitigation measures
During the construction phase, for the purposes of reducing the greenhouse gas emission from the work related to the construction machinery, equipment and transport vehicles, it is necessary to undertake the following measures: - *Application of good construction practices for a more efficient performance of the construction works, thereby reducing the fuel consumption and the greenhouse gas emission;* - *Using proper construction machinery, equipment and transport vehicles for the purposes of avoiding any increase in the fuel consumption, thereby also preventing any increase in the greenhouse gas emission.*

Table 8. Climate change - Operational phase

Assessed potential impacts
The potential impacts on the climate change during the operational phase of the gas pipeline are fugitive emissions which are as a result of leaks through the safety and exhaust valves, as well as a result of gas leakage situations due to the violation of the impermeability of the pipeline. *The significance of the impacts on climate change during the operational phase is* ***low.***
Proposed mitigation measures
During the operational phase, it will be required to conduct a regular control of the safety devices for overpressure relief, whereby natural gas discharge will be reduced. Furthermore, it is necessary to conduct regular control of the impermeability of the gas pipeline in order to minimize any undesired natural gas discharge into the atmosphere.

5.6. Assessed potential impacts from waste generation and proposed mitigation measures

Table 9. Waste generation - Construction phase

Assessed potential impacts
The potential impacts by waste generation during the construction phase of the gas pipeline section is from the following types of waste: - *Municipal waste;* - *Excess of excavated soil and sand;* - *Biodegradable waste;* - *Packaging waste;* - *Construction and demolition waste;* - *Remains of steel pipes;* - *Insignificant amounts of certain fractions of hazardous waste.* *The significance of the impacts from the generated waste on all media, caused in the construction phase is* ***moderate.***

Proposed mitigation measures
In order to improve the manner of waste management during the construction phase, in accordance with the legislation in the field of waste management, the following measures are recommended: - *Prepare a Waste Management Plan (WMP);* - *It is recommended that the inert waste will be stored at a landfill for such waste, the location of which will be determined in advance (as a possibility for the existing landfill for this type of waste to occur, or if it exists at all) manages a company for handling this type of waste, with which the Contractor of the construction activities will conclude a Contract;* - *The humus that will be removed in the thickness indicated in the project should be stored in a temporary landfill for usable material, from where it will be used in the finishing works to arrange the space of the location. The excavation of the humus should be done in favorable weather conditions, when it is not raining. It is necessary for the Operator, i.e. the Contractor of the construction activities to take care that the humus is left in a special place and to be secured from disintegration and contamination so that it can be used in the final arrangement of the space;* - *The packaging of the materials that will be used in this phase should be properly selected depending on their composition (cardboard, paper, plastic, metal, biodegradable waste, etc.) and the selection to be made at certain locations along the route, fenced, protected from external influences and adapted for storage of this type of waste. Authorized company, with which the Contractor of the construction activities will conclude a Contract, should perform their regular raising and removal;* - *As for the plastic packaging of motor oils, which is hazardous waste, it is recommended that it will be temporarily stored in a specially designated place for this type of waste and that the Contractor conclude a contract with a company authorized to handle hazardous waste to take over the site and will deal with it further. This company will have to take over and continue to deal with possibly removed contaminated soil layer with oils, fats and fuels, in case of their spill into the soil;* - *When changing the engine oil, as hazardous liquid waste, it is necessary to store the used oil in separate cans and store it until it is purchased by authorized companies, which would perform their further recycling;* - *Metal waste to be sold to purchasing companies;* - *The felled trees and biodegradable waste to be offered to the local population for heating, construction activities or as a basis for composting.*

Table 10. Waste generation - Operational phase

Assessed potential impacts
The potential impacts by waste generation during the operational phase of the gas pipeline section is from the following types of waste: - *Biodegradable waste from the maintenance of the route;* - *Waste spare parts linings and paints for maintenance of above-ground and underground facilities;* - *Waste generated in the event of failure of underground pipeline.* *The significance of the impacts by waste generation during the operational phase is* ***low.***
Proposed mitigation measures
In order to improve the manner of waste management during the operational phase, the following measures are recommended: - *The vegetation waste should be treated in the same way as during the clearing of the vegetation during the construction phase;* - *The waste that will be created from the intervention of the overhead parts of the gas pipeline (waste spare parts from the Block Stations, etc.) to be disposed of at the municipal landfill;* - *In case of leakage or damage to the underground part of the pipeline, construction works will be performed to repair or replace the damaged part of the pipeline and the generated waste should be treated the same as in the construction phase;* - *Do not dispose waste near watercourses such as rivers Svetinikolska River and Sariderska River.*

5.7. Assessed potential impacts from generation of noise and vibration and proposed mitigation measures

Table 11. Noise and vibration - Construction phase

Assessed potential impacts
The potential impacts from noise during the gas pipeline construction phase will occur as a result of the work of construction machinery, transport vehicles that will be engaged, as well as the equipment used on construction sites. *The significance of the impact - increased noise, vibration and non-ionizing radiation in the construction phase is* ***low to moderate.***
Proposed mitigation measures
The mitigation measures for the impacts caused by noise and vibration during the construction phase comprise the following: - *Careful planning of construction activities (to take place only during the day from 7am to 5pm and with a certain time dynamics) and application of the principles of good construction practice which practically means efficient operation and shortening the duration of construction activities, accompanied by increased noise, as little as possible, so that these negative impacts are as short as possible;* - *Control of construction methods, used mechanization and regular maintenance of equipment in order to minimize possible noise levels (avoid equipment that emits noise above 90 dB) and use sophisticated equipment;*

- *Use of modern "quiet" work equipment that meets the requirements of Directive 2000/14/EC of the European Union on the emission of noise from the use of work equipment in outdoor conditions;* - *Proper maintenance of compressors, ventilation fans with their lubrication and installation of parts for sound deadening;* - *Turn off the construction machinery when not in use;* - *Avoiding the use of loud beeps and restricting the speed of vehicles carrying some building materials and equipment;* - *Activities such as demolition, excavation and operations affecting the terrain to plan not occur in the same time period. Unlike noise produced total level of vibration can be significantly less when every source of vibration is separate;* - *Monitoring vibrations during the performance of critical business processes. In case of damage to nearby buildings as a result of vibrations created by construction works, the damaged buildings should be repaired or compensation should be paid.;* - *The surrounding population should be informed about the activities that will generate noise, in order to reduce the anxiety of the people;* - *Workers who operate equipment that generates noise levels greater than 80 dBA permanently within 8 hours or more should use earmuffs.*

Table 12. Noise and vibration - Operational phase

Assessed potential impacts
The potential impacts by noise and vibrations during the operational phase of the gas pipeline are not expected to occur in normal operation. In case of leakage or damage to the underground part of the pipeline, construction works will be performed to repair or replace the damaged part of the pipeline. In that case, the construction activities are the same as the activities in the construction phase. *The significance of the impact - increased noise, vibrations and non-ionizing radiation in the operational phase is **low.***
Proposed mitigation measures
In case of leakage or damage to the underground part of the pipeline, construction works will be performed to repair or replace the damaged part of the pipeline. These construction works are the same as in the construction phase and accordingly, they will create such noise and vibration. It is necessary to take appropriate measures as in the construction phase.

5.8. Assessed potential impacts on biodiversity and proposed mitigation measures

Table 13. Biodiversity - Construction and Operational phase

Assessed potential impacts
The potential impacts on biodiversity are as follows: *IMPACTS ON THE HABITATS* *Construction phase:* - *habitat loss (direct destruction) – **low to moderate significance*** *Operational phase:* - *habitat fragmentation – **low significance*** *IMPACTS ON FLORA AND FAUNA* *Construction phase:* - *Disruption of the nesting cycle (birds) – **moderate significance*** - *Alteration, impairment or destruction of the habitat of amphibians and reptiles – **low significance*** *Operational phase:* - *Access to natural resources – **insignificant*** *IMPACTS ON PROTECTED AND DESIGNATED AREAS* *Construction phase:* - *Impact on habitat fragmentation and bird disturbance – **low to moderate significance*** *Operational phase:* - *Impact on habitat fragmentation and bird disturbance – **insignificant*** *IMPACTS ON BIOCORRIDORS* *The gas pipeline route does not intersect with any of the core areas, but it does cross the steppe like corridor Ivankovci-Karatmanovo.* *IMPACTS ON CRITICAL HABITATS* *Construction impacts to CH (pseudo-steppe) may impact 1.63 ha, which represents ≈ 0.006% of the habitat's EAAA (25,225 ha). This impact is not considered likely to compromise the habitat's integrity across the EAAA given the relatively small area.* *There are no global estimates for 6220* available, but the habitat occurs mainly in Europe. European estimate (EU only) of 6220* – 706,122 ha. Mediterranean estimate (EU only) – 693,747 ha (98% of EU total), there is no National estimate of 6220*. Habitat of pseudo-steppe vegetation in AoI is approximately 1.63 ha, which is 0.2% of the European estimate. This impact is not considered likely to compromise the habitat's integrity. The impact magnitude is therefore considered to be low.* *Considering the very high sensitivity attributed to the pseudo-steppe EAAAs and the low impact magnitude expected, the overall significance to this habitat will be **moderate.*** *IMPACTS ON PRIORITY BIODIVERSITY FEATURES* *Construction impacts to hill pastures and riparian belt (PBF) are expected to result in a loss of 18.5 ha, which represents ≈ 0.4% of the habitat's EAAA. This impact is not considered likely to compromise the integrity of habitat across the EAAA given these low losses. The impact magnitude to this PBF is therefore considered to be low.*

Considering the high sensitivity attributed to the hill pastures EAAAs and the low impact magnitude expected, the overall significance to this habitat will be low.
Construction impacts to riparian willow belts (PBF) are expected to have impact of 1.65 ha, which represents ≈ 0.1% of the habitat's EAAA. This impact is not considered likely to compromise the integrity of habitat across the EAAA given these relatively low losses. The impact magnitude to this PBF is therefore considered to be low.
Considering the high sensitivity attributed to the riparian belt EAAAs and the low impact magnitude expected, the overall significance to this habitat will be ***low.***
9 species were assessed as being Priority Biodiversity features in line with PR6. Impacts identified include direct mortality from the construction works, from fragmentation of habitats, visual and noise disturbance and impacts from pollution.

Proposed mitigation measures

I. Pre-construction phase
Before the start of the construction activities the route must be fully surveyed for the up-to-date baseline condition and to identify the presence / potential presence of notable species.
SPECIFIC MITIGATION FOR PBF/CH HABITATS
- *Pseudo-steppe with grasses and annuals of the Thero-Brachypodietea Grasslands & Hill Pastures with Sparse Shrubs*

Pre-construction surveys in Spring to Autumn will determine/confirm the extent of these habitats.
Because it is habitat with grass (steppe vegetation), after construction it is best to be left on the natural regeneration - local species of steppe plants to settle instead to be planted by the man.
- *Riparian Willow - Poplar belts*

There would be re-planting of scrub in some areas or vegetation would be allowed to colonize naturally as appropriate. All riparian works and river crossing should follow the prescriptions of the water chapter of the ESIA.
SPECIFIC MITIGATION FOR PBF ANIMAL SPECIES
- *Agile Frog (Rana dalmatina)*

If the ponds are to be destroyed, drainage should be conducted via pumping with a suitable pump filter (to prevent animals and debris being drawn into the pump).
Translocation of amphibians away from works area. All animals present within the pond should be moved to appropriate habitats away from the works. If possible, pond drainage should be avoided April-September. The translocation of specimens identified in work zone into favorable habitat areas identified adjacent to the works. Checks to be conducted by Biodiversity Specialists ahead of the excavation. Routes will be maintained properly in order to avoid creation of puddles capable of attracting amphibians; Conduct standard measures to limit water pollution and soil.
- *Yellow-Bellied Toad (Bombina variegata)*

Identification and mapping of areas occupied by this species prior to the commencement of clearance. River drainage to be avoided April-September where possible. Checks to be conducted by Biodiversity Specialist ahead of excavation. the active working corridors will be maintained properly in order to avoid creation of puddles capable of attracting amphibians; Conduct standard measures to limit water pollution.
Prohibition of access to Nezirlik Ardi of all workers.
- *European Pond Turtle (Emys orbicularis)*

The working areas should be carefully searched by the Biodiversity Specialist prior to the commencement of the work; any individuals found to be carefully transported outside risk areas in habitats matching their ecological requirements; any individuals found on site to be relocated to favorable habitats.
- *Common tortoise (Testudo graeca) and Hermann's Tortoise (Testudo hermanni)*

A morning trench check should be performed, if trapped tortoises are found, a ramp should be installed within open trenches to allow these species to escape.
- *Imperial eagle (Aquila helica) and Egyptian vulture (Neophron perconopterus)*

Given that the pipeline is envisaged to traverse the feeding habitats of all three bird species and that it is in close proximity to a handful of established nests of Eastern Imperial Eagles, it is imperative to monitor the impact of disturbance and potential changes to feeding areas for the priority species during the breeding season (from March till September for the Lesser Kestrel and the Egyptian Vulture), and throughout the year for the Eastern Imperial Eagles (juveniles and immature birds tend to stay close to their nests all over the year before undertaking any migration route). This monitoring ought to be implemented in the entire area of Ovche Pole IBA, and it should survey nesting territories (occupancy, breeding success) and feeding range (especially if there are any changes).
Felling of trees should be undertaken between September and February inclusive, felling of trees during the breeding bird season (March to August inclusive is to be avoided). Noisy work (i.e. hammering is not permitted in these areas from March to August inclusive). Dead wood should be retained on site. RoW to be permitted to be colonized naturally.
Check for nest must be done prior to construction work.

II. Construction phase
- *Prohibition of access to Nezirlik Ardi (near km 21+500.00)*
- *Plan to avoid disturbing pseudo-steppe habitat EUNIS Code E1.3, N2000 code 6220* at Kanda Geoglyph (near km 8+000.00)*

As a general rule, traditional extensive management systems aimed at maintaining a mosaic-like landscape pattern are suitable for most plant and animal species linked to the 6220 habitat type (González & San Miguel 2004, Pardini et al. 2004, Alrababah et al. 2007).*
During operational phase NER have a responsibility to ensure it doesn't cause further harm to the environment. Leaks, emissions, and other damage from pipelines can destroy vegetation, harm local wildlife, and add to local water and air pollution levels. Operators can help avoid these issues by strict inspection and maintenance routines.
- *River protection measures for all stream crossings*

In order to preserve the riverine and aquatic habitats, and maintain water quality in the river as far as possible, the following provisions should be included in the construction contract documentation:
- *No access or works in any river channel or dry watercourse unless absolutely necessary to construct the works;*

- *No parking or storage of any equipment within 100 m of river channels or dry watercourses;*
- *Stabilize construction entrance to prevent the transport of sediment from the work site;*
- *Preparation of the Revegetation and Rehabilitation Plan of riverine habitat;*
- *Revegetation to be conducted with willow and poplar trees which are an effective ecological restoration, in both structure and function to stop erosion processes of the riverbed slopes;*
- *River flow must be maintained at all times. If access is required to the flow channel, measures should be taken to divert the flow in order to bypass the works;*
- *No storage or discharge of any wastewater, effluent, excavation soil or any other material may be made to the river channels or watercourses;*
- *All measurements given in the Detailed Design, in order to prevent any kind of possible pollution of the riverbeds and contact with groundwater, should be fully respected and implemented during construction;*
- *Contractor should be prepared for unlike events like fires; and*
- *Any incident pollution event in the watercourses that could be made by the Contractor, will be supervised by PIU/Supervising Engineer and MoEPP.*

The Contractor should be required to prepare a detailed method statement for working in all watercourses, for approval by the PIU/Supervising Engineer.

In addition, a Biodiversity Specialist should be engaged to monitor the vegetation clearance/excavation works. The Biodiversity Specialist should supervise a pre-construction clearance of any mobile animals (e.g. tortoises) which should occur immediately before the beginning of the construction activities in the area.

The success of these measures will be captured through ongoing water quality monitoring.

- *Protection measures at IBA*

As noted, the IBA is important for trigger species. In order to minimize damage to nesting birds at the IBA, the Contractor should follow these activities along this stretch:

- *Engaging experienced ornithologist to monitor;*
- *Construction work to be done from September till May (to avoid breeding period);*
- *Prohibition of removal of vegetation during the breeding period of Imperial Eagle in the spring, from the end of May to the middle of June;*
- *No entering of any forested areas except those strictly necessary for construction of the permanent works;*
- *No clearing any forest vegetation except within the working corridor;*
- *No excavating any material for fill or aggregate, or any other purpose except within the corridor of the permanent works; and*
- *Not allowing construction workers to enter the forested areas for any purpose, or to search for nests or eggs.*

III. Operational phase

- *Rehabilitation and restoration measures*

Rehabilitation and restoration actions are taken to assist in the recovery of a feature that has been degraded, damaged, or destroyed.

- *Rehabilitation at river crossings, especially Svetinikolska River crossing*

Once the construction works in the river channels are complete, the areas should be rehabilitated by the placement of soil, willow/poplar trees to allow regrowth of natural vegetation. The assistance of Botanical Specialists and a Forestry Expert should be sought to guide the rehabilitation works.

The area should be monitored quarterly following site handover, to establish whether regrowth of vegetation is occurring. If not, additional measures: seeding, transplanting of saplings, import of additional topsoil, etc. should be taken to encourage regrowth of riverine vegetation.

Afforestation activities to be performed in line with the No net loss principle, i.e. preparation of LALRP. Riparian vegetation along the Svetinikolska River to be restored, in order to achieve No Net Loss.

Re-planting of the PBF riparian habitats will take place within and around the EAAAs (cannot be re-planted directly on top of the pipeline for safety reasons). The materials required for replanting will be included in the Bill of Quantities. The land required for replanting will be secured by NER, and will be maintained as the specified habitat type in the long-term (i.e. for the lifetime of the Project), through commitments secured from the landowners by NER. The Detailed Design will include sufficient land for revegetation at a minimum of 2:1 revegetation ratio. This includes Priority Biodiversity Feature species.

- *Rehabilitation at other areas*

The Contractor should consult Public Enterprise ''Nacionalni Shumi'' for the trees from field-protective belts in the vicinity of Sveti Nikole that will be removed. Due to their ecosystem services, these belts need to rehabilitated.

All other areas where vegetation was cleared, should be soiled and rehabilitated by planting with appropriate native vegetation or left for natural regrow (especially at certain location as mentioned above). Area should be monitored quarterly for following site handover, to establish whether regrowth of vegetation is occurring. If not, additional measures: seeding, transplanting of saplings, import of additional topsoil, etc. should be taken to encourage regrowth of vegetation.

A Biodiversity Specialist should oversee this.

- *Plan to control invasive species*

Within the expropriation area, all individual trees and saplings of Robinia pseudoacacia will be located and cut, with the stumps killed. Fallen trunks and branches will not be removed, to provide micro-habitats to specialized species. This work will be overseen by a Biodiversity Specialist. When cutting trees, the best season to do so is in August which gave the lowest volume of sprouts.

The tree of heaven (Ailanthus altissima) and the indigo bush (Amorpha fruticosa) were also observed along the pipeline corridor.

Invasive Ailanthus altissima trees (including saplings) should be eliminated (uprooting all individuals) when clearing vegetation prior to construction works. Indigo bush (Amorpha fruticosa) can be controlled by repeated defoliation and digging and severing the root 3 to 4 inches below the crown.

Monitoring post-construction by NER will ensure that newly restored areas are not inundated with non-native species from adjacent areas.

5.9. Assessed potential impacts on archaeological and cultural-historical heritage and proposed mitigation measures

Table 14. Cultural heritage - Construction phase

Assessed potential impacts
The potential impacts on cultural heritage during the gas pipeline section construction phase are as follows: *IMPACTS ON CHANCE FINDS AND KNOWN ARCHAEOLOGICAL SITES* - *Potential Loss or Partial Damage to Chance finds and Undiscovered Below-Ground Heritage Assets as a result of the construction activities –* ***moderate significance*** - *Potential Loss and Partial Damage to known archaeological sites as a result of the construction activities –* ***moderate significance*** - *Access to the archaeological sites –* ***insignificant*** *IMPACTS ON BUILDINGS AND COMPLEXES WITH CULTURAL HERITAGE VALUE* - *Potential Loss or Partial Damage to the Buildings and cultural heritage Complexes in the AoI of the projected gas pipeline –* ***insignificant*** - *Access to the cultural buildings and complexes –* ***insignificant*** *IMPACTS ON CULTURAL LANDSCAPES* - *Partial Defragmentation of the integrity of the visual effects, of the cultural landscapes- Change in the elements, characteristics, character, and qualities of the landscape as a result of development –* ***moderate significance*** - *Deteriorated panoramic views of the cultural heritage monuments –* ***low significance*** *IMPACTS ON INTANGIBLE CULTURAL HERITAGE AND ASSOCIATIONS* - *Potential Loss or Partial Loss to the intangible cultural heritage and associations (religious rites, tradition, living cultural heritage) in the AoI of the projected gas pipeline –* ***insignificant*** - *Access to the churches and church complexes for religious rites and traditions –* ***insignificant***
Proposed mitigation measures
In the pre-construction and constructive phase, in order to reduce the impacts caused by potential loss or partial damage to chance finds and known archaeological sites, the following measures will be implemented: - *Before the construction of the gas pipeline section, qualified Cultural Heritage Expert team from authorized institution to make survey of the planned route of the gas pipeline section (as stated in the Report No. 08-73/3 from 25th March 2021 from the National Conservation Center of Cultural Heritage-Skopje, North Macedonia);* - *Qualified Cultural Heritage Expert from authorized institution to be present during the construction activities, especially during the activities near the archeological site Kula (km 24+000.00) which is placed on the route of the planned gas pipeline (according to Report No. 08-73/3 from 25th March 2021 from the National Conservation Center of Cultural Heritage-Skopje, North Macedonia);* - *Careful planning of construction works in order to reduce the negative effects and ensure the prevention of damage of the chance finds and known archaeological sites;* - *To make the maximum possible reduction of the size of the construction sites, so the negative impact will be minimized, in order to reduce the loss or partial damage to chance finds and known archaeological sites;* - *To make demarcation of known archaeological sites as required, to avoid indirect disturbance;* - *To develop a Plan for Protection of Cultural Heritage;* - *To make the maximum possible reduction of vehicle and machinery activities, as limited to the areas that have been subject to heritage clearance or previous disturbance;* - *To make the maximum possible reduction of earthworks in the AoI, as limited to the areas that have been subject to clearance or previous disturbance;* - *Workers should undergo basic training on the procedure for the cultural value of the AoI and the region, in order to identify the chance finds and archeological sites assets during the construction works;* - *Implementation of the Law on Protection of Cultural Heritage ("Official Gazette of the Republic of Macedonia" No. 20/04, 71/04, 115/07, 18/11, 148/11, 23/13, 137/13, 164/13, 38/14, 44/14, 199/14, 104/15, 154/15, 192/15, 39/16, and 11/18), Article 49-a, related to management of monumental units and cultural landscapes (in accordance with the Macedonian legislation and EBRD PR8 requirements).* *In order to reduce the impacts caused by potential loss or partial damage to buildings and complexes in the AoI of the projected gas pipeline section to take the following measures:* - *Careful planning of construction works in order to reduce the negative effects and ensure the prevention of damage of the buildings and complexes;* - *To make the maximum possible reduction of the size of the construction sites, so the negative impact of the cultural heritage assets that suffers will be minimized, in order to reduce the loss or partial damage to buildings and complexes with cultural value;* - *To make demarcation of cultural heritage sites as required, to avoid indirect disturbance;* - *Qualified Cultural Heritage Expert from authorized institution to be present during the construction phase;* - *To make the maximum possible reduction of vehicle and machinery activities, as limited to the areas that have been subject to heritage clearance or previous disturbance;* - *To make maximum possible reduction of generation of dust and vibration by operation of heavy machinery, to make ongoing monitoring of dust and vibration levels and inspection of heritage places in proximity;*

- Implementation of the Law on Protection of Cultural Heritage ("Official Gazette of the Republic of Macedonia" No. 20/04, 71/04, 115/07, 18/11, 148/11, 23/13, 137/13, 164/13, 38/14, 44/14, 199/14, 104/15, 154/15, 192/15, 39/16, and 11/18), Article 49-a, related to management of monumental units and cultural landscapes (in accordance with the Macedonian legislation and EBRD PR8 requirements); *- Workers should undergo basic training on the procedure for the cultural value of the AoI and the region, in order to identify the cultural heritage assets during the construction works.* *For prevention and reduction of negative effects with the appearance of the gas pipeline section in the line of the view and to reduce the impacts caused on cultural landscapes in the AoI of the projected gas pipeline section the following measures will be implemented:* *- Low-profile constructions, use of environmental coloration or advanced camouflage techniques to limit visual effects, screening, proper sighting and location to maximize the use of topography and vegetation;* *- The alternative route is analyzed as to make less impact on the cultural landscape;* *- Careful planning of construction works in order to reduce the negative effects and ensure the prevention of the loss and defragmentation of the visual effects on the cultural landscapes;* *- Workers should undergo basic training on the procedure for the cultural value near the AoI and the region, in order to identify the cultural heritage assets and landscapes during the construction works;* *- After the construction, to carry out the activities for rehabilitation of the site, excavations, sand loans and access roads, by planting grass and trees or other appropriate measures;* *- Implementation of the Macedonian legislation and EBRD PR8 requirements.* *During the pre-construction and constructive phase, the responsible persons should take care to give clear instructions to the involved workers, on how to behave towards tradition, religious rites and living cultural heritage in the region. For that purpose, before preparation of the field starts, it is necessary to observe the given measures. In the construction phase, in order to reduce the impacts caused by potential loss to intangible cultural heritage (traditions, religious rites, living cultural heritage) in the AoI of the projected gas pipeline section the following measures will be implemented:* *- Restrict the timing of construction and demolition activities, so as not to disturb the use of religious cultural heritage sites (churches). Stop work at certain times when sites are in use, such as during significant events (weddings, funerals and religious festivals);* *- The workers will avoid disturbance of the religious rites and tradition;* *- The access in the churches and church complexes for religious rites and traditions will not be affected during the construction activities of the gas pipeline section;* *- Implementation of the Macedonian legislation and EBRD PR8 requirements;* *- The workers who come from other places of residence will get acquainted with the culture, customs, habits, and everyday life of the local population. It is especially important to consider the preservation of the living cultural heritage, as part of the customary and ritual practices of the project AoI;* *- It is also necessary to prepare a Plan for project activities for a certain time interval, and to distribute (disseminate) it. The emphasis in this Plan should be on the project activities that create more noise and dust emissions. The increased noise level of the project activities, as well as the higher emission of dust, may prevent the performance of certain religious practices, which in turn will cause certain tension among the population in the affected settlements. The implementation of the Plan for project activities will avoid possible tensions among the local population.*

Table 15. Cultural heritage - Operational phase

Assessed potential impacts
In normal operation of the gas pipeline section is not expected to have negative impacts on the cultural heritage assets. However, some potential impacts on cultural heritage during the gas pipeline operational phase are as follows: *IMPACTS ON THE ARCHAEOLOGICAL SITES* *- Potential Loss or Partial Damage to Chance finds and Undiscovered Below-Ground Heritage Assets as a result of the operational activities or hazards –* ***low significance*** *- Partial Damage to known archaeological sites as a result of the operational activities or hazards –* ***low significance*** *- Access to the archaeological sites –* ***insignificant*** *IMPACTS ON THE BUILDINGS AND COMPLEXES* *- Potential Loss or Partial Damage to the Buildings and cultural heritage Complexes in the AoI of the projected gas pipeline –* ***insignificant*** *- Access to the cultural buildings and complexes –* ***insignificant*** *IMPACTS ON CULTURAL LANDSCAPES* *- Partial Defragmentation of the integrity of the visual effects, of the cultural landscapes- Change in the elements, characteristics, character, and qualities of the landscape as a result of development –* ***moderate significance*** *- Deteriorated panoramic views of the cultural heritage monuments –* ***low significance*** *IMPACTS ON INTANGIBLE CULTURAL HERITAGE AND ASSOCIATIONS* *- Potential Loss or Partial Loss to the intangible cultural heritage and associations (religious rites, tradition, living cultural heritage) in the AoI of the projected gas pipeline –* ***insignificant*** *- Access to the churches and church complexes for religious rites and traditions –* ***insignificant***
Proposed mitigation measures
In the operational phase, in order to avoid unnecessary potential or partial loss of the archaeological assets, it is proposed: *- Qualified Cultural Heritage Expert from authorized institution to be present during some reconstruction or activities connected with hazards that might occur during the regular operation of the gas pipeline section;* *- Careful planning of operational works in order to reduce the negative effects and ensure the prevention of damage of the chance finds and known archaeological sites;*

- To make the maximum possible reduction of vehicle and machinery activities, as limited to the areas that have been subject to heritage clearance or previous disturbance; *- Workers should undergo basic training on the procedure for the cultural value of the AoI and the region, in order to identify the chance finds and known archaeological sites during the operational works;* *- To be implemented Chance Find Procedure (the same as in the construction phase).* *In the operational phase, in order to reduce the impacts caused by potential loss or partial damage to buildings and complexes with cultural heritage value near the AoI of the projected gas pipeline section the following measures will be implemented:* *- Careful planning of operational works in order to reduce the negative effects and ensure the prevention of damage of the buildings and complexes;* *- To make the maximum possible reduction of the size of the reconstruction sites, so the negative impact of the cultural heritage assets that suffers will be minimized, in order to reduce the loss or partial damage to buildings and complexes with cultural value;* *- To make the maximum possible reduction of vehicle and machinery activities, as limited to the areas that have been subject to previous disturbance;* *- To make maximum possible reduction of generation of dust and vibration by operation of heavy machinery, to make ongoing monitoring of dust and vibration levels and inspection of heritage places in proximity;* *- To make demarcation of cultural heritage sites as required, to avoid indirect disturbance;* *- Qualified Cultural Heritage Expert from authorized institution to be present during some reconstruction or activities connected with hazards that might occur during the regular operation of the gas pipeline section;* *- Implementation on the Macedonian legislation and EBRD PR8 requirements.* *In the operational phase, for prevention and reduction of the aesthetic negative effects which mean changed panoramic image and defragmentation with the appearance of the gas pipeline section near the AoI, to take the following measures:* *- Careful planning of reconstruction works in hazard events in order to reduce the negative effects and ensure the prevention of the loss and defragmentation of the visual effects on the cultural landscapes;* *- Workers should undergo basic training on the procedure for the cultural value of the AoI and the region, in order to identify the cultural heritage assets and landscapes during the reconstruction works;* *- After the reconstruction, to carry out the activities for rehabilitation of the site, excavations, sand loans and access roads, by planting grass and trees or other appropriate measures;* *- Implementation of the Macedonian legislation and EBRD PR8 requirements.* *During the operational phase, the responsible persons should take care to give clear instructions to the involved workers, on how to behave towards tradition, religious rites and living cultural heritage in the region. In the operational phase, in order to reduce the impacts caused by potential loss to intangible cultural heritage (traditions, religious rites, living cultural heritage) near the AoI of the projected gas pipeline section the following measures will be implemented:* *- Restrict the timing of activities, so as not to disturb the use of religious cultural heritage sites (churches). Stop work at certain times when sites are in use, such as during significant events (weddings, funerals and religious festivals);* *- The workers will avoid disturbance of the religious rites and tradition;* *- The access in the churches and church complexes for religious rites and traditions will not be affected during the activities connected with hazard events of the gas pipeline section;* *- Implementation of the Macedonian legislation and EBRD PR8 requirements;* *- The workers who come from other places of residence will get acquainted with the culture, customs, habits, and everyday life of the local population. It is especially important to consider the preservation of the living cultural heritage, as part of the customary and ritual practices of the project AoI;* *- It is also necessary to prepare a Plan for project activities for a certain time interval, and to distribute (disseminate) it.*

5.10. Assessed cumulative impacts and proposed mitigation measures

Table 16. Cumulative impacts - Construction phase

Assessed potential impacts
I. Cumulative impacts with existing installations or objects *It is important to see the crossings of the gas pipeline section under the following excisting roads:* *- Motorway A4 "Miladinovci – Shtip"* *- Regional Road R1204 "Sveti Nikole – Kadrifakovo"* *- Local Asphalted Road "Milino – Lozovo"* *- Regional Road R1312 "Milino – Karatmanovo"* *- Regional (Expressway) Road R1312 "Veles – Kadrifakovo"* *- Motorway A1 "Skopje – Gevgeija"* *At the crossings of the gas pipeline section under those roads, is expected to occur the following cumulative impacts:* *- exhaust gases;* *- dust (PM10);* *- noise and vibrations.* ***II. Cumulative impacts with planned installations or objects*** *There are possible cumulative impacts of the gas pipeline section project activities and other planned project activities in the surrounding area if the construction phases overlap. The planned projects near the gas pipline section Project area are: Future solar power plant, Wind Park Bogoslovec and Regional landfill Mechkuevci.* *The possible cumulative impacts of the gas pipline section and those planned projects are the following:* *- generation of fugitive emissions of dust and exhaust gases;*

- *alteration of surface and groundwater quality due to input of pollutants and pre-existing contamination or as a result of leakage or spills;* - *noise emissions from construction vehicles and machinery;* - *pressure on local and regional waste infrastructure and facilities, due to the generated waste from all project activities;* - *another potential source of additional waste from excavated materials (from planned projects), if not adequately managed;* - *increased demand for communal services, such as drinking water and wastewater disposal, and increased traffic on local roads;* - *increased habitat fragmentation and vegetation removal;* - *increased biodiversity disturbance due to all construction activities;* - *landscape and visual changes will be caused;* - *increased opportunities for businesses to increase sales revenue and overall viability through the supply of goods and services;* - *existing businesses may expand, and new businesses are likely to move to the region at least temporarily to provide services to projects under construction;* - *the employment rate in the area is anticipated to increase.* *The cumulative impacts during construction are expected to be of **insignificant to low** significance.*
Proposed mitigation measures
I. Mitigation measures for cumulative impacts with existing installations or objects *With implementation of all proposed mitigation measures to reduce the air pollution and mitigation measures for the impacts caused by noise and vibration in construction phase, the cumulative impacts that are expected to occur at the crossings of the gas pipeline section under the existing roads will be minimized, and will occur only in limited time.* ***II. Mitigation measures for cumulative impacts with planned installations or objects*** *If the construction phases of the gas pipeline section and other planned projects overlap, than the following mitigation measures should be implemented:* - *The Contractor for the pipeline Project will be required to communicate with the Contractors of the other planned Projects that are identified for cumulative impacts, and together ensure that mitigation for their respective projects minimizes the potential for cumulative effects;* - *The potential impacts that will occur in the construction phase, will be managed and mitigated though implementation of the ESMPs for these Projects;* - *All identified ongoing projects should be designed and constructed in compliance with current standards and using best practice techniques, thus reducing the potential for cumulative impacts in construction phase.*

Table 17. Cumulative impacts - operational phase

Assessed potential impacts
*It is assumed that the cumulative impacts in operational phase will be **insignificant** if all projects are designed and constructed in compliance with national standards and using best practice techniques.* *It is likely that a beneficial effect will occur as a result of the operation of the ongoing projects and the gas pipeline Project itself.*
Proposed mitigation measures
I. Mitigation measures for cumulative impacts with existing installations or objects *With implementation of all proposed mitigation measures to reduce the air pollution and mitigation measures for the impacts caused by noise and vibration in operational phase, the cumulative impacts that may occur at the crossings of the gas pipeline section under the existing roads will be minimized, and will occur only in limited time.* ***II. Mitigation measures for cumulative impacts with planned installations or objects*** *All identified ongoing projects should be designed and constructed in compliance with current standards and using best practice techniques, thus reducing the potential for cumulative impacts in operational phase.*

6. CONCLUSIONS

In general, the construction of the main gas pipeline, Section Sveti Nikole-Veles, is not expected to have significant negative impacts on the quality of the environment. The potential impacts that will occur in the construction phase, will be managed and mitigated through the implementation of the ESMP's for these Project.

The Contractor is required to implement all precautionary measures as outlined in this EIA Study and the Environmental and Social Management Plan, to consistently apply them in practice, in order to eliminate possible disturbances in the quality of the environment.

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A STRATEGIC EVALUATION FRAMEWORK TO MEASURE AND GUIDE EFFORTS TO PROTECT BIODIVERSITY: EFFECTIVENESS OF THE NATURA2000 POLICY IN FRANCE

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Abstract: *Through the Natura 2000 policy, EU member states are committed to maintaining or restoring the favourable conservation status of a list of habitats and species throughout their territory. We show here that evaluating the effectiveness of this policy regarding its assigned objectives requires translating these objectives into normative reference and then describing the constraints on habitats and species that the policy seeks to conserve. We propose a strategic evaluation framework based on this principle, applied at the level of the Metropolitan French territory, by relying on the exploitation of several data sets, whose are generally not mobilised by the standard evaluation procedure. The results are broken down by natural ecosystems and biogeographical regions, providing a dashboard for the policy that is the basis for a comprehensive strategic evaluation.*
Keywords: *Strategic Evaluation, Environmental Management, Policy Evaluation, Spatial Planning, Natura 2000.*

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1. INTRODUCTION

To avoid biodiversity erosion, the European Union has adopted a wildlife conservation policy, focused on a selection of species and habitats, whose lists are provided in the annexes of the 'Birds Directive' which came into force 40 years ago, and the 'Habitats Directive' which came into force 25 years ago. Under these 'Nature Directives', member states designate a functional network of sites and appropriate management measures that ensure the restoration or maintenance of natural habitats and species of community interest at a favourable conservation status (EEC Council 1992). This Natura 2000 (N2000) network is one of the largest coordinated protected area networks in the world with more than 27,500 sites covering 18% of the EU's land area (European Commission 2018, Orlikowska et al. 2016) and is presented as the EU's major tool for protecting biodiversity. If the N2000 policy consists of creating sites and implementing management measures, the desired effect must be evaluated Europe-wide and divided into large sectors: biogeographical regions. It is on this scale that states commit to improving biodiversity conservation status. Thus, every six years, they must provide the European Commission with a comprehensive diagnosis, for each biogeographical region, of the status of the target species and habitats, whether they are within the network of sites or not. This evaluation, called 'reporting', consists of assigning a conservation status score to each habitat and species on the lists set by the Directives. This evaluation is based on parameters defined at European level. So far, these summaries have painted an overall negative picture, with only 15% of habitats and 27% of species in a favourable condition (EEA 2020). In terms of evaluation, this monitoring system provides essential information in terms of results. But, as reporting does not differentiate between results from inside or outside the network, and does not tie into the management measures implemented, it does not allow appraisal of how the action of the N2000 network influences species and habitats conservation status. The problem of assessing the effectiveness of the N2000 policy is, however, a major issue. Given the wide diversity of approaches to environmental policy evaluation (Crabbe and Leroy 2008), three underlying rationales of public policy evaluation are generally distinguished : a juridical or judicial rationale (focused on the rule of law and the principle of good governance), an economic rationale (sometimes referred to as a business/ managerial rationale), which focuses primarily on the policy goal attainment, effectiveness and efficiency, and a political rationale (with reference to democratic principles, representativeness, transparency, participation, etc.). Together, they are known as the JEP Triangle (Arts and Goverde 2006). However, most existing evaluations that deal N2000 policy, carried out on the initiative of European Union (McKenna et al. 2014; Milieu et al. 2016; European Court of Auditors 2017; European Commission 2015), or from scientific literature (Beunen and De Vries 2011; Lordkipanidze et al. 2018; Winkel et al. 2014; Watzold 2010; Pellegrino et al. 2017) have focused on the types of contracts, actors' logics and the strengths and shortcomings of the rules of implementation. Whilst the value of such evaluations can only be emphasised, on the other hand it is regrettable that there are not focused on the evaluation of the ecological performance of the policy (Busca and Salles 2005; Leroy et al. 2006; Leroy and Mermet 2014).

However, several studies have gone further by questioning the effect of the N2000 policy on other policies, whether through its capacity to influence the environmental policies of other member states (Bouwma et al. 2017) or its integration through other sectoral policies (Blicharska et al. 2011, Christensen and Kornov 2011, Sarvasova et al. 2013). These studies are very relevant in that they do not consider the N2000 scheme to be an isolated policy but look at its interactions with other policies, both in terms of the multiplication of its effects and external factors that counterbalance its effectiveness. Nevertheless, they all have in common that they do not focus on the policy's conservation objectives, at the risk of not being able to truly measure its impact. This focus on the issues at stake is better integrated into studies based on measurements of the conservation status of certain species or habitats, on reduced scales, especially that of sites (Bretagnolle et al. 2011; Zehetmair et al. 2014a, 2014b; Brodier et al. 2013, Santana et al. 2014). While these works carried out on site, or even on the scale of individual plots, makes it easier to conclude on the specific effect of the management measures implemented by the N2000 policy, it does not give any indication of their effects on the biogeographical territories level, whereas it is on this level that states are committed to Europe. Some authors are looking for effects on a larger scale, by comparing temporal trends in conservation status indicators inside and outside the site network, either on a continental (Donald et al. 2007, Gamero et al. 2017) or country level, either using range parameters (Kubacka and Smaga 2019, Rodriguez-Rodriguez et al. 2019, Chetan and Dornik 2021) or population dynamics parameters (Silva et al. 2018, Princé et al. 2018, Rada et al. 2019), However, they are still too rare and only focus on a portion of the targeted biodiversity (often birds such as Gamero et al. 2017 or Princé et al. 2021). Finally, a significant part of the evaluations focused on the relevance of the policy, i.e. the way he conservation issues are considered within the different policy tools. They mainly on established site networks, in order to evaluate their coherence, and in particular their 'representativeness' namely their adequate coverage of the range of species and habitats to be protected. These studies are based on the principles of systematic conservation planning (Margules and Pressey 2000) and deals with the European scale (Jantke et al. 2011; Albuquerque et al. 2012; Gruber et al. 2012; Trochet and Schmeller 2013; Maiorano et al. 2015; Zisenis 2017; Times et al. 2018), or on certain states (Verovnik et al. 2011; Rosso et al. 2018; Times et al. 2017). These studies, which often conclude by a relatively imperfect representation, do not, however, provide any information on the effectiveness of the N2000 policy, i.e. the effects of the network on the conservation status of species and habitats. Despite their diversity, these studies therefore produce relatively disjointed evaluations that do not allow us to conclude on the adequacy or not of the N2000 policy to its mission of curbing the erosion of biodiversity in Europe. Rather than evaluating the environmental policy's effectiveness, they focus either on the ecological relevance of the management arrangements implemented (based mainly on the representativeness of the sites), or on the organisational relevance regarding the forms of coordination that these arrangements promote, or the coalitions that are deployed within them, which generally promise an outcome that should find itself improved, without this result being directly measured. Faced with these shortcomings, the objective of this article is to provide a strategic framework for analysis and measurement that will improve the evaluation of the effectiveness of the N2000 policy. It is based on the principle that this effectiveness, and therefore the efforts made by the functional network of sites, can only be measured can only be measured in relation to all the practices impacting the species and habitats they aim to preserve. As certain studies on public policy evaluation have shown, particularly those involving strategic environmental management analysis (Mermet et al. 2010 ; Billé 2007; Leroy, 2006), the evolution of the state of ecological systems, in this case the species and habitats covered by the Nature Directives, does not depend unequivocally on the protection actions being implemented, in this case the N2000 policy, but on all the actions and policies that affect, either positively or negatively, the state of these ecosystems. Because, without the ability to compare, on the one hand, the specific efforts undertaken in favour of the environmental policy objectives and, on the other hand, the resistance that sectoral development policies put up against these efforts, it is not possible to assess the extent to which an environmental policy is effective or not (Mermet et al. 2005). In concrete terms, the aim is to carry out a rigorous diagnosis of the ecological situation in relation to conservation issues in the identified territories by specifying (i) the choice of the prescriptive referential on which the evaluation is based: What are the ecological objectives targeted? (ii) the current ecological situation, assessed on the scale expected from the policy objectives : What is the gap, between these objectives and the current state that can be observed, that would have to be bridged to achieve them? (iii) the accountability system analysis: What are the factors that need to be addressed to explain this discrepancy? This implementation of a relative strategic evaluation, an "on-board" framework evaluation approach (Leroy and Mermet 2012), makes it possible to prevent blurring of environmental bottom-line and identify the levers to improve the situation. We applied this methodological framework to the French N2000 network. It is one of the largest in Europe, with an important diversity of ecosystems and socio-economic contexts, partly due to the presence of four biogeographical regions. Its size and complexity make it a appropriate case study for assessing the policy. In the first part, we will therefore present the analytical and methodological framework, and the data from various sources that we have triangulated in order to establish a robust diagnosis. Then we will present the results obtained for France through the proposed strategic evaluation framework. These results will be presented on the scale of ecosystems and biogeographical regions, according to a threefold breakdown: the translation of the prescriptive referential into issues in the field, the analysis of the conservation status and the deviation from the objectives, and the analysis of pressures on these same scales and therefore the factors to be acted upon. We will conclude on the perspectives opened up by such a strategic evaluation framework.

2. ANALYTICAL FRAMEWORK

Application of the Strategic Environmental Management Analysis framework to the N2000 policy

The framework for strategic environmental management analysis (SEMA, Mermet et al. 2005; Mermet 2011) that we have decided to apply to the evaluation of the N2000 policy is an evaluation process following four work stages (Mermet et al. 2010; Leroy and Mermet 2012). In this article, we have focused on the first two stages that provide the basis for strategic evaluation: (stage 1) understanding the issues for the territory under consideration using the prescriptive referential and (stage 2) the dynamics of effective management that make it possible to identify the gap between policy objectives and the current observable state, as well as the factors that may explain this discrepancy. We will not develop the other two stages, namely (stage 3) intentional management, i.e. the full description of the action implemented by the N2000 policy (regulatory mechanisms and management measures, the statistical effect of site creation on conservation status) as well as other environmental policies that might play a role in achieving the objectives set by the 'Nature Directives', nor (stage 4) the identification of room for manoeuvre to redirect N2000 from this strategic diagnosis of the system of responsibilities (Rouveyrol and Leroy 2020).

These first two stages are as follows:

Defining the issues of the N2000 policy in the territory concerned : this involves translating the prescriptive referential set by the Nature Directives, i.e. the species and habitats of Community interest, into concrete issues for the territory concerned.

To this end, on the one hand we have identified the ecosystems (grassland, coastal, forest, etc.) with which the species and habitats targeted by the Nature Directives are associated, and on the other hand, their distribution by biogeographical regions. The approach by ecosystem rather than individual species and habitats permits to synthetize data while at the same time taking into account the pressures and management measures that remain largely specific to these different ecosystems. Their distributions by biogeographical regions (**Figure 1**) allow us to reduce our data to the scale at which member states are committed to achieving results. This dual entry ecosystem /biogeography allows us to mobilise georeferenced datasets on the state of these ecosystems that go beyond the information produced by the N2000 policy alone.

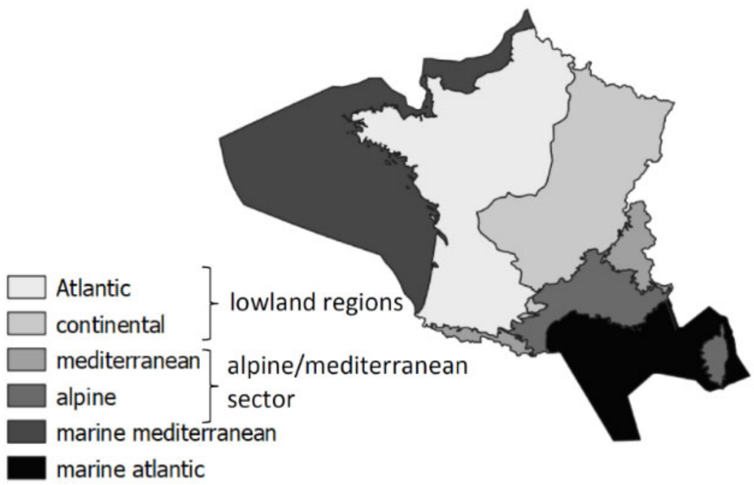

Figure 1. Biogeographical regions in France (Source MNHN 2011-EEA 2007): Regions with homogeneous ecological conditions on a European level. The Habitats Directive defines eleven terrestrial biogeographical regions and seven marine biogeographical regions.

Describing 'effective management' is based on an inventory of all practices, whether voluntary or not, of any actor and, more generally, of the sectoral policies that impact the conservation objective set, and assesses their effects. It allows identification of objective responsibilities in "de facto management." For N2000, it will result in, on the one hand, work on the conservation status of habitats and species, making it possible to ascertain the distance to the target of the policy, which is their restoration or maintenance at a favourable conservation status. On the other, we will study the nature, intensity and location of the pressures exerted on them, which are the factors that explain this distance. Let us now give details of the data mobilised to deploy such an analysis.

3. CONCEPTION AND CALCULATION OF THE INDICATORS

3.1 Data used

As previously mentioned, member states account for achievement of the objectives of the Nature Directives by means of reporting. For the Habitats Directive, it consists of providing an evaluation of the conservation status of each species and habitat of community interest on the level of each biogeographical region in which they are present. For the Birds Directive, the evaluation focuses on numbers and trends. The evaluations are made by experts (more than 400 experts mobilised for the Habitat Report in 2019), based on the best available knowledge (Bensetitti and Gazay 2019).

These data present two limitations in answering the questions being considered:

- They constitute an evaluation list by species or habitat, which are of little operational value for a global diagnosis. We have therefore broken them down into indicators, grouped thematically by ecosystem, and spatially according to biogeographical regions.
- They are open to criticism due to the excessive importance they give to expert opinions (Jeanmougin et al. 2017, Moser et al. 2016). In response, we have chosen to cross-reference them with several other sources of data relevant to the questions asked.

The information contained in the "Standard Data Forms" ("SDF database" in the article) is derived from biological field inventories describing each N2000 site. Their updating is the responsibility of the state services under the scientific responsibility of the MNHM. In 2017-18, a large amount of work was carried out to update this database on a national level (Rouveyrol et al. 2018). This SDF database is transmitted twice a year to the European Commission. We used here the version transmitted in December 2019

Table 1 presents all the data used to establish our diagnosis and the treatments they have been subjected to. On the one hand, we have benefited from important updates of N2000 data conducted by the French National Museum of Natural History (MNHN), and on the other hand, we produced data specific to this analysis, covering the mapping of the ranges of species and habitats and the major types of ecosystems, detailed in supplementary materials, Annex 1. As mentioned in table 1, Some data were used to define the issues the policy has to deals with and other to assess its effectiveness.

Table 1: data used for the diagnostic

Data / Source	Nature	Scale	Constructed indicator	Goal	Data processing
Reporting Fauna-Flora Habitats Directive *MNHN 2019*	Expert opinion (national)	Bioregion	Conservation status of habitats and species Major pressures cited for each ecosystem	Policy effect	1- Conversion of evaluations to scores (unfavourable-bad=1, unfavourable-inadequate=2, favourable=3) 2- calculation of average scores according to ecosystem and biogeographical region
Reporting Birds Directive *MNHN 2013*	Expert opinion (national)	National	Short term population trends by species	Policy effect	1- Conversion of trends to scores (reduction = 1, stable/fluctuating = 2, increase = 3) 2- calculation of average scores by ecosystem
Redlists *IUCN/MNHN 2009-2019*	Expert opinion (national)	National	Evaluation of risks of species extinction	Policy effect	1- Conversion of evaluations to scores (CR=1, EN=2, VU=4, NT=5, LC=5) 2- calculation of average scores according to environment and biogeographical region

Data / Source	Nature	Scale	Constructed indicator	Goal	Data processing
'SDF' Base *MNHN 2019*	Expert opinion (from sites)	Bioregion	Occurrences of species and habitats* Total surface area of habitats * State of conservation of habitats and species*	Issues Policy effect	1- Conversion of conservation notes to scores A=4, B=3, C=2, D=1) 2- calculation of average scores according to ecosystem and biogeographical region/ total area and species reported.
Layer Main types of ecosystem *MNHN 2019 (synthesis)*	Layer crossover	Bioregion	Surface area of different types of ecosystem	Issues	Cf. supplementary materials, annex 2 1- construction of layers. Main types of ecosystem 2- Crossover with biogeographical regions and calculation of total surface area by ecosystem and biogeographical region
Species distribution area *MNHN 2018*	Modelling/ Kriging method or occur-ence data	Bioregion	Surface area of species distribution area	Issues	Cf. supplementary materials, annex 1 1- Assignment of each species to a type of environment 2- Calculation of total surface area by ecosystem and biogeographical region

* only within the Natura 2000 network

3.2 A double declination of data by ecosystems and biogeographical regions

• Declination by ecosystem

The analysis by large types of natural ecosystems was based on the European typology Corine Biotope (Bissardon et al. 1997). Six types of ecosystems have been defined: grassland (code Corine biotope 3), coastal (1), continental waters (2), forests (4), rocky (rocks, screes and sand) (6), wetlands (5). In order to establish the links between the species covered by the Nature Directives and these major types of ecosystems, a table was drawn up beforehand linking each species to its biotope. We excluded generalist species in order to select only species representative of these biotopes. These biotopes were then reduced to the level of the six types of ecosystem. The species-ecosystem and habitat-ecosystem link was made using the HabRef Knowledge Base (Gaudillat et al. 2017). The category "Agricultural land and artificial landscapes" has been excluded from our typology: analysis of species-habitats links has shown that only 4% of the links were related to this ecosystem. For the habitats covered by the Directive, none relate to agricultural or urban areas.

• Declination by biogeographical region

The data from each N2000 site in the SDF database was linked to the biogeographical region that covered it in the majority. For the other spatialised data, the connection to the biogeographical regions was done by cross-referencing with the biogeographical region layer.

3.3 Methodology for defining issues: construction and analysis of species and habitat distribution indicators

For the distribution of species and habitats, we evaluated, through several sub-indicators, the proportion of habitats and species present, for the ecosystem under consideration, in each of the biogeographical regions. The indicators were constructed calculating proportion of surface area for habitats, of distribution ranges or total occurrences for species and using at last average values. The results for each sub-indicator were reduced to three indicators: one species-specific (presence of species), one habitat-specific (habitat surface area) and one global indicator associated with both habitats and species (ecosystem coverage) (**Table 2**). The average of these three indicators is the final distribution indicator used for each ecosystem.

Table 2: construction of distribution indicators

Indicator	Sub-indicators used	Metrics
Ecosystem coverage	Surface area by major ecosystem type	Total surface area
Species populations	Species occurrences within the N2000 network (base SDF) a. Habitats Directive b. Birds Directive	Number of occurrences (=one mention by site)
	Terrestrial species: Distribution ranges on the biogeographical region scale a. Flora b. Terrestrial fauna c. Birds	Total surface area
	Marine species: Encounter rates within the SAMM programme network a. Marine mammals b. Birds	Levels
Habitat surface area	Accumulation of surface area of habitats within the N200 network (base SDF)	Total surface area
	Distribution ranges on the biogeographical region scale	Total surface area

3.4 Effective management data: construction of indicators of conservation status and pressure

• Conservation status indicators

We considered that conservation status could be evaluated using three sources. First, we used the 'Reporting' data which are clearly aiming this evaluation. We added the 'SDF' database which provides a field named 'Conservation" for each species and habitats within each Natura 2000 site. At last, we integrated the 'Red Lists' categories as the parameters used are quite similar (Puissauve et al. 2016). Each data has been translated into numerical scores. To get reliable indicators for each ecosystem and bioregions, the effect of biogeographical regions and ecosystems variables on the value of the scores of status conservation was then tested by statistical analyses. It was measured by fitting mixed linear models and Tukey's post-hoc tests with the lmer function of the lme4 package (Kuznetsova et al, 2017). For SDF and Reporting scores, biogeographic regions and/or ecosystems and taxonomic groups are used as explanatory variables and site codes as random variables (ε) in the form:

$$SDFi\_SCORE = \alpha + \beta_1 biogeographic_i + \beta_2 Taxonomic\ group_i + \varepsilon_i$$

$$SDFi\_SCORE = \alpha + \beta_1 Ecosystem_i + \beta_2 Taxonomic\ group_i + \varepsilon_i$$

For red list scores, ecosytems are used as explanatory variables and taxonomic groups as random variables (ε) in the form of:

$$SDFi\_SCORE = \alpha + \beta_1 Ecosystem + \varepsilon_i$$

• Pressure indicators from SDF and reporting database

Pressures are entered into SDF and reporting databases. We excluded pressures with a positive impact or with insufficient information. 61% of the 19,663 pressure data on the SDF database and all 6,106 pressure data from the Reporting database were included in the analyses. As the typologies used for these two data bases were different, an initial reconciliation of the two typologies had to be carried out beforehand, resulting in a classification comprising of 17 categories and 50 sub-categories.

Each mention of a pressure is associated with a site in the SDF database and with a species or habitat in a given biogeographical region in the Reporting database. We linked these pressures with biogeographical regions and ecosystems using the species or habitats / ecosystems and sites / biogeographical regions links we had already established (see 3.2). In both databases, the threat level is provided by the Reporting in three classes: low, medium and high. We have translated it into a score from 2 to 4 for each increasing level, and a score of 1 assigned to unknown pressure levels. These scores allowed averages to be established on the different scales under consideration.

• Pressure indicators from Corine Land Cover change of land use data

At national level, only Corine Land Cover data and Teruti-Lucas survey (Eurostat 2016) are available on this topic with sufficient temporal hindsight: We used Corine Land Cover data because of their more precise typology.

Six categories of change of land use have been defined:

Table 3: categories of change of land use

Land use 2006	Land use 2012	Category of change
Grasslands	Scrubland ou wooded areas	Agricultural decline
Scrubland ou wooded areas	Pastures and grasslands	Creation of pastures and grasslands
All ecosystems	Urban areas	Urbanisation
Grassland or natural areas	Crops	Agricultural intensification
Urban areas/crops	All areas except urban	Renaturation
Other land use changes		Other

4. RESULTS

4.1 Conservation issues: what ecosystems and territorial distribution?

The distribution of species and habitats listed in the Nature Directives has been shown by indicators of relative presence, showing the distribution of species and habitats in different biogeographical regions, and in ‘density’, relating this distribution to the surface area of these biogeographical regions (see 3.3).

The Atlantic and continental regions, which cover much larger areas than the others, are logically home to most of these targeted species and habitats (**Figure 2** : ‘relative presence indicators’). This is the case for all ecosystems, with the exception of rocky ecosystems, which are mostly located in alpine and coastal regions. However, in terms of ‘density’, i.e considering the amount of species and habitats for the same surface area (**Figure 2** : ‘density indicators’), the distribution is reversed: the Alpine region is the richest in rocky, grassland and forested ecosystems. The Mediterranean region is in second position for grassland and forest regions, whilst continental waters and wetlands are more evenly distributed. Variations in ‘density’ between the Atlantic and continental regions are smaller. However, the continental region is better supplied with regard to forest ecosystems.

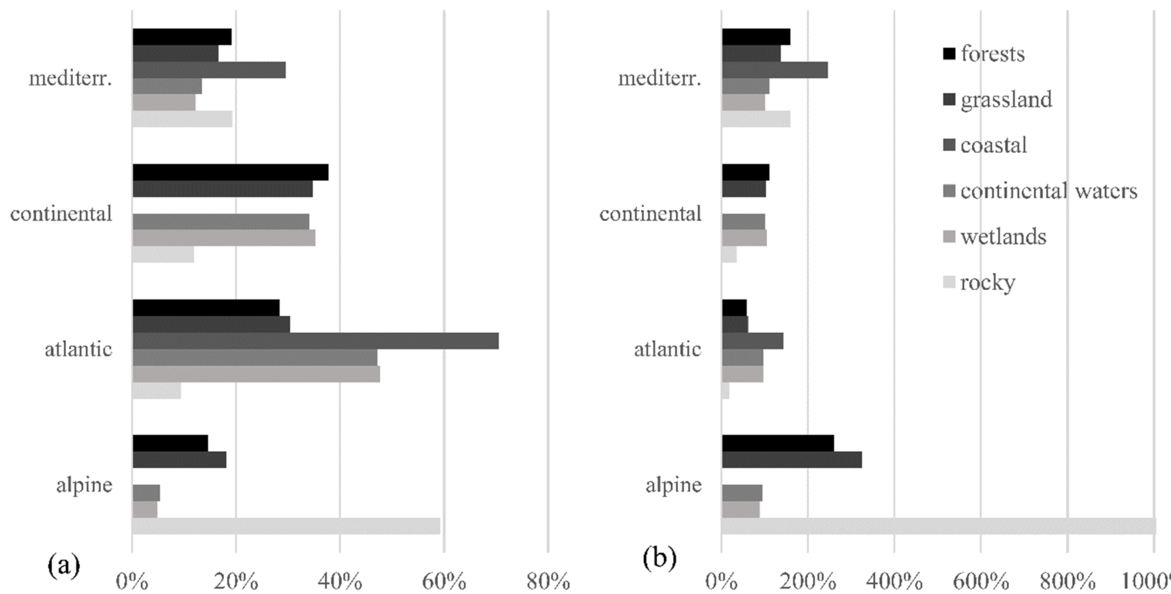

Figure 2. Distribution of habitats and species of community interest by ecosystem and biogeographical region for land: (a) relative presence indicator (b) density indicators

4.2 Effective management: how far wide of the target and what factors of degradation?

The evaluation of conservation status by ecosystem and biogeographical region is useful to prioritize the conservation needs, about the gaps to be filled in relation to the objectives set for favourable conservation status.

- **Conservation status by biogeographical region**

Comparisons between biogeographical regions is only possible with conservation status data from the SDF and Reporting databases. According to the SDF data, conservation status in Continental and Atlantic regions is significantly lower than in Mediterranean and Atlantic marine regions. According to the Reporting data, only the Alpine region stands out: its conservation status is significantly better than in the Mediterranean, Continental and Atlantic regions.

- **Conservation status by ecosystem**

To compile results from the three data sources (SDF, Red Lists or Reporting) analyses (see 3.4), the mean conservation status for each ecosystem was compared in pairs. All significant differences go in the same direction regardless of the data used: therefore, the results do not contain any contradiction between the three sets of data.

To prioritise the conservation status of the ecosystems relative to one another, we counted, for each ecosystem, the number of comparisons with other ecosystems for which its conservation status is significantly lower or higher (**Figure 3).**

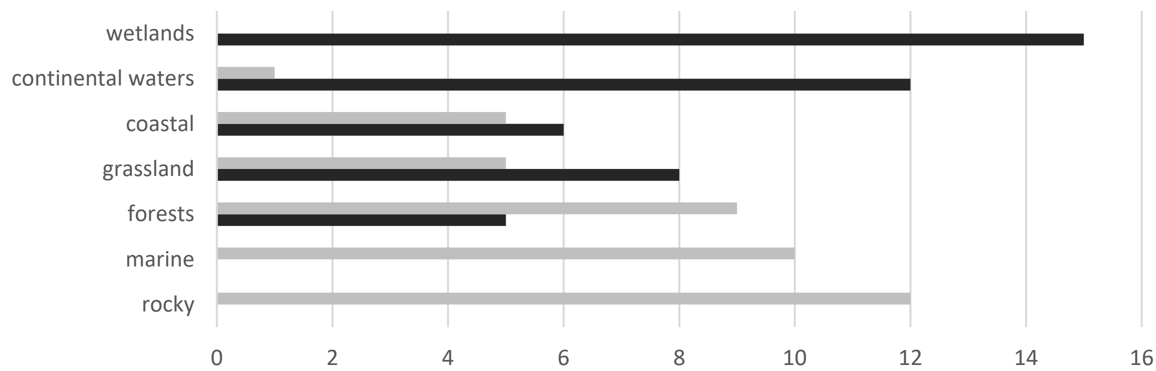

Figure 3. Number of comparisons in pair between ecosystems for which the average conservation status of the ecosystems is significantly higher (in grey) or lower (in black) than that of the ecosystem with which it is compared

The conservation status of wetlands is much lower than that of all other ecosystems, as all comparisons implying this ecosystem, and another showed wetland conservation status was the lowest. Continental waters are also almost systematically more degraded. Conversely, marine, and rocky ecosystems are in better condition than any other ecosystem. Between the two, coastal and grassland ecosystems are comparatively in a state of significant degradation, whilst forest ecosystems score higher than most other ecosystems.

- **Comparison between conservation statuses by ecosystem and biogeographical region**

We have grouped the Atlantic and Continental regions under the category ‘lowland regions’ as distinguished from the Alpine/Mediterranean sector. The scores are significantly higher in the Alpine/Mediterranean sector, so their conservation status is much better than in ‘lowland’ for all ecosystems according to SDF data and for grassland ecosystems according to Reporting data. Overall, lowland regions are significantly more degraded.

- **Summary of habitats and species distribution and their conservation status**

Due to their large surface areas, the Atlantic and Continental regions therefore contain most of the issues covered by the Nature Directives even though the Alpine region has the highest "density" of biodiversity. These lowland regions also show the worst conservation statuses. In terms of ecosystems, wetlands, and continental waters and, particularly for lowland areas, grassland regions are the most degraded. Marine and rocky ecosystems, and, to a lesser extent, forest ecosystems are in a more favourable condition.

In order to continue the evaluation and identify the levers for action, it is now necessary to consider the causes of these differences in conservation status. This is the second stage in the analysis of effective management, that of identifying responsibilities, which involves identifying the pressures that affect conservation targets.

- **Common transversal pressures, and a clear hierarchy of pressures, linked to ecosystems and biogeographical regions**

Of the 17 pressure types defined, 8 account for between 76% and 78% of the total number of mentions, depending on whether the "Reporting" or "SDF" databases are considered. These are, in descending order, agricultural intensification, forestry, urbanisation, human disturbance, changes in hydraulic conditions, transport networks, natural processes and agricultural decline. In the data used, the impacts of agricultural intensification correspond mainly to the conversion from grassland to crops, agricultural pollution and the impacts of irrigation, catchment, and drainage. Forestry is mainly cited due to the impacts of logging. Regarding urbanisation, by cross-referencing with the works of Fontes-Rousseau and Jean (2015), it is mainly attributable, over this period and on this scale, to individual habitat. Both data sources are consistent on these trends. However, some discrepancies add nuance to this conclusion: two of the most impacting pressures, forestry, and urbanisation, are less cited on the N2000 sites (SDF database), which may be a sign either that the policy is restrictive on these activities or that the sites have been placed in localities already spared from these pressures. On the other hand, attendance is a much more cited pressure on the sites (SDF database) than on the whole of the territory (Reporting). The attractiveness of N2000 sites to the public may be the reason for this, but it is nevertheless necessary to ensure that there is not a bias related to data producers (who include more managers for the SDF database), or on an observational level (greater ease in identifying this pressure on a site level than on a wider spatial level). **Table 4** classifies these results by biogeographical region, combining SDF and Reporting data. The first line gives the average number of strong negative pressures mentioned for each site: the Atlantic and Continental regions are the ones for which the most pressures are mentioned. The details of the categories on a national level, in the following lines, reflect both constants: the strongest pressures (agricultural intensification, urbanisation and even human disturbance) are found throughout the territory, but also geographical specificities: agricultural intensification is more pronounced in the Atlantic and Continental regions, whilst urbanisation particularly affects the Mediterranean region, and the problems related to disturbance are highest in the Alpine region. The most marked distinction is between land and marine ecosystems, with very specific issues for the latter: pollution, frequentation, and fishing.

Table 4. Distribution of the 8 most cited pressures in the Reporting (Rep.) and SDF data by categories and biogeographical regions. The occurrences of the pressures are weighted by their level of intensity.

	ALP		ATL		CON		MED		MATL		MMED	
	Rep.	SDF	Rep.	SDF	Rep.	SDF	Rep.	SDF	Rep	SDF	Rep.	SDF
Average number of intense pressures cited per site (SDF data)	2,4		3,4		3,1		2,6		2,6		2,7	
Agricultural intensification	19%	24%	20%	27%	27%	28%	18%	18%	7%	8%	0%	3%
Urbanisation	11%	7%	12%	8%	10%	8%	20%	12%	7%	7%	11%	7%
Forestry	15%	5%	10%	9%	12%	12%	10%	4%	1%	2%	0%	2%
Human frequentation and public safety measures	7%	29%	7%	12%	6%	12%	8%	21%	5%	24%	12%	26%
Mixed source pollution	5%	3%	9%	6%	7%	5%	5%	5%	17%	8%	24%	8%
Development and use of transport networks	7%	6%	5%	6%	6%	9%	7%	9%	5%	9%	4%	8%
Human-induced changes to hydrological systems from multiple or unknown causes	5%	8%	7%	10%	8%	10%	5%	6%	3%	9%	1%	4%
Agricultural decline	6%	4%	6%	6%	5%	2%	4%	3%	1%	6%	4%	5%

To clarify these findings, we analysed national land use change rates using Corine Land Cover data. They allow for triangulation of information provided by the 'SDF' and 'Reporting' data for the three most frequently cited pressures, which are correlated with an identifiable change of land use: urbanisation, agricultural intensification, and agricultural decline. Two reverse trends, renaturation for urbanisation and the creation of grassland for agricultural decline, were also represented.

However, these analyses are not relevant to pressures that do not result in changes in land use, such as pollution and impacts related to agricultural intensification, disturbance, overgrazing, etc.

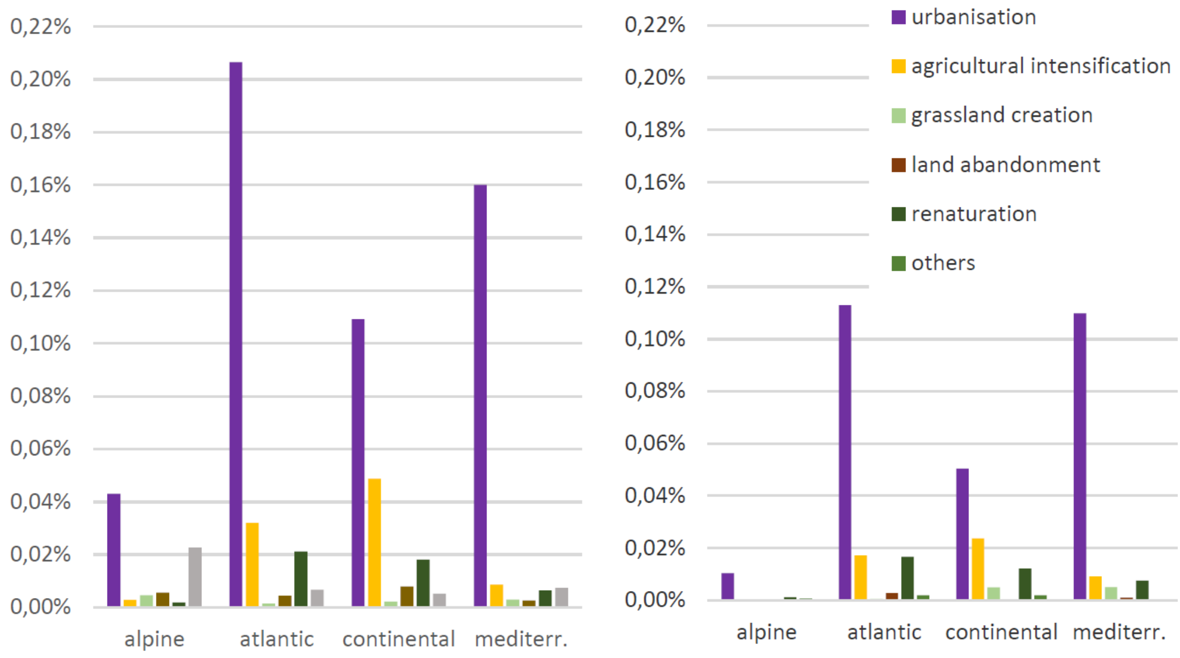

Figure 4. Proportion of territory affected by different types of land use change between 2006 and 2012 (left) and between 2012 and 2018 (right) - Corine Land Cover data

The results confirm the importance of urbanisation, the main cause of land use change for the entire territory. None of the other changes in land use considered reach comparable levels. Part of the phenomenon of agricultural intensification, that related to the planting of crops, mainly grassland reversals, is also visible. It mainly affects the Atlantic and Continental regions, confirming the results obtained by the SDF and Reporting data. Other land use changes are insignificant in comparison.

The comparison between the periods 2006-2012 and 2012-18 shows a significant decrease in the levels of land use change, covering all the major trends observed in the previous period. This possible sign of decrease in pressure levels has nevertheless been reversed by more recent data (Bocquet 2019).

Grassland ecosystems are most affected by the various pressures of land use changes. This is the case for agricultural activities: cultivation linked to agricultural intensification (land clearing), as conversely the phenomena of fallowing and reversion to shrub and forest. This is also the case for urbanisation: 13.1% of artificialized areas between 2006 and 2012 were previously occupied by pastures (January et al. 2015), making it the ecosystem the second most impacted by urbanisation after agricultural land.

The Reporting data allow to add ecosystems data to the pressure/biogeographical regions data (Table 5). Pressures are thus specific to certain ecosystems: silviculture for forests, changes in hydraulic conditions for wetlands and aquatic ecosystems, agricultural intensification and urbanisation for grassland ecosystems and human frequentation for rocky ecosystems.

Table 5. List of the three most frequently cited pressures in the Reporting results by ecosystem and biogeographical region.

	Alpine	Atlantic	Continental	Mediterranean
Grasslands	Ia Ur Sy	Ia Ur Sy	Ia Ur Sy	Ia Ur Da
Wetlands	Ia Mh Ur	Ia Mh Sy	Ia Cc Mh	Ia Ur Sy
Continental waters	Ia Mh Ee	Ia Mh Ur	Ia Mh Pn	Ia Ur Mh
Forest	Sy Ia Rt	Sy Ia Ur	Sy Ia Rt	Sy Ia Ur
Rocky	Cc Fh Ur	Ia Fh Rt	Ia Fh Ur	Ur Fh Ia
Coastal		Ur Pn Ia		Ur Ia Rt
Marine		Pe Cc Ur		Ur Pe Po

Ia Agricultural intensification
Ur Urbanisation
Sy Silviculture
Da Agricultural decline
Mh Hydraulic modifications
Cc Climate change
Ee Invasive species
Po Mixed source pollution
Fh human disturbance/security measures
Rt Transport networks
Pn Natural processes
Pe Fishing

5. DISCUSSION

Our results made it possible to construct an operational territorial diagnosis of the issues surrounding the N2000 policy in France. We showed that focusing the analysis on ecosystems and biogeographical regions allows identification of significant differences in conservation statuses, as well as the distribution of pressures on a national level. These differences also make it possible more solid hypotheses about the mechanisms at the origin of the degradations, in particular the impact of sectoral economic development policies, that will be developed in the later stages of the strategic analysis. It validates the methodological framework chosen for the evaluation.

Our results show the value of cross-referencing data from a variety of sources in order to put clearly into perspective the strategic challenges facing the N2000 policy, namely, to meet its objectives in the face of existing degradation dynamics. These data, some of which are only very rarely analysed, have points of convergence largely in the majority on the analytical grid used. While some authors have worked on occurrence data taken from the SDF database (Zub et al. 2018) or on conservation statuses taken from Reporting (Sanderson et al. 2016; Zisenis 2017), none of this work focused on a national diagnosis comparing the states of conservation with the levels of pressure, and therefore confronting the policy with the challenges that it really has to take up; and thus, making it possible to analyse whether the means implemented are up to the challenges. This is where the work presented in this article is innovative, by providing a strategic evaluation framework to measure and guide efforts to protect biodiversity in the face of clearly identified degradation dynamics at work on domestic territory.

For conservation statuses, the absence of contradiction between the different data used provides an additional guarantee of the reliability of the results. It supports the results of Puissauve et al. (2016) on the coherence of the Red List and Reporting data on a national level, whereas this coherence is much weaker on a European level (Moser et al. 2016). The pressure data from the Reporting and SDF databases had never, to our knowledge, been used in a comparable study in France. Ciapala et al (2014) and Tsiafouli et al (2013) analysed them in other territories but without linking them to other indicators: our work, by showing that land use change data can be correlated with the pressures identified in the SDF and Reporting databases, underlines the value of fully exploiting these types of sources in order to triangulate the data.

Our results place urbanisation and agricultural intensification at the top of the list of pressures and are therefore in line with the IPBES (2019) report, which identifies habitat loss as the primary cause of biodiversity extinction on a global scale and links this habitat loss primarily to these two pressures. Conversely, the N2000 data give little importance to invasive species and climate change, which are nevertheless cited among the five major pressures in France in 2017 (ONB 2017) and worldwide (IPBES 2019). Further work is needed on these two points to test the possible hypotheses explaining this discrepancy: scale-dependent perception, difficulty in apprehending future threats, etc. The extent of the impact of species disturbance in the SDF database, a pressure not reported by neither IPBES nor the French National Biodiversity Observatory, is also notable, as already highlighted by Ciapala (2014)'s work in the Alpine regions of Slovakia. It seems that the impact of leisure activities on biodiversity needs to be re-evaluated in the light of our data.

The difference between lowland regions and Alpine and Mediterranean areas is well documented, the first ones being, for example, known to be the most degraded of aquatic environments (Blard-Zakard and Michon 2018) or in terms of ecosystem fragmentation (ONB 2019). On the other hand, our findings add nuance to the great patrimonial responsibility usually placed on the Alpine and Mediterranean regions (Médail and Quezel 1997), showing that whilst these sectors are indeed richer, their small surface area and their relatively low level of exposure to degradation means that most of the issues are found elsewhere. Also, although many rare species and habitats are more present in Alpine and Mediterranean areas and indeed deserve to be well protected, it is important to remember that the Nature Directives aim for conservation of biodiversity in the broader sense, including "ordinary nature" (Mougenot 2003), which is still very present, although degraded, in the Atlantic and Continental regions.

6. CONCLUSION

The strategic evaluation methodology implemented in these first two stages has therefore made it possible to outline a genuine national scoreboard for the N2000 policy, fulfilling several conditions:

- objectivity, based on data from a wide range of sources,
- operationality, by providing information on (1) the location of needs: how are the ecosystems targeted by the Nature Directives and where intervention is needed spatially distributed? (2) the nature of the interventions to be carried out: in a given biogeographical region, which ecosystems require action and to counteract the effect of what pressure?
- legibility, by providing synthetic results, making it possible to compare the different situations (location, ecosystems, pressures) in order to identify priorities, segment the diagnosis and thus be able to compare it with other data.

This strategic evaluation framework for the N2000 policy provides at this stage a strategic diagnosis: it is intended to be one of the building blocks of a mechanism that makes it possible to compare the problems that need to be solved in order to achieve the objectives set out in the Nature Directives, on the one hand, with regard to the measures implemented within the framework of this policy, but also with other environmental programmes (intentional management), and on the other hand in the face of sectoral policies or external factors that have an impact on the results achieved (effective management).

Without downplaying the value of environmental policy evaluations that focus more on the logics of governance, representativeness, transparency and public participation, the current context of biodiversity degradation requires us to cross-reference these evaluations with strategic evaluations focused on the environmental effectiveness of public policies. Our work shows that starting from a clearly defined strategic analytical framework, which encourages the mobilisation of previously untriangulated data, we can effectively provide a scoreboard to measure the environmental effectiveness of a policy focused on biodiversity protection, the N2000 policy. The first, unavoidable, step is the analysis of the issues at stake. The work we have presented here provides a diagnosis of these issues on the scale where the results are expected: biogeographical regions over their entire surface area, and broken down by natural ecosystem, as close as possible to the realities of management. It is only the first stage of the evaluation, but this basis is essential for this evaluation to produce results that are useful for steering the policy, in order to improve its impact on biodiversity conservation throughout the territory.

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AN EXAMPLE OF THE PROTECTION OF A DEEP EXCAVATION IN AN URBAN ENVIRONMENT

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Abstract: *The paper presents the design of deep excavation support system in an urban environment. Excavation is carried out in the vicinity of surrounding buildings whose structural stability must be ensured during the execution of the construction works. The 60 cm thick diaphragm wall supported by the two rows (17.00 m and 18.25) of geotechnical anchors was selected as an excavation support system. The approximate floor plan dimensions of the diaphragm wall are 81x118 m, and the maximum excavation depth is 10.5 m. An additional challenge in designing the diaphragm wall is the presence of groundwater, whose maximum level is observed at a depth of approximately 5.8 m. In order to ensure the execution of construction works in dry conditions, a system of drainage trenches and wells is designed at the bottom of the pit. The diaphragm wall is designed in accordance with Eurocode 7.*

Keywords: *diaphragm wall, deep excavation, geotechnical engineering, Eurocode 7*

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1. INTRODUCTION

Because of the continuous progress of urbanization, there is often a need for more above-ground spaces for development and construction in urban areas. It resulted in the accelerated utilization of underground construction opportunities, which is especially important for developing large urban areas (Feng et al. 2022). Efficient utilization of underground spaces can improve the sustainability of urban development, i.e. contribute to the overall quality of life (Broere 2016). However, along with the many advantages of using underground spaces, it also brings specific challenges. For example, the execution of deep excavations necessarily results in ground movements, including horizontal movements and settlements. The above can threaten the safety and stability of neighboring buildings (Sun & Xiao 2021). In order to evaluate the potential negative impacts of this type of work on neighboring buildings, it is necessary to evaluate the displacements that occur as a result of deep excavation. The aforementioned can be carried out using empirical and semi-empirical methods, laboratory tests, analytical methods and numerical simulations (Yang et al. 2021). With the development of computers, the finite element method (FEM) is becoming one of the most widely used methods in geotechnical analyses of deep excavations (Chen et al. 2022). On the site of the former electric light bulb factory in Zagreb, Croatia, a residential-commercial building is planned. The building's floor plan is approximately rectangular, with dimensions of 80x117 m. The building consists of three underground and nine above-ground floors. In order to ensure the structural stability of the soil and surrounding buildings, as well as the execution of construction works in dry conditions, it is necessary to design a proper excavation support system. The design and construction of the excavation support system is an integral part of the design of buildings containing underground floors (Frydrych et al. 2021). The design process involves modelling the complex foundation-soil interaction with a series of important input parameters: the initial stress state in soil, groundwater level, soil lithology, and relative stiffness between the structure (Popa et al. 2015). An additional challenge in the geotechnical analysis of the support system is the relatively high groundwater level, which was observed at a depth of 5.8 m.

In accordance with Eurocode 7 (European Committee for Standardization 2004), the excavation support structure is categorized in Geotechnical category two. This category includes common structures and foundations without high risk or unusual or extremely difficult conditions in the underlying soil. The design of geotechnical category two structures should typically include quantitative geotechnical data and calculations to ensure that the basic requirements are met. For design in geotechnical category 2, standard procedures for field and laboratory testing and calculation may be used.

2. LOCATION

The construction pit is located at 10 Frana Folnegovića Street in the Trnje district of Zagreb (**Figure 1**). Within the construction pit's location, some of the existing buildings and installations were removed before the start of the works. Near the excavation, along its eastern side, there is a road, and along the northern, western and southern sides, there are buildings whose structural stability should be ensured during the works.

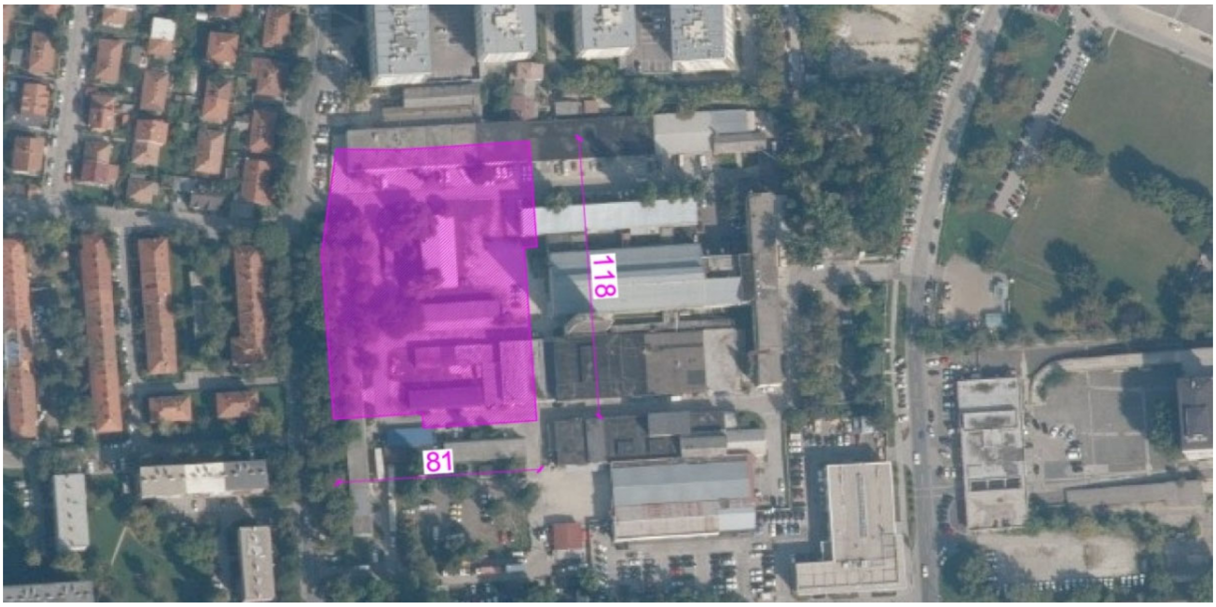

Figure 1. Location of the construction pit

Data on the maximum value of horizontal acceleration at the location were read from the "Map of Earthquake Areas of the Republic of Croatia" prepared by the Geophysics Department of the Faculty of Science and Mathematics in Zagreb in 2011. Maps with an interpreter are an integral part of the National Annex to the series of norms HRN EN 1998-1:2011/NA:2011, Eurocode 8: Design of seismic resistance of structures - Part 1: General rules, seismic actions and rules for buildings (Croatian Standards Institute 2011; 2021). **Table 1** shows the values.

Table 1. Maximum horizontal ground acceleration

RETURN PERIOD (years)	a_{max} (g.)
95	0,123
475	0,243

2.1. Geotechnical investigation works

Relevant information on the geotechnical composition of the soil, necessary for finding the optimal design of the excavation support system, was obtained from the geotechnical investigation works. In general, the program of geotechnical investigation works is designed in such a way that a sufficient amount of data is collected from the location to define:

- geotechnical model of the location with the type and characteristics of the underlying soil,
- soil strength and deformability parameters for the implementation of geotechnical limit states analyses,
- recommendation for the design and construction of foundations and excavation support system.

Geotechnical field investigation works were carried out at the beginning of September 2019. Four (4) investigation borings were drilled. The works included the following activities:

- drilling of four (4) borings, 21 m deep, with a motorized rotary drill, including continuous soil coring (**Figure 2**),
- soil relative compaction exploration using the method of the standard penetration test (SPP test), to assess the relevant properties of the soil,

- monitoring and field AC classification of the drilled core and selection of representative undisturbed and disturbed soil samples for the conduction of laboratory tests,
- during and after drilling, the occurrence of groundwater level was monitored.

Table 2. Markings and characteristics of investigation borings

BORING	WELL DEPTH (m)	SPP (pc)	US* (pc)	DS** (pc)
NB-1	21	10	1	-
NB-2	21	9	1	-
NB-3	21	10	-	-
NB-4	21	10	1	-

** US, Undisturbed Sample; ** DS, Disturbed Sample*

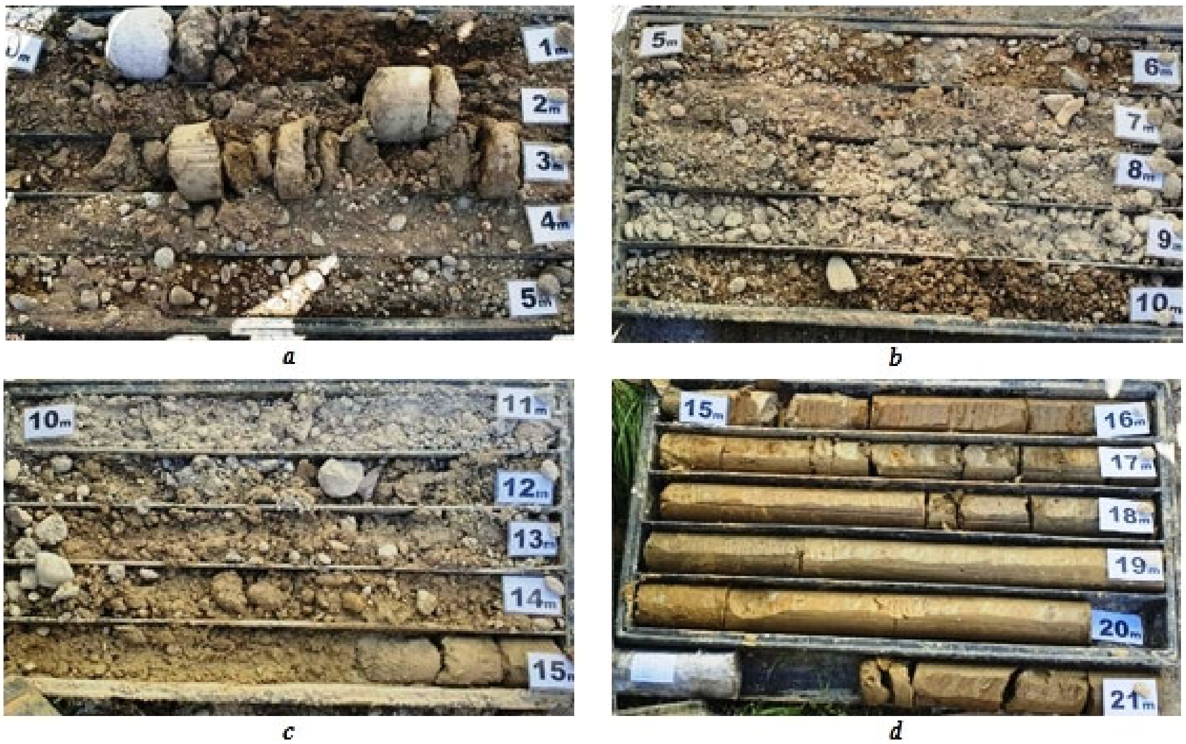

Figure 2. Drilled cores

Laboratory tests on disturbed and undisturbed soil samples were performed according to appropriate standards and in accordance with Croatian norms and included the following tests:

- identification tests to determine the general properties of the soil:
  - examination of the granulometric composition
  - consistency limits (Atterberg limits) and soil plasticity index
- identification tests to determine soil strength and deformability properties:
  - shear strength by direct shear
  - soil compressibility using an oedometer
  - uniaxial soil strength

Based on field investigations and laboratory tests, geometry, and geotechnical characteristics of the half-space of soil are defined. The soil generally consists of four layers. The first layer is silty sand, up to a maximum depth of 3.7 m. The following soil layer is a very dense well-graded gravel to the depth of the groundwater level. Below the groundwater level, up to a depth of 15-16 m, the layer of dense gravel is identified. Below 15-16 m is a 1 m thick layer of clay mixed with sand, and finally, the drilling was finished in highly plastic clay. The groundwater during the drilling was observed at 7.0-7.3 m. Later, groundwater in the previously drilled holes was observed at 5.8 m. Given the excavation depth of 10.5 m, it is evident that the elevation of the bottom of the construction pit is below the groundwater level. Based on the investigation works results, six geotechnical environments were defined as follows:

1. Embankment
2. Clayey-silty sand, SC/SM
3. Well-graded gravel, GW-1
4. Well-graded gravel, GW-2
5. Clayey sand, SC
6. High-plasticity clay, CH

Table 3. Markings and characteristics of exploratory wells

SOIL	DEPTH (m)	γ (kN/m^3)	c (kPa)	ϕ (°)	M_v (MPa)	c_u (kPa)
Embankment	0-0.6	18	5	15	4	-
SC/SM	0.6-2.5	18	6	32	8	-
GW_1	2.5-7.0	18	0	38	65	-
GW_2	7.0-15.35	18	0	33	32.5	-
SC	15.35-16.10	18	2	31	35	-
CH	>16	18	25	21	40	120

3. THE EXCAVATION SUPPORT SYSTEM – CONCRETE DIAPHRAGM WALL

The excavation is planned at 101.25 and 101.95 m above sea level, while the existing terrain is approximately horizontal at approximately 111.75 m above sea level. The excavation support system was designed considering the restrictions at the location and technology used by the selected contractor. Accordingly, a concrete diaphragm wall supported by two rows of geotechnical anchors was selected as the excavation support system. The floor plan of the construction pit is shown in **Figure 3**.

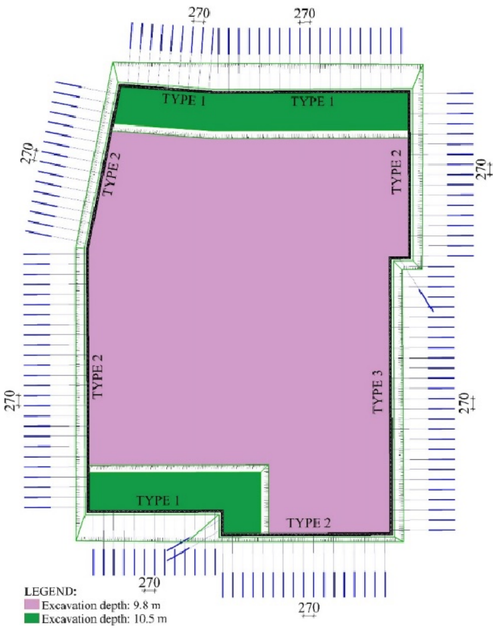

Figure 3. Diaphragm wall layout

During construction, the diaphragm wall ensures that the works are carried out in dry conditions. After completing the works, it represents a load-bearing structural element to bear external horizontal and vertical actions. Geotechnical analyzes of ultimate and serviceability limit states of all relevant construction work phases were carried out: excavation with the action of geotechnical anchors enabled, construction work advancement including connection of the diaphragm wall with ceiling slabs and the stage of the building use. The details of the diaphragm wall's connection with the building's ceilings are harmonized with the requirements given by the structural engineer. The designed diaphragm wall consists of the following:

- 60 cm thick diaphragms wall

- head beams measuring 70/70 cm
- two rows of geotechnical anchors
- guide trench, concrete C 25/30, reinforcement steel Q 335

The following materials are used for the construction of the diaphragm wall and geotechnical anchors:

- concrete C 30/37, consistency S4, D_{max} = 16 mm
- steel reinforcement B 500B
- steel for geotechnical anchors S 1670/1860 N/mm2
- injection mixture C 25/30

Due to different conditions regarding the neighboring buildings, three types of the cross-section are provided:

- TYPE 1: it is performed on parts of the construction pit's floor plan, where the plot's edge is approximately 7.5 m distant from the external contour of the diaphragm wall (**Figure 4**).
- TYPE 2: it is performed on parts of the construction pit's floor plan, where the plot's edge is approximately 3.0 m distant from the external contour of the diaphragm wall (**Figure 5**).
- TYPE 3: it is performed on parts of the floor plan of the construction pit, where the neighboring buildings are located - the eastern side (**Figure 6**).

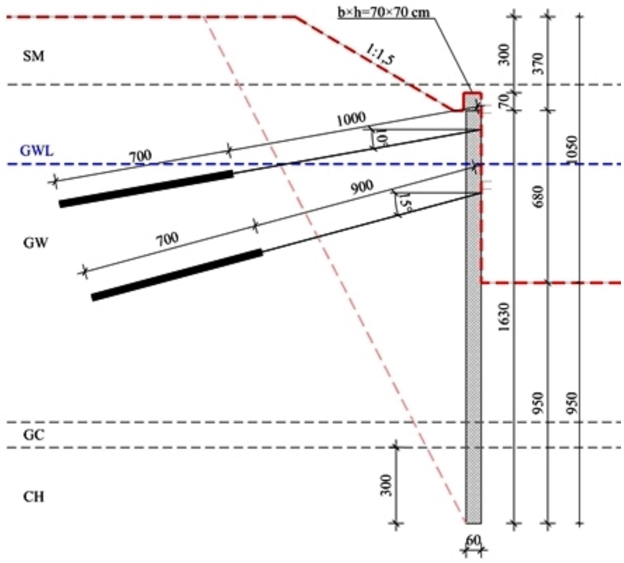

Figure 4. Cross section Type 1

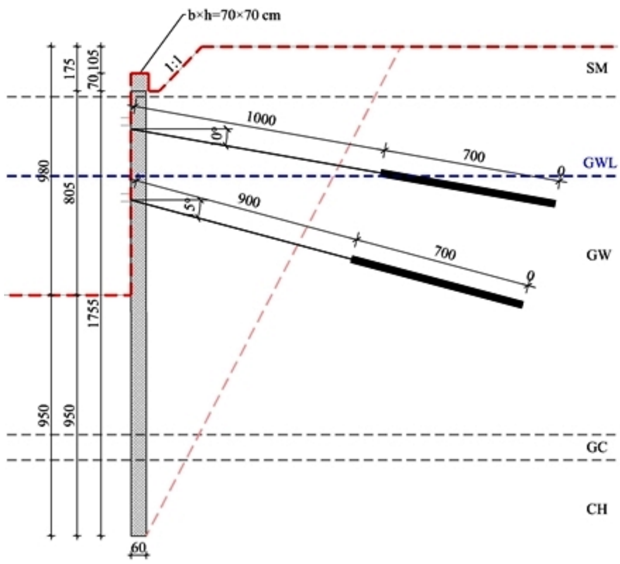

Figure 5. Cross section Type 2

3.1. Geotechnical analyzes and results

Numerical modelling of the diaphragm wall behavior in interaction with the soil (deformation analysis) was carried out using the commercial program Plaxis 2D. The calculations were performed assuming a two-dimensional deformation state. The calculation stages are aligned with the construction stages. For each calculation phase, the distribution of displacements, internal forces and all other relevant data necessary for the design of the diaphragm wall and geotechnical anchors were determined. The soil is modelled using the Hardening Soil soil model, in which the stiffness of the soil depends on the stress. The load-bearing capacity of all structural elements was verified according to regulations, i.e., Eurocode 7 (European Committee for Standardization 2004). This paper presents the results of geotechnical analyses only for cross-section type 3. **Tables 3, 4** and **5** show input parameters of the diaphragm wall, geotechnical anchors, floor slab and mat foundation.

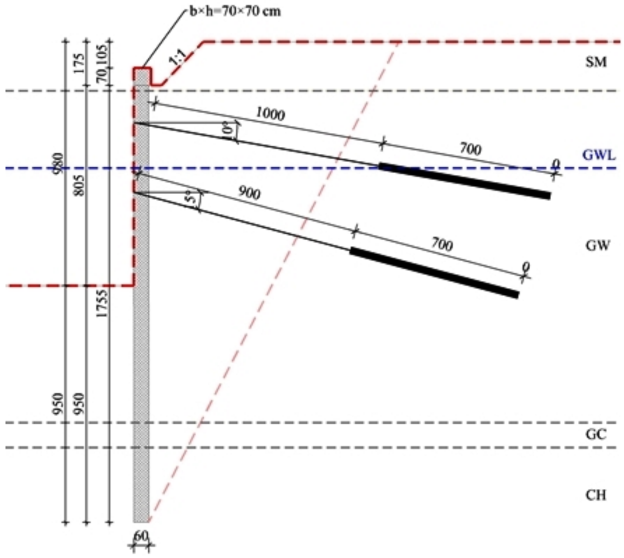

Figure 6. Cross section Type 3

Table 3. Input parameters of the diaphragm wall

IDENTIFICATION	Diaphragm wall D=60 cm
MATERIAL TYPE	Elastic
ISOTROPIC	Yes
EA_1	$18 \cdot 10^6$ kN/m
EA_2	$18 \cdot 10^6$ kN/m
EI	$540 \cdot 10^3$ kNm^2/m
d	0.6 m
w	3.6 kNm/m
ν	0.25

Table 4. Input parameters of geotechnical anchors, floor slab and mat foundation

IDENTIFICATION	GEOTECHNICAL ANCHORS	FLOOR SLAB	MAT FOUNDATION
MATERIAL TYPE	Elastic	Elastic	Elastic
EA	$176 \cdot 10^3$ kN	$3 \cdot 10^6$ kN	$30 \cdot 10^6$ kN
L_SPACING	2.7 m	2.7 m	1.0

Table 5. Input data of geotechnical anchors bond length

IDENTIFICATION	Bond length 300 mm
MATERIAL TYPE	Elastic
E	$3 \cdot 10^7$ kN/m^2
γ	24 kN/m^3
BEAM TYPE	Predefined

PREDEFINED BEAM TYPE	Massive circular beam
DIAMETER	$0.3\ m$
A	$0.07069\ m^2$
I_	$0.3976 \cdot 10^{-3}\ m^4$
L	$2.7\ m$

Table 6. Soil parameters design values

IDENTIFICATION	MATERIAL MODEL	DRAINAGE TYPE	γ	E_{50}^{ref}	E_{OED}^{ref}	E_{UR}^{ref}	c_{ref}	φ
			kN/m^3	kN/m^2	kN/m^2	kN/m^2	kN/m^2	(°)
Embankment	HS	Drained	16	4000	4000	12000	4	12.10
SM	HS	Drained	19	10000	10000	30000	4.8	26.56
GW_1	HS	Drained	19	65000	65000	195000	0	32.01
GW_2	HS	Drained	19	35000	35000	105000	0	27.45
GC	HS	Drained	19	35000	35000	105000	1.6	25.67
CH	HS	Drained	20	40000	40000	120000	20	17.07

Figure 7 shows the numerical model of the excavation support system in Plaxis. **Figures 8, 9, 10, 11** and **12** show the results of deformation analysis for cross-section type 2. **Table 8** shows the summary results of internal forces and displacements for all three types of cross-sections.

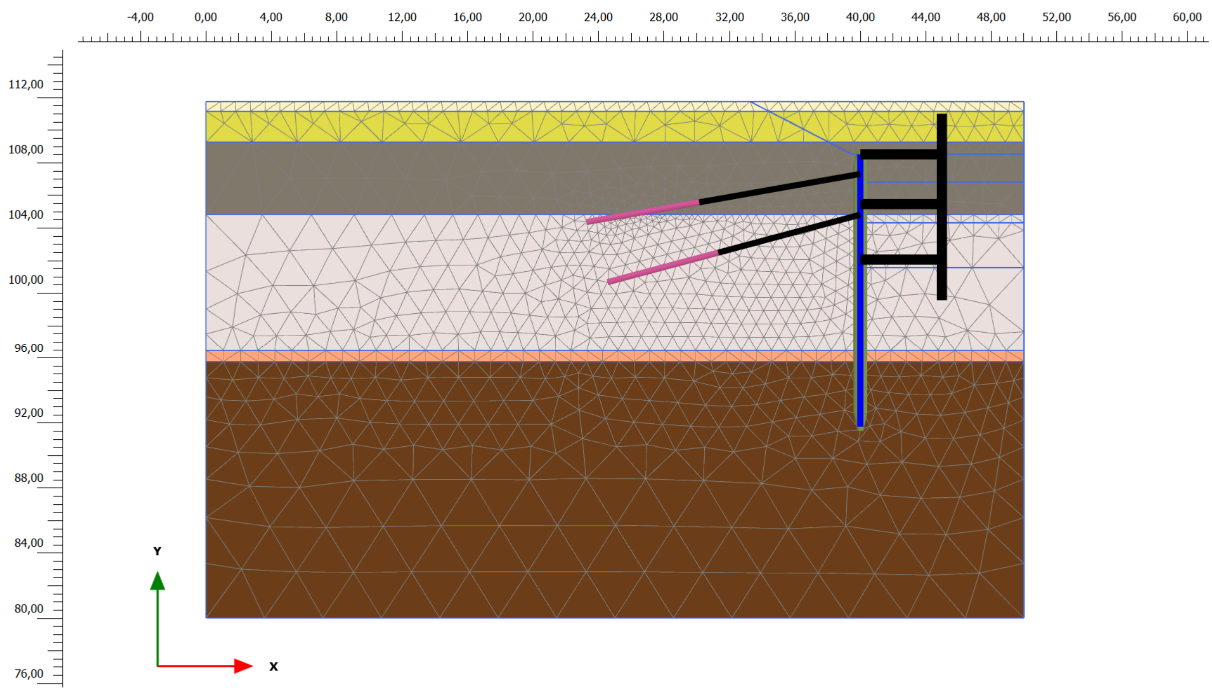

Figure 7. Plaxis model

The dimensioning of geotechnical anchors and diaphragm reinforcement is carried out for the internal forces shown in **Tables 7** and **8**. However, the procedure for their dimensioning is not presented in this paper. The maximum calculated horizontal displacement of the diaphragm wall is 2.6 cm, obtained in cross-section type 1.

Table 7. Axial forces in geotechnical anchors

STRUCTURAL ELEMENT	NODE	LOCAL NUMBER	X [m]	Y[m]	N [kN]	N_{min} [kN]	N_{max} [kN]
NODETONODEANCHOR_1_1 ELEMENT 1-1 (NODE-TO-NODE ANCHOR)	926	1	40.000	107.300	510.466	0.000	516.764
	16302	2	30.150	105.560	510.466	0.000	516.764
NODETONODEANCHOR_3_1 ELEMENT 2-2 (NODE-TO-NODE ANCHOR)	1684	1	40.000	104.800	583.559	0.000	583.559
	16367	2	31.310	102.470	583.559	0.000	583.559

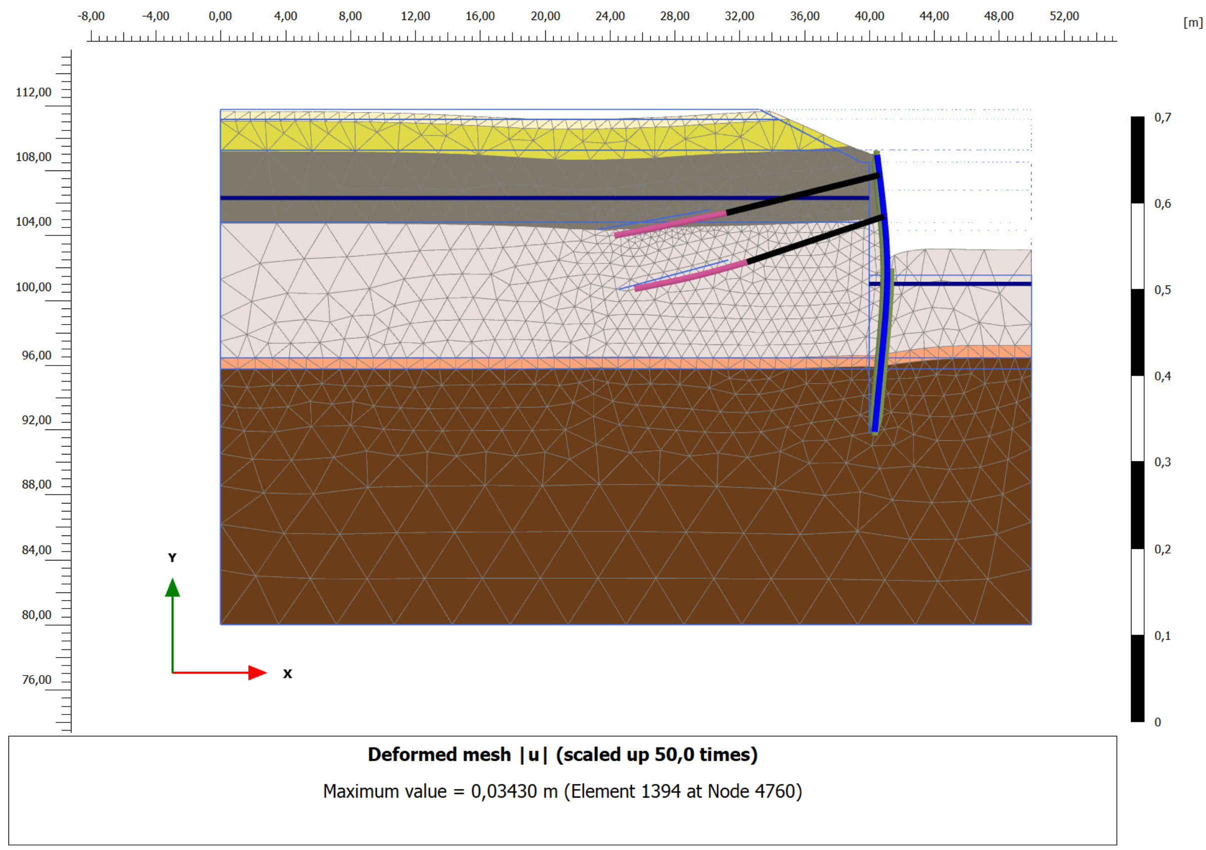

Figure 8. Horizontal displacements in the final stage of excavation

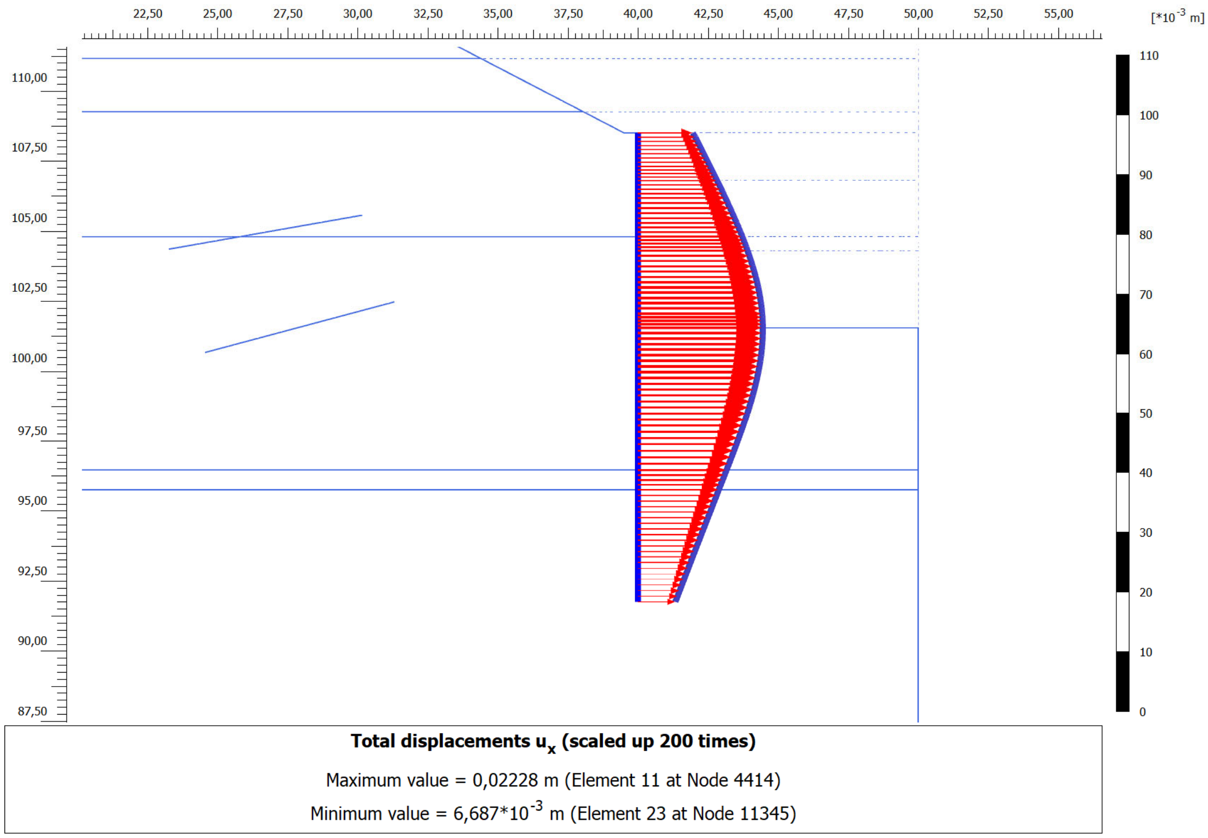

Figure 9. Horizontal displacements of the diaphragm wall

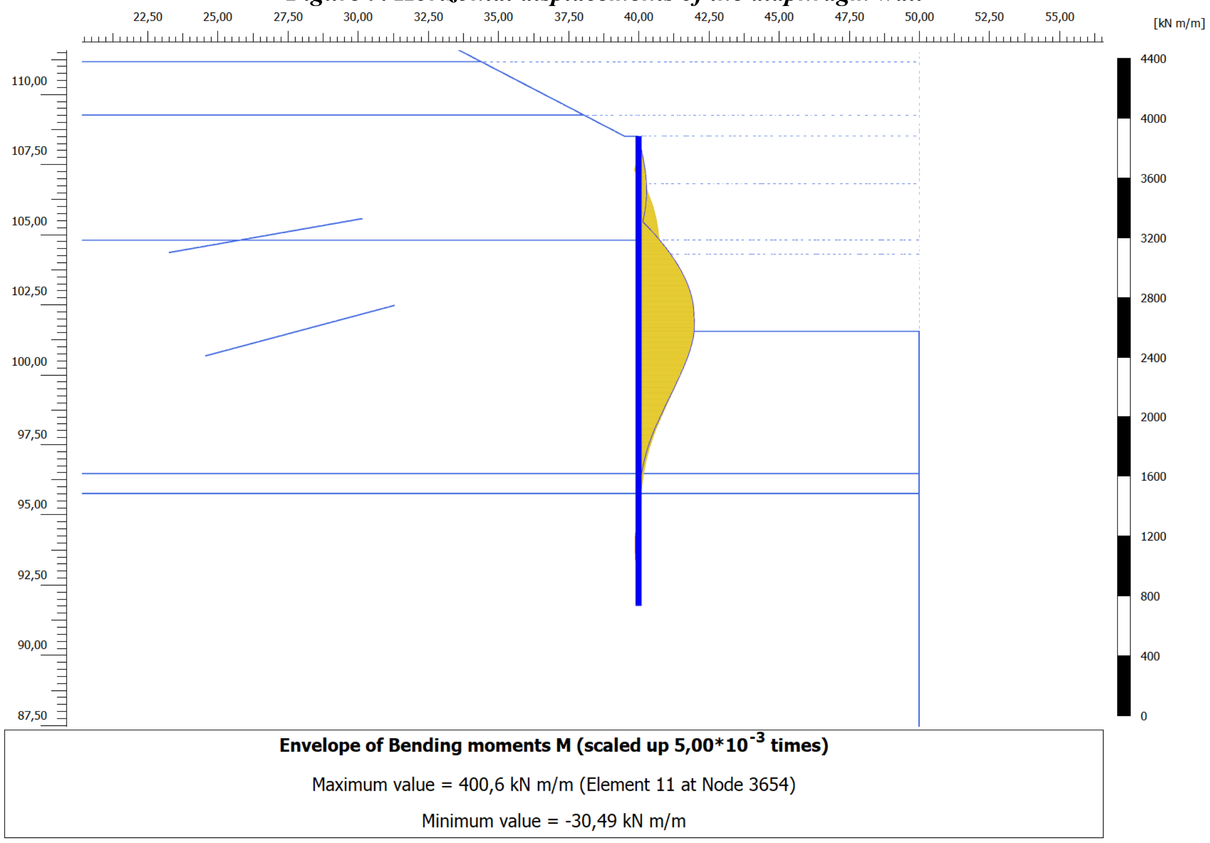

Figure 10. Envelope of diaphragm bending moments

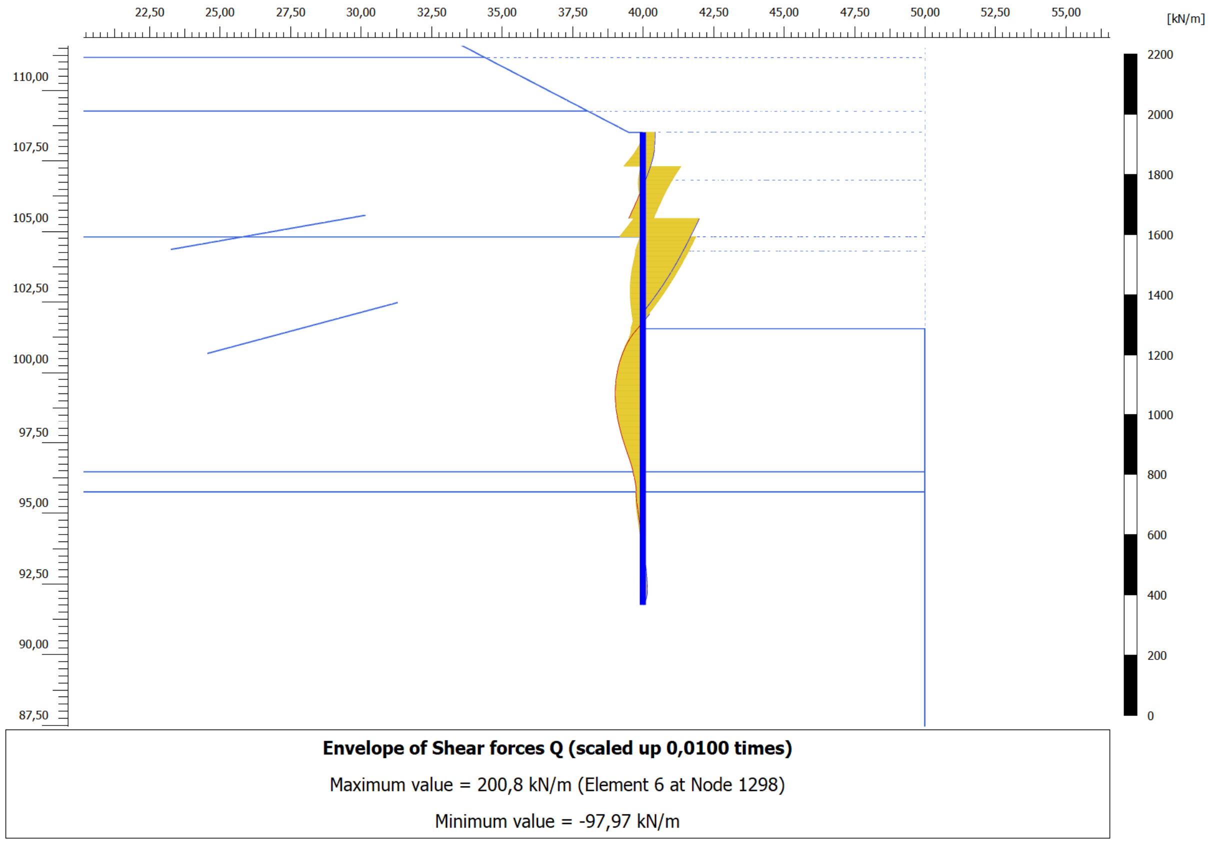

Figure 11. Envelope of diaphragm transverse forces

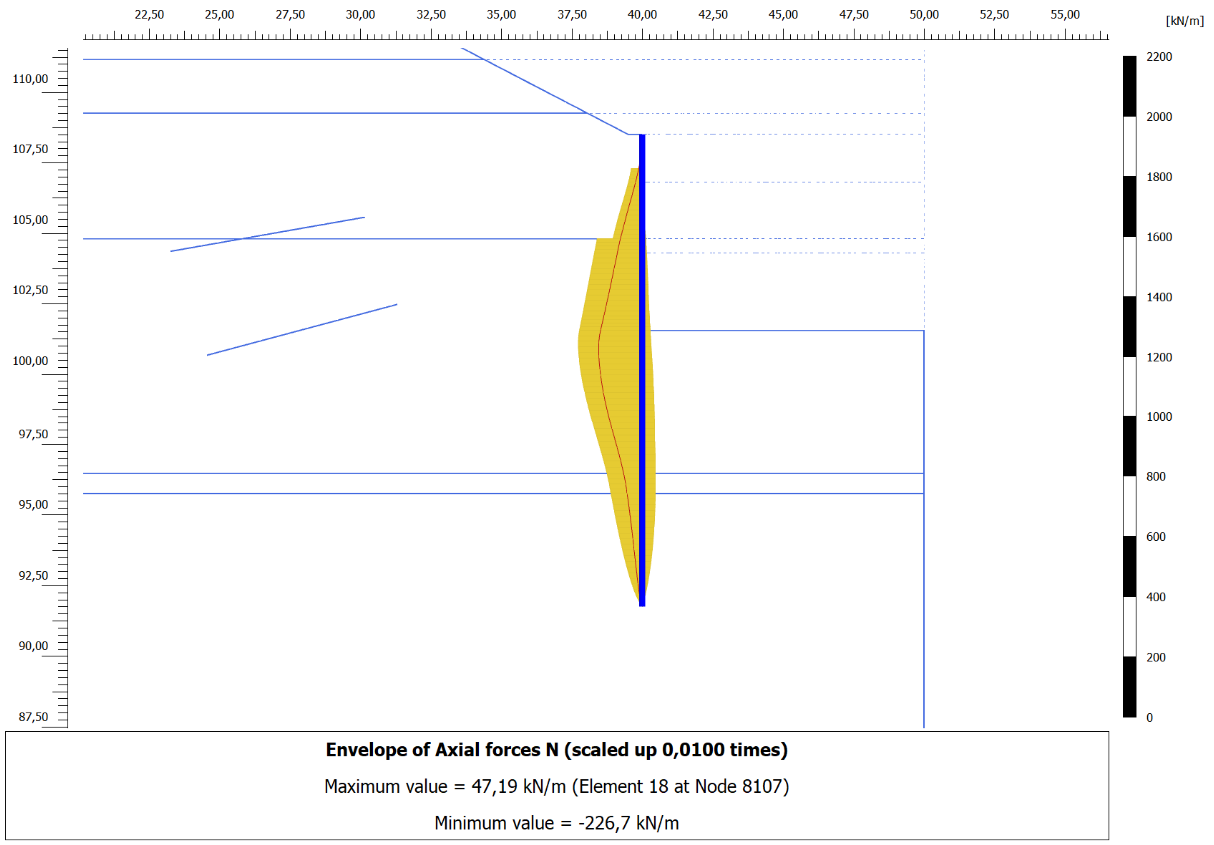

Figure 12. Envelope of longitudinal diaphragm forces

Table 8. Actions and displacements of the diaphragm

DIAPHRAGM WALL d = 60 cm	M_{maks}	Q_{maks}	N_{maks}	u_x
	[kNm/m]	[kN/m]	[kN/m]	[cm]
DESIGN SITUATION	Cross section Type 2			
PERMANENT	400,6	200,8	-226,7	2,2
	Cross section Type 1			
PERMANENT	418,8	207,9	-270,6	2,6
	Cross section Type 3			
PERMANENT	275,1	167,2	-230,8	1,4
RELEVANT VALUES	418,8	207,9	-270,6	

4. DISCUSSION AND CONCLUSION

The paper presents an example of a deep excavation support system design in an urban environment. Excavation is being carried out to construct the three underground floors of a commercial-residential building located at 10 Frana Folnegovića Street in the Trnje district of Zagreb, Croatia. The maximum excavation depth is 10.5 meters. During the geotechnical investigation, the groundwater level is determined at a depth of 5.8 m. Since the excavation is carried out in soil of high hydraulic conductivity, one of the selected support system's essential features was ensuring the execution of construction works in dry conditions. Considering relevant factors, a concrete diaphragm wall with a width of 60 cm and lengths of 17 and 18.25 m was selected as an excavation support system. Due to the different conditions in proximity to existing buildings, three types of cross-sections were chosen, shown in **Figures 4, 5** and **6**. The diaphragm wall ends in a layer of highly plastic clay (CH), reducing groundwater inflow into the construction pit. In addition, a system of drainage trenches and wells is planned at the bottom of the pit. The diaphragm wall is supported by two rows of geotechnical anchors. The length of the anchors in the upper row is 17 m (10+7), and in the lower row is 16 m (9+7). Geotechnical analyzes were carried out using the commercial geotechnical software Plaxis 2D. The results of geotechnical analyses are shown in **Figures 8-12**. Based on these results, the diaphragm wall reinforcement and geotechnical anchors are dimensioned, which is not shown in this paper. However, as the deep excavation is carried out in an urban environment, potential deviations in the behaviour of the diaphragm wall could threaten the stability of neighbouring buildings. For this reason, continuously monitoring the diaphragm's wall displacements is necessary. The purpose of monitoring is the confirmation of design assumptions and the possibility of interventions if there are more significant deviations than anticipated. The project includes the monitoring activities:

- monitoring the diaphragm wall movement using inclinometers,
- monitoring displacements of the header beam.

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IMPACT OF GLOBAL WARMING ON AVERAGE ANNUAL AIR TEMPERATURE IN VARAŽDIN

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Abstract: *Climate change implies a statistically significant change in the long-term mean state or characteristics of the variability of climate elements. It can be caused by natural and/or anthropogenic factors. Recent global warming is often cited as an example of human-induced climate change. Global warming refers to the increasing trend of the average global surface temperature of the Earth, defined as the global average of the mean annual surface temperature of the ocean, usually to a depth of 30-100 cm, and the mean annual surface temperature of the air above the land at a height of 1-2 m above the ground. In 1988, the World Meteorological Organization (WMO) and the United Nations Environment Program (UNEP) established the International Panel on Climate Change (IPCC), which assesses the state of the climate and the risk of climate change caused by human activities.To project climate change, it is necessary to determine the future emissions of greenhouse gases in the atmosphere. According to the IPCC, with appropriate scenarios of greenhouse gas emissions, an increase in the average global surface temperature of 1.5 °C to 4 °C is predicted by the end of the 21st century. The purpose of this paper is to show the relationship between the trend and variability of the global average of the mean annual surface temperature on Earth and the trend of the mean annual air surface temperature in Varaždin for the period 1949-2021. The results show significant correlations among them because Varaždin is located in an big area of surface air temperature anomalies which has a significant contribution to a global average anomalies in several last decades.*
Keywords: *climate change, global warming, long-term projections of mean global surface temperature, air temperature in Varaždin*

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1. INTRODUCTION

Climate of Earth atmosphere stands out as one of the most important components of the environment. The human population has to adapt to the climate and protect itself from possible harmful climatic influences. Global climate changes are associated with changes in the Earth's energy balance. Local climate changes refer to geophysical changes in a smaller area (e.g. deforestation) (Branković 2014). **Figure 1** shows the 10 globally warmest years from the beginning of continuous meteorological measurements until 2021.

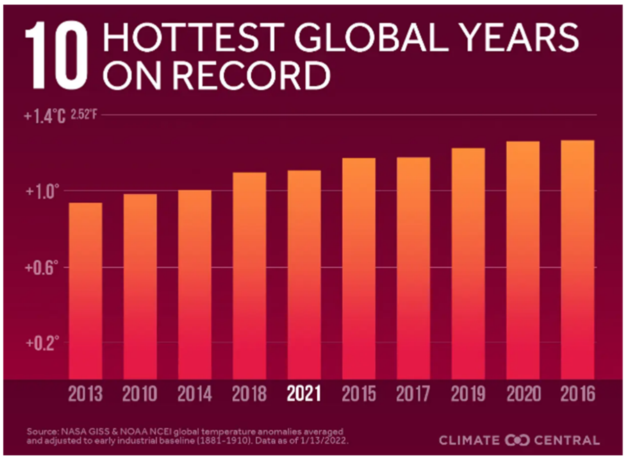

Figure 1. *The 10 warmest years globally from the beginning of systematic meteorological measurements until 2021 (Climate Central 2022)*

According to temperature analyzes of the National Aeronautics and Space Administration (NASA) and the National Oceanic and Atmospheric Administration (NOAA), the year 2021 was the 6th warmest year on Earth since the beginning of systematic meteorological measurements. According to the analysis of the non-profit organization Climate Central, the year 2021 was 1.1 °C warmer than the multi-year average for the period from 1881 to 1910 (Climate Central 2022).

NASA declared 2020 the warmest year so far since the beginning of systematic meteorological measurements, while NOAA declared it the second warmest year. According to the analysis of the organization Climate Central, the year 2020 was 1.25 °C warmer than the multi-year average for the period from 1881 to 1910 (Climate Central 2021).

Scientists, with very high confidetality, are sure that the global temperature will continue to rise in the coming decades, mainly due to greenhouse gases created by human activity. In its latest 6th report, the IPCC, in the preparation of which thousands of scientists around the world were involved, predicts the growth of global temperatures from 1.5 °C to 4 °C by the end of the 21st century (**Figure 2**) based on the results of the IPCC special report on limiting global warming to 1.5 °C (IPCC 2021). The five illustrative scenarios are referred to as SSPx-y, where 'SSPx' refers to the Shared Socio-economic Pathway or 'SSP' describing the socio-economic trends underlying the scenario, and 'y' refers to the approximate level of radiative forcing (in watts per square metre, or W/m^2) resulting from the scenario in the year 2100. **Figure 2** shows five scenarios of the development of greenhouse gas emissions: SSP1-1.9, SSP1-2.6, SSP2-4.5, SSP3-7.0 and SSP5-8.5. Also, the change in the global surface air temperature from 2081 to 2100 is presented in reference to the average for the period from 1850 to 1900. Within a particular scenario, the first column shows the total global surface warming [°C], in the second column warming caused by CO_2 emissions, in the third column warming caused by emissions of other gases except CO_2 and in the fourth column net cooling from land-use aerosols. A vertical line on each column shows the possible warming range. The influence of CO_2 emissions is dominant compared to non-CO_2 emissions. Darker shaded bars indicate warming so far. A smaller contribution to mitigating global warming comes from aerosols and land use (IPCC 2021). The net annual costs due to the adverse effects of weather and climate extremes will increase over time as the global temperature increases (IPCC 2007).

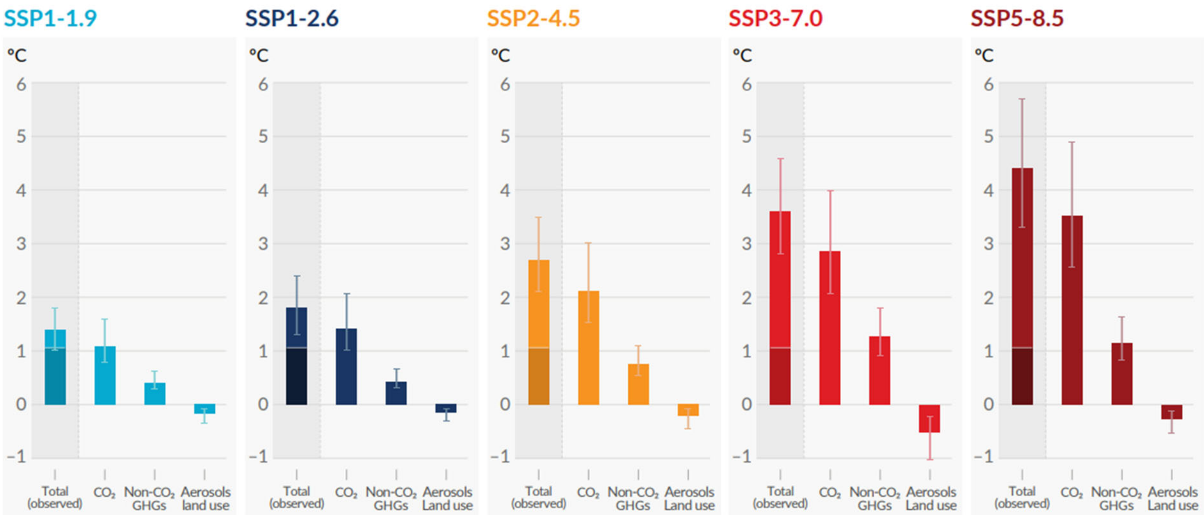

Figure 2. *Greenhouse gas emission scenarios until the end of the 21st century and changes in global surface temperature for the period 2081 - 2100 compared to the period 1850 - 1900 (IPCC 2021)*

Figure 3a, in the upper part of the figure, shows a comparison of the measured and climate model-simulated changes in the mean annual air temperature at global warming of 1 °C. Regional warming, which corresponds to global warming of 1 °C, is visibly more pronounced on the continents than over the oceans, it is more pronounced in the northern hemisphere than in the southern, and especially in the Arctic area. It can be concluded that the measured and simulated changes in mean annual air temperature are consistent. **Figure 3b**, in the lower part of the figure, shows the simulated change in the mean annual surface air temperature in reference to the period from 1850 to 1900 at global warming of 1.5 °C, 2 °C and 4 °C. It should be noted the consistency in the geographical distribution of the intensity of change in mean annual temperature for all three scenarios of global warming (IPCC 2021).

This paper presents and analyzes the change in mean annual air temperature for Varaždin meteorological station for the period from 1949 to 2021. Average daily air temperature data for the city of Varaždin were taken from the Croatian Meteorological and Hydrological Service (DHMZ). The annual average, five-year moving average and a multi-year average of the mean annual temperature were calculated, and a graph was created based on these data. To confirm the stochastic connection between the mean annual global surface temperature and the mean annual air temperature for the city of Varaždin, it was necessary to show the change in the mean annual surface temperature for the period from 1949 to 2021 for the global level. At the end, the stochastic relationship of the respective global and temperature for the weather station Varaždin was analyzed and graphically presented.

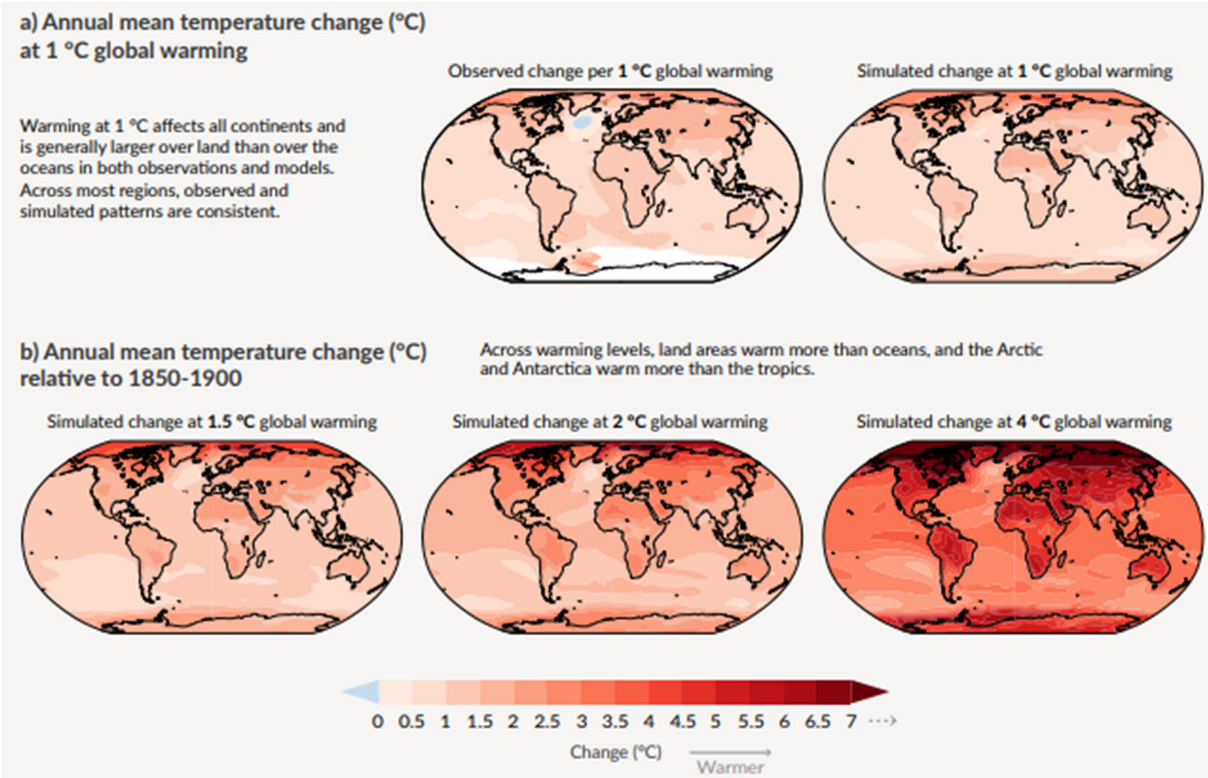

Figure 3. *a) comparison of the geographical distribution of the observed and climate model-simulated change in mean annual temperature corresponding to global warming of 1 °C; b) distribution of the simulated change in mean annual temperature at global warming of 1.5 °C, 2 °C and 4 °C (IPCC 2021)*

2. MATERIALS AND METHODS

In Varaždin, continuous measurement of air temperature began in 1949. **Equation 1** is used to calculate the average daily air temperature:

$$t_{average} = \frac{t_7 + t_{14} + 2t_{21}}{4} \qquad (1)$$

At which:
$t_{average}$ - mean daily temperature
t_7 - temperature value measured at 7 a.m.
t_{14} - temperature value measured at 2 p.m.
t_{21} -temperature value measured at 9 p.m., local time (DHMZ 2022).
t_{21} is multiplied by 2 to be emphasised t_{21} as night term as there are 2 daily terms t_7 and t_{14}. The mean annual temperature is obtained as the sum of the mean daily temperatures divided by the number of days in the year.

With the help of data taken from DHMZ and (NASA Global Climate Change 2022), the annual temperature average and five-year moving average can be calculated for Varaždin and at the global level for the period from 1949 to 2021. The annual average represents the mean value of all mean daily temperatures in the year. The sum of average daily temperatures in a year is divided by the number of days in that year and the annual average is obtained. The five-year moving average is calculated to get an overall idea of quasi-periodic so-called interdecadal temperature fluctuations in addition to trend. In statistics, moving average refers to a calculation used to analyze data by creating a series of averages of different subsets of the entire data set (Investopedia 2022).

Equation 2 is used for calculating the simple moving average:

$$SMA = \frac{A_1 + A_2 + \cdots + A_n}{n} \qquad (2)$$

At which:
A_k - average in a certain time period k, for k =1, ..., n
n - number of time periods (Investopedia 2022).

The multi-year average refers to the 30-year reference period from 1951 to 1980 used by NASA. The multi-year average of the mean annual air temperature for the period from 1951 to 1980 for Varaždin is 9,866 °C, and at the global level it is 13,889 °C (NASA Earth Observatory 2022). The annual average surface temperature at the global level can be calculated by adding 13,889 °C to the temperature anomaly, considering the period from 1951 to 1980. In this paper, time series were formed, trends and stochastic connection between time series were analyzed at the global (average annual surface temperature) and local level (average annual air temperature for the city of Varaždin).

3. RESULTS AND DISCUSSION

3.1. Analysis of the relationship between local and global temperature trends

Figure 4 shows annual averages, five-year moving averages and multi-year averages (1951-1980) of the mean annual air temperature for Varaždin. The annual average of the mean air temperature is shown by the blue line, the five-year moving average of the mean annual air temperature by the orange line, and the multi-year average (1951-1980) by the gray line.

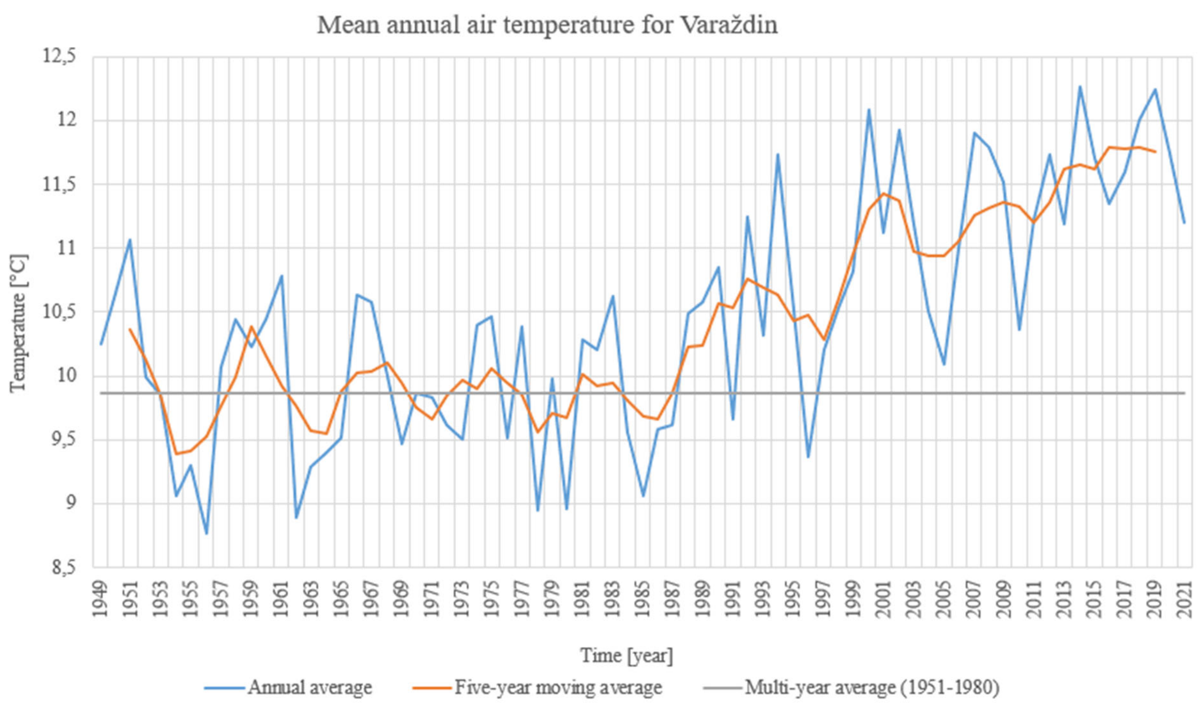

Figure 4. *Graphic display of time series of annual average (1949-2021), five-year moving average and multi-year average (1951-1980) of air temperature for Varaždin*

From the graphic representation, it can be concluded that the annual average or mean air temperature for Varaždin is gradually increasing and since 1997 it has been higher than the multi-year average for the period from 1951 to 1980. In the five-year moving average, a similar increase has been observed since 1987. The minimum annual average air temperature for Varaždin is 8.76 °C for the year 1956 when it was one of the strongest winters in Croatia since measurements have been available. The maximum annual average air temperature for Varaždin is 12.27 °C in 2014.

Figure 5 shows annual averages, five-year moving averages and multi-year averages (1951-1980) of mean global surface temperature. It can be concluded that since 1977, the annual average of the mean global surface temperature has not fallen below the reference average, although accompanied by certain interannual changes.

Figure 6 shows a scatter diagram between the mean annual global surface temperature and the mean annual air temperature for Varaždin. Each data pair is shown with a blue dot, and the points are assigned a regression line, to which belongs the corresponding regression equation and the coefficient of determination that represents the square of the correlation coefficient. The coefficient of determination shows how much percent of the variance of one variable can be described by another variable. In this case, the R-squared value is 0.4958. According to the coefficient of determination, it is determined whether there is a significant stochastic (statistical) relationship between the corresponding global surface temperature and the air temperature for Varaždin: including the increase in air temperature for Varaždin from 1949 to 2021, which follows the global warming clearly expressed since the beginning of the 1980s.

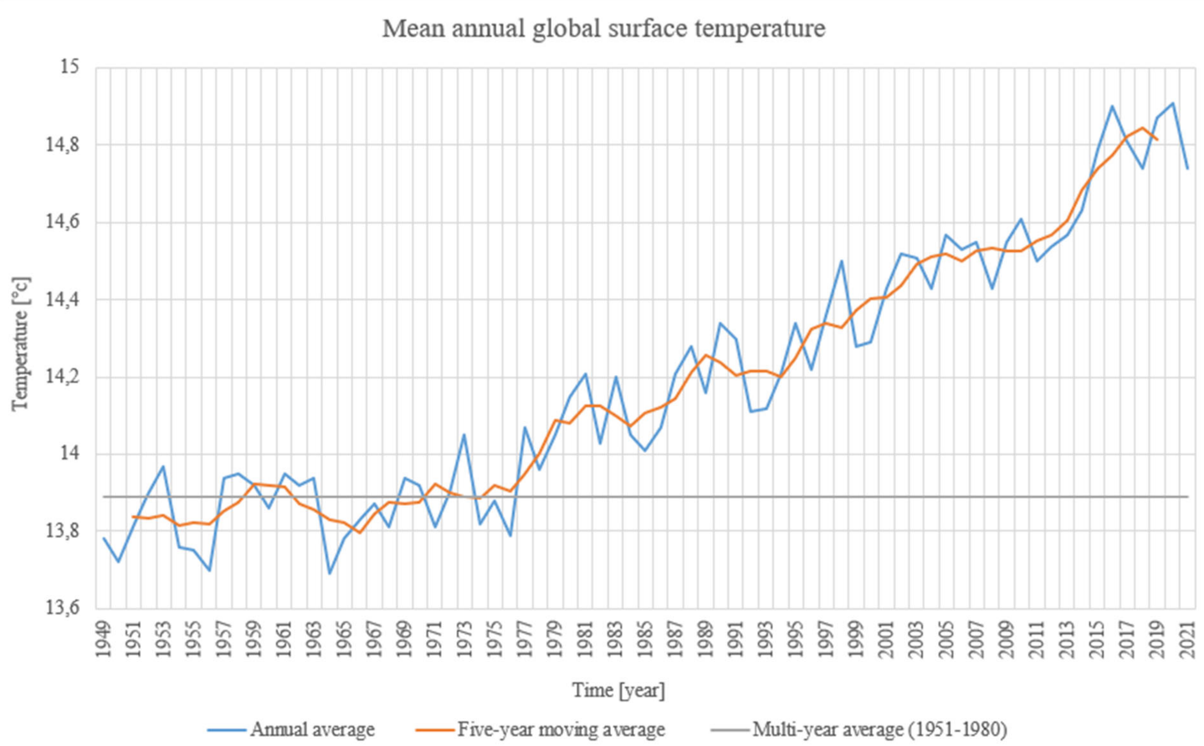

Figure 5. *A presentation of annual average, five-year moving average and multi-year average (1951-1980) of mean annual global surface temperature for the period 1949-2021*

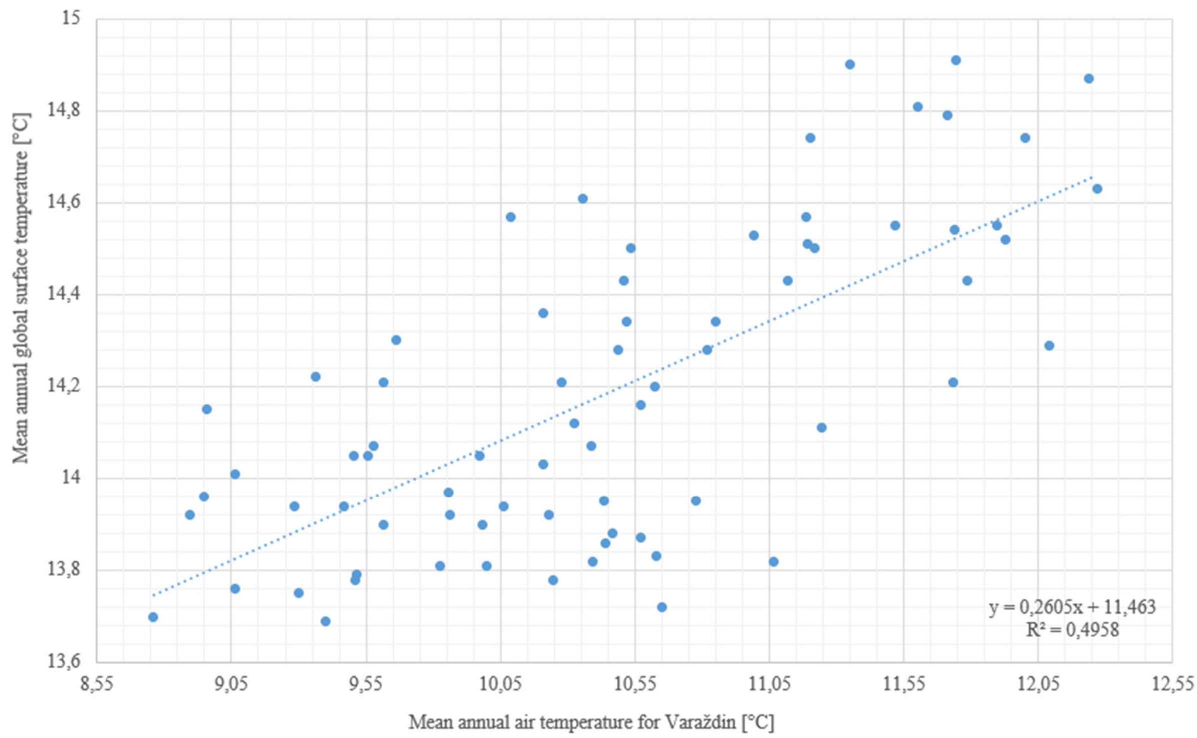

Figure 6. *Scatter diagram between mean annual global surface temperature and mean annual air temperature for Varaždin*

To get an overall idea of the trend in the data set, a graphic representation of the relationship between global and mean daily temperature for Varaždin was created using five-year moving averages (**Figure 7**). The five-year moving average of the mean annual temperature for Varaždin is shown on the abscissa, and the five-year moving average of the mean annual temperature on the global level is shown on the ordinate. In this case, the R-squared value is 0.8362. From the above, it can be concluded that the stochastic relationship between the rise of temperature at the global level and in Varaždin, especially after the 1990s of the last century until 2021. Such a result is a consequence of the spatial distribution of the increase in mean annual surface temperature anomalies up to now in reference to the pre-industrial period (1859-1900) shown in **Figure 3a**. A similar relationship is expected until the end of the 21st century (1981-2100), for which period the scenario of the spatial distribution of changes in mean annual temperature is shown in **Figure 3b**.

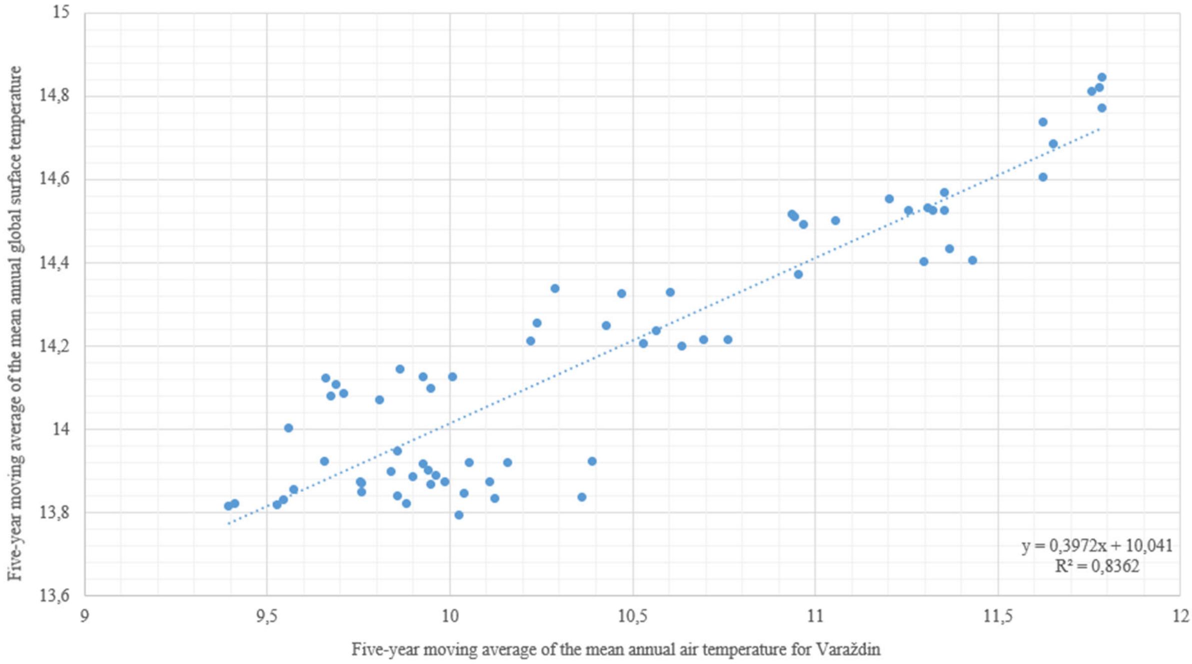

Figure 7. *Scatter diagram between the five-year moving average of the mean annual global surface temperature nad the moving average of the mean annual air temperature for Varaždin*

The NASA results published on its website are very illustrative (NASA Scientific Visualization Studio 2021**).** Five-year surface temperature anomalies compared to the 1951-1980 average were published on that portal. Until the beginning of the 1980s, positive and negative anomalies were evenly distributed around the globe (**Figure 8a**). After that, positive anomalies occupy more and more space on Earth (**Figure 8b**). The significant correlation between global and temperature for Varaždin is a consequence of Varaždin's position in relation to the vast European-Asian area with the most pronounced global warming in the entire globe. It is interesting that, according to the results of climate models, the approximate configuration of global warming anomalies is expected until the 21st century almost independently of the greenhouse gas emission scenario, taking into account the fact that anomalies are larger for scenarios with higher greenhouse gas emissions.

3.2. Time series analysis

A time series is a chronologically arranged set of values of a variable that shows a certain phenomenon in time (Šošić 2006). In our case, it is about two variables: the average annual air temperature for Varaždin and the average global surface air temperature, respectively, in a time interval of 73 consecutive years (from 1949 to 2021). Graphic representation of these time series can be found in **Figures 4** and **5** (the corresponding graph lines are marked in blue). Since the increase in the average annual air temperature in Varaždin and the average global surface air temperature is visible from the graphic display, linear trend models will be constructed for both variables in order to describe the behavior of the observed temperature over time and so that temperature in the future can be extrapolate using them for years.

The linear model was incorporated into the time series of mean daily temperature with the purpose of determining the presence of a trend of increasing air temperature in Varaždin and global surface air temperature.

The linear trend model is essentially the same as the simple linear regression model in which the independent variable is time t (Šošić 2006). The direction coefficient in that model represents the average linear temperature change in a year, and the constant term is treated as the value of the linear trend for the year preceding the first term of the time series.The representativeness indicator of the trend model is the coefficient of determination R^2.

The mentioned linear trend was modeled in Excel, and the function of the linear trend of the mean annual temperature for Varaždin was obtained using **Equation 3** (**Figure 9**):

$$T = 0.028517 \cdot t + 9{,}397761 \qquad (3)$$

where t represents the time in years (t=1 represents the first year for which measurements were made, 1949), and T average annual air temperature for Varaždin.

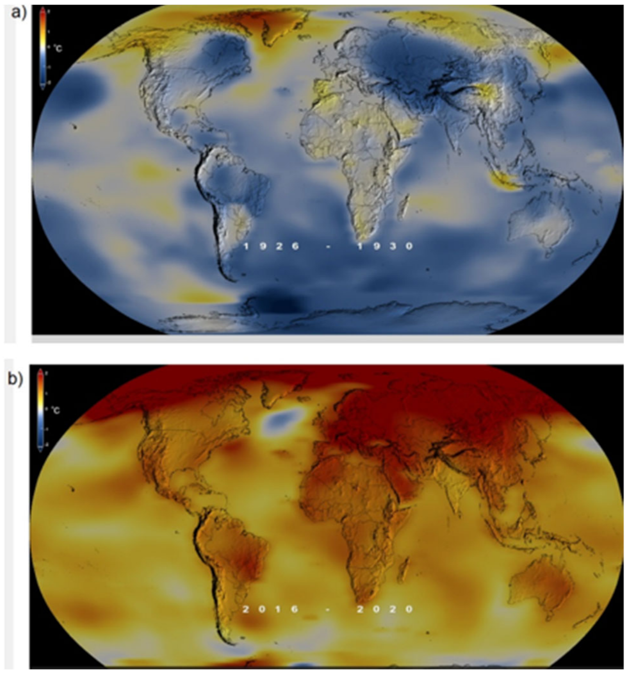

Figure 8. *Change in the distribution of the five-year mean of surface temperature anomalies in relation to the reference period 1951-1980 for the period: a) 1926-1930 and b) 2016-2020 (NASA Scientific Visualization Studio 2021)*

Note that the constant term is 9.397761, and the direction coefficient is 0.028517. This means that it was estimated that in 1948 the average annual air temperature in Varaždin would be 9.397761 °C, and the mean annual temperature for Varaždin increases on average linearly by 0.028517 per year. Using this linear trend model, we can estimate future trends in the average annual air temperature for Varaždin. For example, we can predict that the average annual air temperature in Varaždin in 2028 (t=80) would be (**Equation 4**):

$$T = 0{,}028517 \cdot 80 + 9{,}397761 = 11{,}679121\ °C. \qquad (4)$$

The coefficient of determination of this linear trend amounts to R^2=0.439043, which we interpret as a poor representative trend.

Equation 5 shows the linear trend function of the mean annual global surface air temperature (**Figure 10**):

$$T = 0{,}014938 \cdot t + 13{,}63277 \qquad (5)$$

where t= time in years, and T is the mean annual global surface air temperature.

In this model, the constant term is 13.63277 and it represents the estimated value of the mean annual global temperature for the year 1948, while the direction coefficient is equal to 0.014938 and we interpret it as a linear increase of the mean annual global temperature in a year. Using this model, we can forecast values for the following years, for example, the forecast value of the mean annual global temperature in 2028 (t=80) is (**Equation 6**):

$$T = 0{,}014938 \cdot 80 + 13{,}63277 = 14{,}82781\ °C. \qquad (6)$$

The coefficient of determination of this linear trend amounts to R^2=0.880278 which leads us to the conclusion that it is a representative linear trend.

3.2. Testing hypotheses about the significance of the regression variable on linear trend models

As we mentioned earlier, the linear trend model is a linear regression model. Now we will test the hypotheses about the significance of the regression variable (t) in the model:

- H_0: the direction coefficient is equal to 0 (that is, the variable t is redundant in the model)
- H_1:the direction coefficient is different from 0.

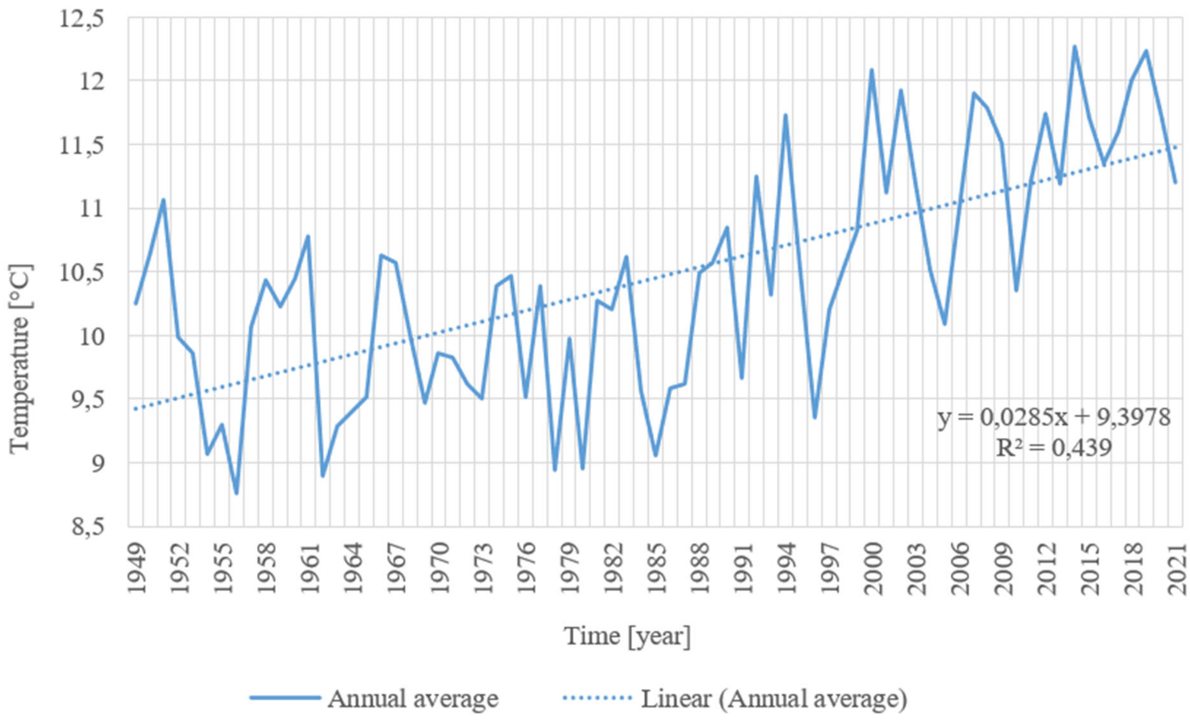

Figure 9. *The linear trend of mean annual air temperature for Varaždin*

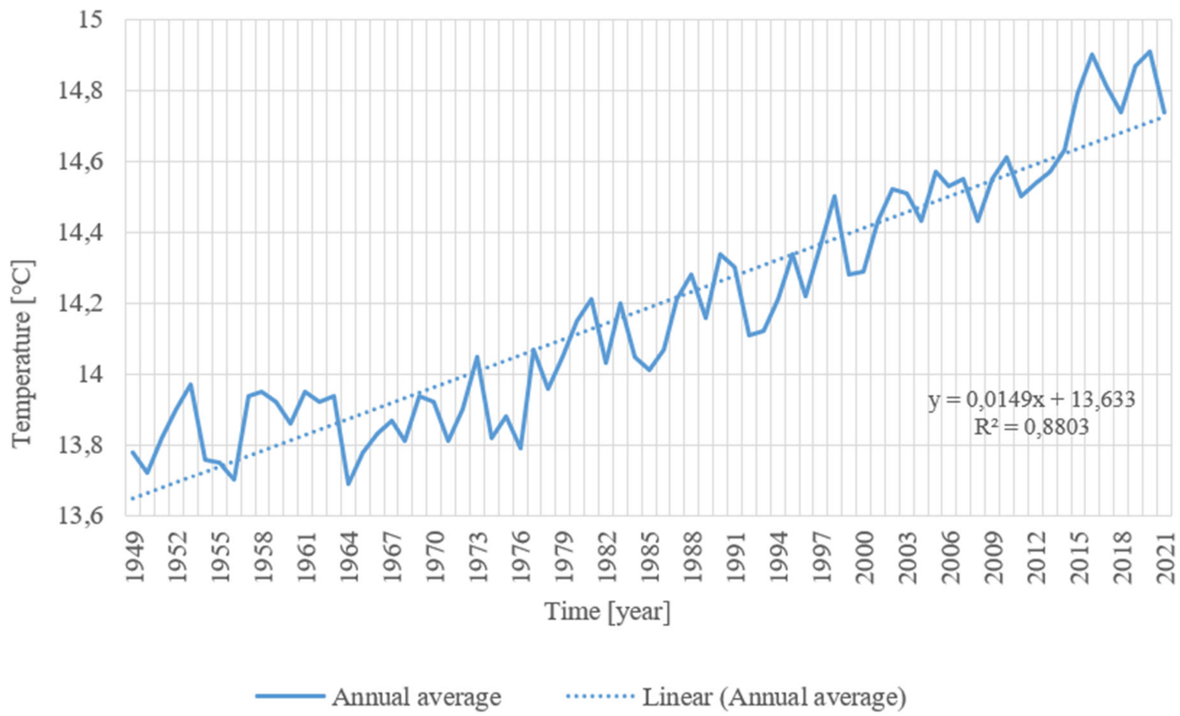

Figure 10. *The linear trend of mean annual global air temperature*

The null hypothesis (H_0) can be interpreted in such a way that the air temperature (for the city of Varaždin or globally) does not depend on time, that is, it does not change with the years. This test is based on a test statistic that has an F-distribution with (1, n-2) degrees of freedom (Pauše 1993) and whose value is obtained when calculating the regression linear model in Excel. For the level of significance α=0.05 from the F-distribution table (Pauše 1993) for (1.71) degrees of freedom, we read the threshold value 252.2.

In the first case, when the dependent variable is the average annual air temperature for the city of Varaždin, the value of the test statistic is 55.6, which is less than the threshold value, so in this case, we cannot reject the null hypothesis. In the second case, when the observed dependent variable is the mean annual global surface air temperature, the value of the test statistic is 522, which is higher than the threshold value, so in this case, we can reject the null hypothesis, that is, we accept the obtained linear trend model.

Let's note that in the case of the first model, where the coefficient of determination is much lower than 1, and thus the model itself is poorly representative, testing the hypothesis about the direction coefficient of that linear model resulted in the conclusion that such a model is not accepted. On the other hand, in the second model where the coefficient of determination is much higher (and therefore the model is also representative), testing the hypothesis about the direction coefficient of that model resulted in the conclusion of acceptance of such a model.

3. CONCLUSION

It is often a question among the public how pronounced global warming has been in recent decades compared to the local one. This paper aims to show the stochastic relationship between the mean global annual temperature and the mean annual air temperature for Varaždin from 1949 to 2021. The results show that there is a significant relationship between the mentioned temperatures because the Varaždin area belongs to the European-Asian area where global warming is the most pronounced in the world, which according to climate scenarios will continue until the end of 21st century. According to the presented results, it can also be concluded that the linear trend model is representative in the case of the average annual global surface temperature and can be used in the prediction of future values, but with due caution given that the circumstances affecting global warming are constantly changing, for example, the concentration of greenhouse gases in the atmosphere. An additional resource for global surface temperature forecasts are scenarios of climate models. In this case, the considered regression relationship between global and local temperature for Varaždin is a preferable alternative, as are the results of climate models. The next step in researching this topic could be researching the impact of global warming on the entire area of Croatia or wider.

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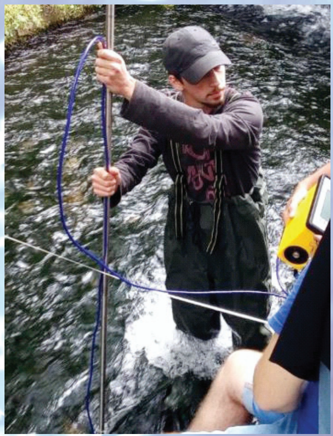









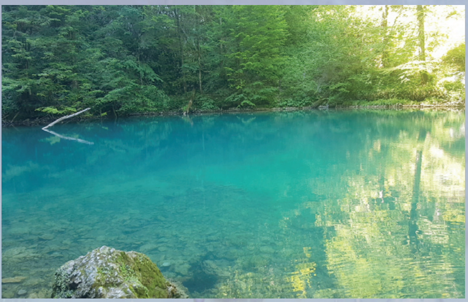


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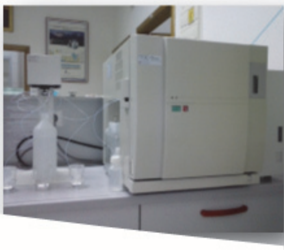

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~ atomskom apsorpcijskom spektrometrijom: Al, As, B, Ba, Ca, Cd, Co, Cr, Cu, Fe, Hg, K, Li, Mg, Mn, Mo, Na, Ni, Pb, Se, Si, Sr, Ti, V, Zn
~ amonijak, nitriti, nitrati, ukupni dušik
~ bromidi, fenoli, fluoridi, fosfati, jodidi, kloridi
~ silikati, sulfidi, sulfati, sulfiti
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~alkalitet, ukupna tvrdoća, karbonatna tvrdoća, nekarbonatna tvrdoća, kalcijeva tvrdoća, magnezijeva tvrdoća
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~ ukupni organski ugljik i ukupni dušik – TOC/DOC/TN
~ razaranje tla zlatotopkom
~ ekstrakcija izmjenjivih kationa iz tla amonijevim acetatom i kalijevim kloridom

Provođenje agrokemijskih analiza tla u svrhu modernizacije poljoprivredne proizvodnje, racionalizacije gnojidbe, povećanja prinosa i zaštite prirodnih resursa.

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Saša Zavrtnik, dr.med.vet.
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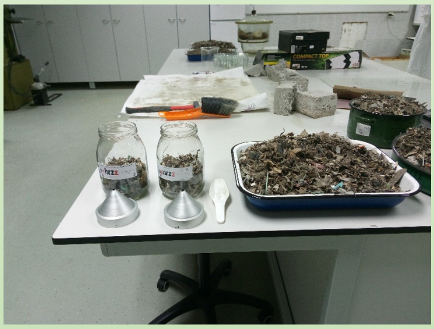

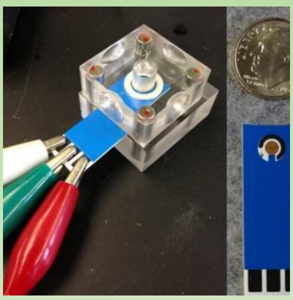

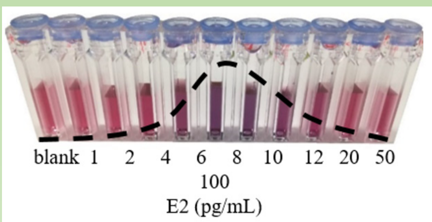

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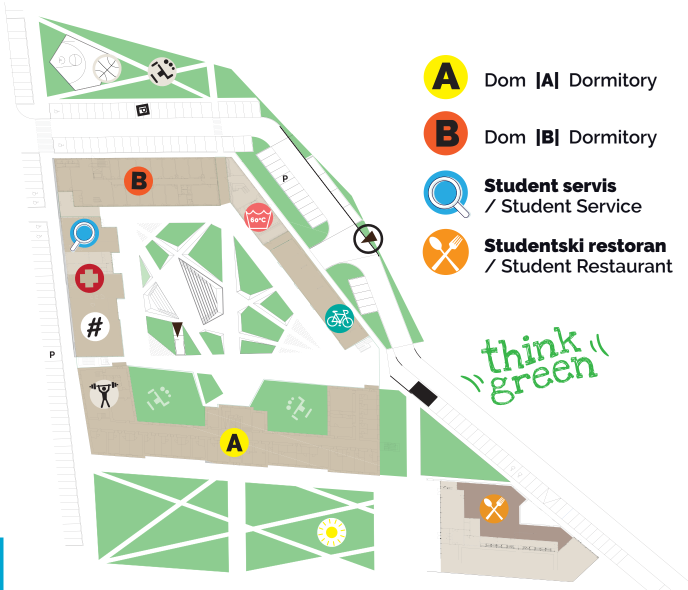

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studentska.referada@gfv.unizg.hr

Točne datume upisa i ostale relevantne informacije možete potražiti na web stranicama fakulteta: www.gfv.unizg.hr

ADRESA: Geotehnički fakultet Sveučilišta u Zagrebu, Hallerova aleja 7, 42000 Varaždin

Studij inženjerstva okoliša – Geotehnički fakultet

inzenjerstvo_okolisa

STUDIJ INŽENJERSTVA OKOLIŠA

FAKULTET
KOJIM ĆEŠ
MIJENJATI SVIJET
NA
BOLJE

STUDIJ INŽENJERSTVA OKOLIŠA

Geotehnički fakultet Sveučilišta u Zagrebu

Opis zvanja - kompetencije i osposobljenost

Završetkom sveučilišnoga **preddiplomskog studija** na Geotehničkom fakultetu steći ćeš osnovne kompetencije u identificiranju, definiranju i rješavanju inženjerskih zadaća u Inženjerstvu okoliša.

Od praktičnih znanja kao prvostupnik Inženjerstva okoliša posjedovat ćeš sposobnost korištenja laboratorijske i terenske opreme, promatranja, bilježenja i analize podataka dobivenih laboratorijskim i terenskim ispitivanjima. Znat ćeš izraditi tehničke nacrte ručno i pomoću računala, te pripremiti prezentaciju tehničkih izvješća.

Znanja i kompetencije koja stekneš završetkom sveučilišnoga preddiplomskog studija odgovarajuća su za praćenje diplomskoga sveučilišnog programa na Geotehničkom fakultetu, a omogućavaju ti i praćenje diplomskih studija iz srodnih područja na drugim tehničkim studijima te praćenje različitih programa cjeloživotnog obrazovanja.

Diplomski studij Inženjerstvo okoliša traje dvije godine, a uključuje smjerove Geoinženjerstvo okoliša, Upravljanje vodama i Upravljanje okolišem. Ovaj studij mogu upisati studenti koji su završili sveučilišni preddiplomski studij ili strani studij ekvivalentnog programa.

Završetkom diplomskoga studija bit ćeš osposobljen upravljati okolišem na održiv način i preuzeti osobnu i timsku odgovornost za strateško odlučivanje i uspješnu provedbu zadataka pri izradi elaborata, studija i projekata iz inženjerstva okoliša, kao i primijeniti legislativu iz područja zaštite okoliša te preuzeti društvenu i etičku odgovornost za posljedice.

Doktorski studij Inženjerstvo okoliša traje tri godine, a njegovim završetkom stječu se kompetencije za provođenje samostalnog istraživačkog rada.

Mogućnost zaposlenja

Znanstvenu karijeru možeš nastaviti razvijati upisom na poslijedoktorski studij Inženjerstvo okoliša na našem Fakultetu. A ako si bio vrlo uspješan student, možda započneš svoju akademsku karijeru kao asistent na našem Fakultetu.

Izvan akademske ili znanstvene sredine, popis mogućih poslodavaca kod kojih se možeš zaposliti doista je raznolik. To su sve institucije državne i lokalne uprave, kao i svi gospodarski subjekti koji zapošljavaju osobe za obavljanje stručnih poslova zaštite okoliša, kao što su na primjer komunalna poduzeća, centri za gospodarenje otpadom, pročišćivači otpadnih voda, eksploatacijska polja. Nadalje, to su i svi oni gospodarski subjekti koji se bave obnovljivim izvorima energije te oni koji svojim proizvodnim procesom mogu naštetiti okolišu.

Ako želiš možeš postati i inspektor za zaštitu okoliša, a s ovim stručnim nazivom ti ni vrata Europske unije neće biti zatvorena.

Pogodnosti studiranja

Tijekom studiranja na našem Fakultetu kao student Sveučilišta u Zagrebu na raspolganju imaš razne pogodnosti. Detaljnije o pogodnostima možeš saznati u našem vodiču za brucoše:
http://www.gfv.hr/modules/m_gfv/datoteke/vodic_za_brucose_a5_final_v1.pdf

Znanost i suradnja s gospodarstvom

Na Geotehničkom fakultetu provode se i znanstvena istraživanja. Fakultet raspolaže akreditiranim geotehničkim laboratorijem, kao i laboratorijem za inženjerstvo okoliša, laboratorijem za geokemiju okoliša, informatičkim centrom za GIS. Primjereno smo opremljeni i za terenske istraživačke radove. Budući da istraživači koji ih provode sudjeluju i u izvođenju nastave, studentima se prenose najnovije spoznaje i rezultati istraživanja.

Velik doprinos nastavi i znanstvenom radu daje znanstvena i stručna suradnja Geotehničkog fakulteta sa srodnim visokoškolskim institucijama u Republici Hrvatskoj i svijetu. Usporedno s nastavom i znanstveno-istraživačkim radom, Fakultet održava i razvija i suradnju s gospodarstvom kroz izradu mnogobrojnih studija i projekata iz područja Inženjerstva okoliša.

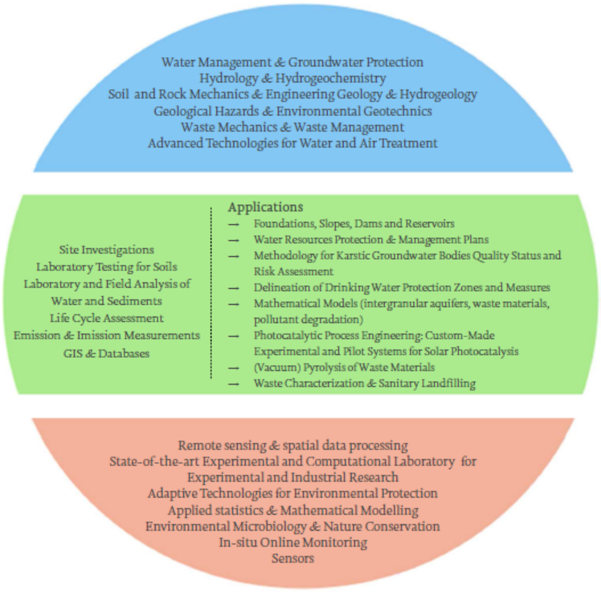
Sveučilište u Zagrebu
GEOTEHNIČKI FAKULTET

Sveučilišni doktorski studij Inženjerstva okoliša

odgovor je na zahtjeve naše svakodnevice gdje se susrećemo s problemima onečišćenja okoliša, klimatskim promjenama, potrošnjom resursa kao što su mineralne sirovine, tlo, vode, neadekvatnog upravljanja otpadom i niz drugih okolišnih problema.
https://www.gfv.unizg.hr/static/doktorski-studij

Nastavna struktura doktorskog studija koncipirana je u formi pet izbornih modula:

1. Održivo gospodarenje otpadom
2. Okoliš i priroda
3. Geoinženjerstvo okoliša
4. Upravljanje vodama
5. Energetika



Postgraduate doctoral study of Environmental Engineering

Problems concerning the field of environmental engineering demand both professional and scientific research approach, which is the only way of finding specific solutions to them. The programme emphasizes current socitetal needs concerning circular economy, which should enable sustainable waste management, natural resources management and protection, introduction of renewable energy sources and contributes to the mitigation of climate changes.
https://www.gfv.unizg.hr/static/doktorski-studij

The curriculum of the doctoral study consists of five modules:

1. Sustainable waste management
2. Environment and nature
3. Environmental Geoengineering
4. Water management
5. Energetics