THE INTERNATIONAL CONFERENCE
SYNERGY OF ARCHITECTURE & CIVIL ENGINEERING
SINARG 2023

PROCEEDINGS

VOLUME 1

sinarg 2023

International Conference
Synergy of Architecture & Civil Engineering

Niš (SERBIA) - Science & Technology Park Niš - September 14-15, 2023

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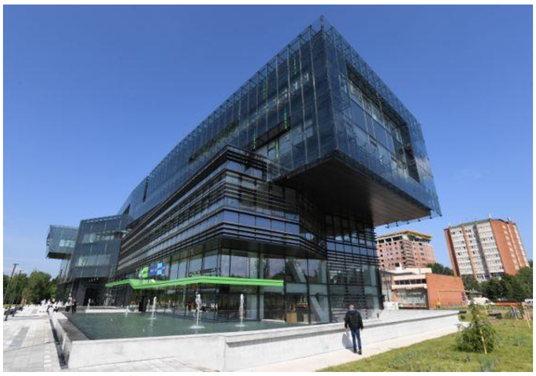

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PREFACE

The primary goal of the SINARG 2023 conference is to present contemporary achievements in the scientific and practical aspects of architecture and civil engineering. The organizers of the conference aimed to facilitate the participation of both national and international professionals in theoretical and experimental research related to the processes of design, project management, construction, and building maintenance within the construction industry.

Simultaneously, this scientific conference serves as a platform for exchanging experiences and information regarding innovations and advancements in planning, design, new materials, and construction and reconstruction technologies within the fields of architecture and civil engineering.

Therefore, this conference should serve as a forum where experts from civil engineering, architecture, and other related fields have the opportunity to present the results of their research. In that context, conference topics have been carefully selected to provide focus on current issues in the field and encourage productive discussion bringing fresh and original insights and concepts to the forefront.

More than 180 paper proposals have been submitted to the conference. A single-blind review process was used to assess the full papers. The reviewers are esteemed scientists holding PhD degrees in the same field as the paper's topic. There are more than 70 reviewers from ten countries who have significantly contributed to the scientific quality of the conference, and their names are printed in the proceedings.

A total of 142 full papers have been accepted for publication. Some of the papers have been selected for publication in our journals, with nineteen papers in Facta Universitatis: Architecture and Civil Engineering and nine in the Journal of the Faculty of Civil Engineering and Architecture. The conference proceedings consist of 114 papers divided into two volumes.

The total number of authors and co-authors accepted for publishing at SINARG 2023 exceeds 320. Out of this number, more than 80 authors come from abroad, representing 19 countries (Albania, Bosnia and Herzegovina, Bulgaria, Croatia, Germany, Greece, Hungary, India, Indonesia, Netherlands, North Macedonia, Montenegro, Oman, Poland, Romania, Serbia, Slovakia, Turkey, United Kingdom).

The editors express their gratitude to all the authors for their participation and to the reviewers for their valuable comments, which have contributed to the improvement of the original manuscripts and have enhanced the overall quality of the conference..

Niš, September 2023 *Editors*

CONTENTS

RECONSTRUCTION OF THE MOUNTAIN HOUSE ACCORDING TO THE PRINCIPLES OF SUSTAINABLE DEVELOPMENT

Mirko Stanimirovic[1], Miomir Vasov[2], Marko Mancic[3], Boris Rancev[4], Milena Medenica[5]

Abstract

This paper presents the conceptual design of the house on Stara planina. The old house was reconstructed according to the principles of sustainable development. In this example, we analysed the advantages and disadvantages of using natural and artificial materials. According to the assumption we made at the beginning of the research, the necessary energy efficiency of the building can be achieved by using natural materials. Building upon the limitations of the original study, this research further substantiates that the use of natural materials aligns with sustainability principles. Additionally, through LCA analysis, this study demonstrates that renovating an old house is a better choice compared to constructing a new building or utilizing an existing one in terms of reducing the negative impact on the environment.

Key words: *Sustainability, reconstruction, mountain house*

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INTRODUCTION

Nature conservation is becoming increasingly important due to the negative consequences of the digital era, pandemics, economic instability, and climate change. In Serbia, domestic tourism offerings are being relied upon more during times of crisis. In recent years, there have been improvements in capacities and tourist offerings in the Stara Planina (Old Mountain or Balkan) region and its
1. surroundings. This region offers a wide range of winter and summer activities that aim to preserve the local traditions. As a protected nature park, the construction of new buildings in the area requires a complex architectural and administrative procedure. This has resulted in the growth of rural tourism instead of hotel accommodations. Making adaptations to country houses is a common construction practice that is easier to carry out. However, a common issue is the use of cheap and artificial materials, as well as the disregard for the architectural style of country houses. If tourism continues to develop in Stara Planina, there will be a justifiable desire to convert old houses into tourist apartments.

The subject of sustainability is thoroughly addressed in the literature. Numerous scientific studies focus on reducing the ecological and economic footprint [1–6], implementing bioclimatic strategies in architecture [7], and promoting sustainable development of traditional housing [8–18]. Considering these factors, our research aims to explore the integration of architectural and technological aspects in the renovation of country houses, aligning them with a modern interpretation of folk architecture and sustainable development principles. Traditional architecture is widely recognized as a vital component of national heritage, reflecting the cultural identity of a specific nation.

To the best of the authors' knowledge, the literature has not yet addressed the topic of sustainable development of traditional architecture in Serbia. Therefore, we conducted a research study [19] to address the gap in international scientific literature. The summary of the results confirms that natural products, such as panels made of sheep and hemp wool, offer the necessary thermal comfort and have a significantly more positive environmental impact compared to artificial materials (EPS). When considering the duration of renovating a traditional house over an extended period, the cost of hemp and sheep wool panels becomes justifiable. Furthermore, the use of these materials does not compromise the principles of architectural design in relation to the renovation of traditional houses in Serbia or the creative reinterpretation of inherited building principles. The synthesis of the results indicates that the hemp wool panel slightly outperforms the sheep wool panel.

Considering the slightly lower thermal properties of hemp and sheep wool insulation (based on their thermal conductivity, λ, in W/mK), the same thickness of these materials leads to different thermal values (thermal transmittance, U, in W/m2K). In order to achieve an equal heat transfer coefficient, varying amounts of material are required, resulting in differences in the life cycle assessment (LCA) analysis for the use stage. It is important to note that this research focuses on evaluating the same quantity of material, and addressing the limitations of this study is recommended for future research endeavours.

Due to these reasons, the aim of this study is to compare different thicknesses of insulation materials that achieve the same thermal conductivity of $\lambda = 0.036$ W/mK. On the other hand, this study also compares whether house renovation has a lesser environmental impact compared to constructing a new building following sustainability principles.

Based on the initial assumption, it is expected that the new findings will exhibit minor variations compared to the original study. Furthermore, it is anticipated that the results obtained from the CARE tool will indicate that renovating a house is more efficient than constructing a new one, particularly concerning sustainability principles.

MATERIALS AND METHODS

This research focuses on materials that can be utilized during the renovation process of country houses, aligning with the principles of sustainable development and energy reduction. Sheep's wool is considered a suitable material for this purpose
2. [20–22], as well as hemp [23–28]. Hemp has been gaining popularity worldwide as a construction material, including in Serbia. The substitution of mineral aggregates with plant aggregates in building materials can have a significant impact on energy consumption within the construction sector [26,29–33] . In this context, energy efficiency, eco-materials, and eco-design are presented to emphasize the importance of exploring environmentally friendly and natural materials and technologies that facilitate the reduction of material and energy consumption in buildings.

The research findings were acquired through a multi-stage process. In the initial stage, the limitations of the initial study were addressed. The insulation thickness was determined to assess the environmental impact of materials with identical thermal conductivity. The subsequent stage involved updating the Life Cycle Assessment (LCA) to compare different materials and their varying quantities utilized in renovating a rural house. Lastly, the CARE tool [34,35] was employed in the third stage to compare the carbon footprint of renovating a house against constructing a new one.

SolidWorks/Sustainability Software was employed for conducting the Life Cycle Assessment (LCA) analysis. This software evaluates the environmental impact throughout the entire life cycle of a product and adheres to the ISO 14040 [36] quality standard. SolidWorks/Sustainability calculates the environmental impact in four significant areas: carbon dioxide emissions (kg CO_2e), energy consumption (MJ), acidification (kg SO2e), and eutrophication (kg PO4e). LCA is a widely used tool for evaluating the environmental impact of products [33].

The research synthesis involved comparing the results with the data from the
3. original study. Furthermore, the outcomes of the CARE tool were utilized to evaluate whether constructing a new building is more environmentally responsible compared to renovation. This assessment confirmed the accuracy of the results obtained in the original study.

RESULTS

The conceptual solution was developed in line with the principles of sustainable construction and rural architecture. To the south, an entrance porch was incorporated into the elevated section of the house, creating a tourist apartment. The timber-framed walls were expanded in areas where openings were required to accommodate the internal layout of the apartment. The majority of windows face south to harness solar energy during winter. The roof extension over the porch provides shade, reducing heat inside the building during summer (figure 1, 2).

Figure 1. Three-dimensional rendering (renovation), Source: Mirko Stanimirovic

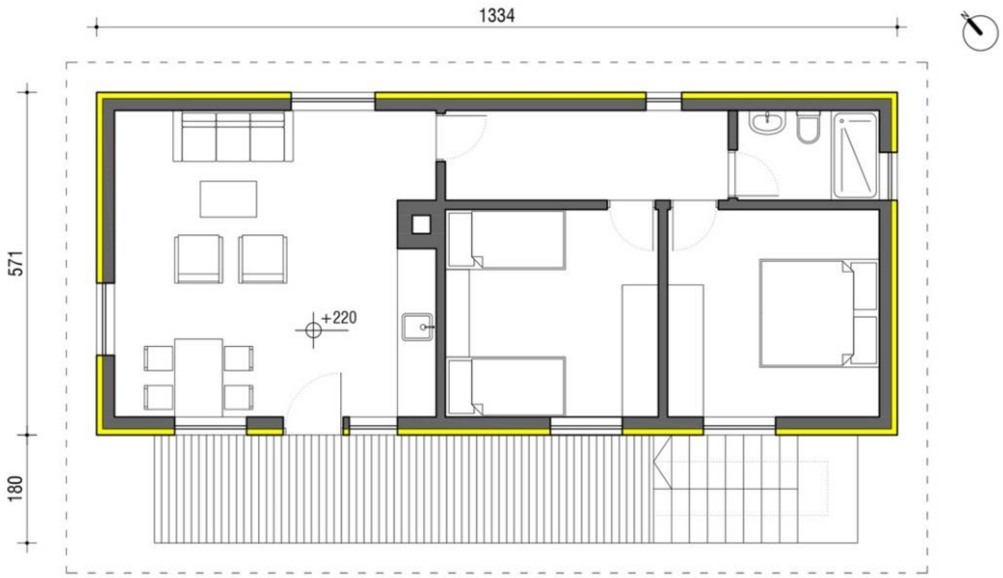

Figure 2. Renovation: Floor plan, Source: Mirko Stanimirovic

To achieve the same thermal conductivity (λ = 0.036 W/mK) in all three cases, we can use the basic formula for heat conduction: $Q = (\lambda \times A \times \Delta T) / d$, where: Q - heat flow (desired result), λ - thermal conductivity of the material, A - surface area covered by insulation, ΔT - temperature difference between the interior and exterior, d - insulation thickness.

This formula is used for all three materials. For hemp wool (λ = 0.036 W/mK): $Q = (0.036 \times A \times \Delta T) / d1$. For sheep wool (λ = 0.032 W/mK): $Q = (0.032 \times A \times \Delta T) / d2$. For EPS (λ = 0.035 W/mK): $Q = (0.035 \times A \times \Delta T) / d3$. Since Q is the same for all cases, we can equate the expressions: $(0.036 \times A \times \Delta T) / d1 = (0.032 \times A \times \Delta T) / d2 = (0.035 \times A \times \Delta T) / d3$. Now we can solve these equations to find the insulation thickness for each material:

$$d1 = (0.036 / 0.032) \times d2 = (0.036 / 0.035) \times d3$$

$$d2 = 0.032 / 0.036 \times d1 = (0.032 / 0.036) \times (0.036 / 0.035) \times d3 = 0.8889 \times d3$$

$$d3 = 0.035 / 0.036 \times d1 = 0.035 / 0.036 \times (0.036 / 0.032) \times d2 = 0.9722 \times d2$$

We conclude that the insulation thickness relative to d1 (hemp wool) is:

$$d2 = 0.8889 \times d1 = 0.8889 \times 10 \text{ cm} \approx 8.889 \text{ cm}$$

$$d3 = 0.9722 \times d2 = 0.9722 \times 8.889 \text{ cm} \approx 8.639 \text{ cm}$$

Therefore, to achieve the same thermal conductivity of λ = 0.036 W/mK in all three cases, we would need to predict an insulation thickness of approximately 10 cm for hemp wool, 8.889 cm for sheep wool, and 8.639 cm for EPS.

Tables (1, 2, and 3) show the results of LCA for three different scenarios. In the first scenario, Sheep's Wool was used as the insulation panel material. In the second scenario, Hemp Wool was used as the panel material. Finally, EPS was used as the artificial material. Tables 1 and 2 present data on carbon dioxide emissions (kg CO_2e), energy consumption (MJ), acidification (kg SO2e), and eutrophication (kg PO4e) for the extraction, production, transportation, and lifetime of 10 cm thick EPS panels used for insulating the entire analyzed object. The values in the tables are specific to the suspension polymerization manufacturing method, which is commonly used, and were obtained using the SolidWorks Sustainability software package. Based on information from ArchiCAD, a total of 267 m2 of insulation is needed for the house renovation. The table displays data for 188 panels. The data for insulation with sheep and hemp wool were sourced from the literature since they couldn't be directly incorporated into the software package used [37,38]. For this analysis, it was assumed that the expected lifespan for all insulation materials mentioned is 50 years.

Table 1. Thermal characteristics of sheep wool, hemp wool and expanded polystyrene

Thermal Characteristics	*Sheep's Wool*	*Hemp Wool*	*EPS*
Thermal conductivity λ (W/mK)	*0.032*	*0.036*	*0.035*
Flammability class	*B2*	*B2*	*B1*
Water vapor resistance factor μ	*1*	*7.4-11*	*30-70*
Density (kg/m^3)	*22*	*20-68*	*16-28*
R thermal resistance of the material (m^2 K/W)	*285.7–222.2*	*263.2–232.56*	*294.12–263.12*

Table 2. Total Carbon Footprint, Total Energy Consumed, Air Acidification and Water Eutrophication for production (extraction and manufacturing), transport, end of life for expanded polystyrene, sheep's wool and hemp wool, with a thickness of 10 cm.

	Sheep's Wool	Hemp Wool	EPS
Carbon Footprint (kg CO_{2e})	624.99	117.49	9598.71
Total Energy Consumed (MJ)	793.90	149.78	179,660.1
Air Acidification (kg SO_{2e})	3.55	0.41	39.41
Water Eutrophication (kg PO4e)	0.63	2.59	6.81

Table 3. Total Carbon Footprint, Price and Average Success for expanded polystyrene, sheep's wool and hemp wool.

	Sheep's Wool	Hemp Wool	EPS
Insulation thickness (cm)	10	9	9
Carbon Footprint (kg CO_{2e})	624.99	130.54	10665.23
Price (€)	4806	3711	1335
Average Success (%)	41	42.5	16.5

The results in the third phase of the research were obtained using the CARE tool. Since this software only allows project location selection within the United States, a comparison was made between the climates in Serbia and the USA. The city of Medford in the state of Oregon provided the closest match in terms of climate. In the vicinity of Pirot, Serbia, summers are warm while winters are cold with heavy snowfall. A similar distance from the equator has resulted in a comparable situation in Medford [39]. Based on the input data regarding materials and the surface area of the reconstructed object, the obtained results can be compared with the value of the total added embodied and operational emissions over a 10-year period (Table 4, Figures 4 and 5).

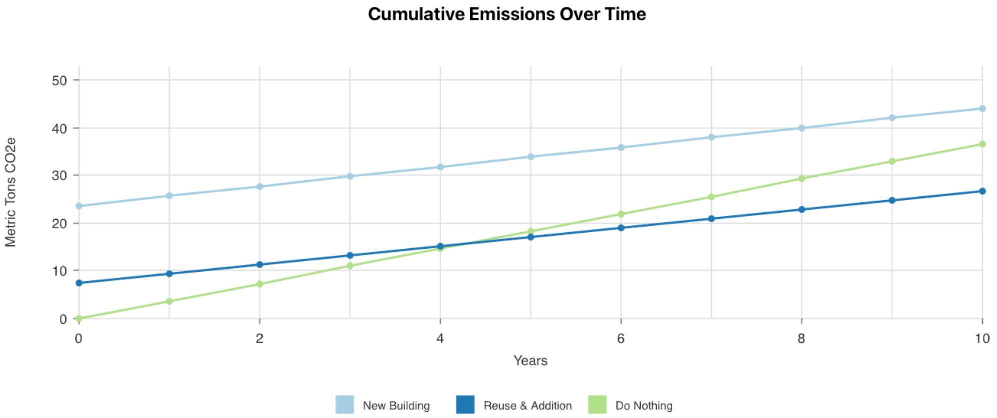

Figure 3. Total Added Embodied & Operational Emissions over 10 Years, Source: CARE tool

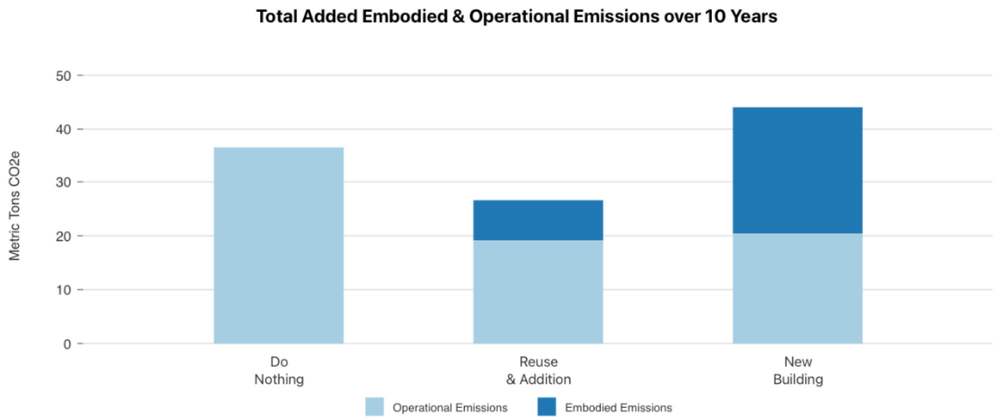

Figure 4. Cumulative Emissions Over Time, Source: CARE tool

Table 4. Total Added Embodied and Operational Emissions

Metric Tons CO_{2e} / 10 years	*Do Nothing*	*Renovation*	*New Building*
Embodied Emissions	*/*	*7*	*24*
Operational Emissions	*37*	*19*	*20*
Total Emissions	*37*	*27*	*44*
Total Emissions Intensity	*41*	*30*	*49*

4. DISCUSSION

The research results are expected and they show the connection between architecture, technology and sustainable development. The results of the LCA analysis offer valuable insights into the environmental impact of natural materials utilized in the restoration of traditional houses. The study compared three insulation materials, namely sheep's wool, hemp wool, and EPS, in terms of their carbon footprint, total energy consumption, air acidification, and water eutrophication. The findings unequivocally demonstrate that natural materials like sheep and hemp wool have considerably lower environmental impacts compared to artificial materials like EPS.

In the first part of the research, the thickness of the insulation panels was calculated to achieve the same thermal conductivity. This goal was derived from a previous study that assumed the limitation lies in observing the same panel thickness with different λ coefficients. Since the quantity of material is related to the panel thickness, this would have an impact on LCA, potentially yielding different results than those obtained. In this study, the thickness of the sheep's wool insulation panel was kept at 10 cm, while the thickness of the hemp wool and EPS insulation was reduced by 1 cm. As further indicated by the LCA in the second part of the research, the proportion of the CO_2 footprint remains the same, with the hemp wool panel still outperforming the sheep's wool panel. Nevertheless, natural material insulation significantly has a lesser environmental impact compared to EPS panels. However, due to its significantly lower cost, the overall performance of EPS approaches half of the efficiency of wool panels.

In the third part of the research, three scenarios were considered. In the first scenario, the old house was used for tourism purposes without adding any insulation. In the second scenario, the old house was renovated using natural material insulation, which significantly reduced the need for additional cooling and heating. In the third scenario, a completely new house was built with natural material insulation. According to the results obtained using the CARE tool, over a 10-year period, the least harmful impact on the environment is exhibited by the house that was renovated following sustainability principles. This justifies the renovation process as presented in the original study [19].

The study's findings align with prior research in the field of energy-efficient buildings constructed from ecologically sustainable materials [39]. Furthermore, the paper underscores the significance of employing local and natural materials in sustainable construction, which is in accordance with previous studies that have examined the ecological aspects of building practices [40]. Based on the LCA analysis results, the authors of this paper recommend the utilization of natural materials for the sustainable renovation of traditional architecture in Serbia. They argue that by doing so, it is possible to mitigate the effects of climate change and ensure that sustainable renovation aligns with contemporary architectural design and thermal comfort standards. Overall, this study offers valuable insights into the potential of natural materials in reducing the environmental impact of building renovation and highlights the importance of integrating sustainable design principles into construction practices.

In conclusion, EPS panels have a high carbon footprint and negative environmental impact, despite being the most affordable option. On the other hand, hemp panels and sheep wool panels are sustainable and biodegradable materials with a lower carbon footprint and positive environmental impact. Sheep wool panels, although more expensive, provide excellent insulation properties and support the local economy. Hemp panels are a more affordable alternative, but they may have a slightly higher CO_2 footprint and environmental impact.

Sheep wool panels are generally pricier compared to hemp panels due to the premium nature of sheep's wool, which requires more processing and labor. In contrast, hemp is a more cost-effective material as it is easier to grow and process. Sheep wool panels have a smaller carbon footprint during production compared to hemp panels because sheep's wool is a natural material that requires less energy and resources for processing and transportation. Additionally, sheep's wool is biodegradable and can naturally decompose, while hemp panels may release carbon dioxide during decomposition.

Both hemp and sheep wool panels are sustainable materials with low environmental impacts. Hemp is a renewable and fast-growing crop that requires less water and pesticides compared to traditional crops. Sheep wool panels are made of a natural material that is both biodegradable and recyclable, making them a more sustainable alternative to synthetic insulation materials. Sheep's wool can be sourced locally from nearby farms, supporting the local economy and reducing transportation emissions. In contrast, EPS panels are often manufactured in centralized factories and transported over long distances (Tables 5 and 6). Ultimately, the choice between these materials will depend on the specific requirements of the rural architecture reconstruction project, considering factors such as availability and cost.

Table 5. Emissions Advantages of sheep wool, hemp wool and expanded polystyrene

Sheep's Wool	*Hemp Wool*	*EPS*
Natural and renewable	*Natural and renewable*	*The most affordable option for insulation*
No chemical treatment is required when washing wool	*No chemical protection is required during hemp growth*	*The most common insulation material*
At the end of its life, it can be completely recycled or composted	*Renewable materials store carbon throughout their lifetime*	*Lightweight material*
Good vapor permeability properties	*Vapor permeable materials*	*Low water absorption*
Naturally absorbs and releases moisture	*Naturally absorbs and releases moisture*	
Simple and safe installation	*Simple and safe installation*	*Simple and safe installation*
Good thermal conductivity characteristics (λ)	*Good thermal conductivity characteristics (λ)*	*Good thermal conductivity characteristics (λ)*
Good fire resistance properties	*Good fire resistance properties*	
Good acoustic performance	*Good acoustic performance*	*Good acoustic performance*
Low carbon footprint	*Low carbon footprint*	*Good mechanical properties*
Absorbs and neutralizes harmful substances from the air	*Do not cause irritation of the skin and respiratory organs*	
Contributions to the creation of a natural and healthy environment within the facility where it is applied	*Does not affect the growth of mould or the attack of insects and rodents because the fibres do not contain proteins*	
Compatible with ventilated constructions	*Compatible with ventilated constructions*	

Table 6. Limitations of sheep wool, hemp wool and expanded polystyrene

Sheep's Wool	*Hemp Wool*	*EPS*
Vulnerability to insects, especially moths	*Most products are produced abroad and imported*	*High carbon footprint due to the production process that involves the use of petrochemicals*
The price is currently significantly higher than competitors based on oil or minerals	*The price is currently significantly higher than competitors based on oil or minerals*	*Negative environmental impact due to being made from non-renewable resources and generating significant amounts of waste*
The choice of exterior finishes limits the application	*The choice of exterior finishes limits the application*	*Release toxic gases when burned or decomposed*
	Requires thicker walls	*Unstable in contact with UV radiation*
	Use limited to above damp-proof course or equivalent level	*Exposed to the sun it becomes brittle*

5.

CONCLUSION

This study examines the renovation of a mountain house in Stara planina, Serbia, focusing on the impact of three different insulation materials: EPS, hemp, and sheep wool. The results demonstrate that the original study was appropriately designed, and its results and conclusions were validly formulated. While it can be expected that natural materials have a significantly lower environmental impact compared to synthetic materials, this study substantiates this claim through energy simulation and LCA analysis. Furthermore, in this study, the assumed limitations of the original research were addressed. It was further demonstrated that hemp wool insulation holds a slight advantage over sheep wool insulation. Finally, using the CARE tool, it was proven that renovating an existing house instead of constructing a new one makes sense in order to minimize the detrimental effects of construction.

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PERSPECTIVES FOR THE RECONSTRUCTION OF THE SITE AND THE UNDERGROUNDS OF THE DIMITROV MAUSOLEUM

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Abstract

In the last two decades, the reconstruction of the site and the undergrounds of the former Mausoleum of Georgi Dimitrov at Sofia into an interactive urban space has been opened up to the Bulgarian society. The objects of the paper are the research of archival documents on the history of the Mausoleum, the subsequent debates about its fate and the competitions for the transformation of the Mausoleum site into a space for contemporary art, held by Sofia Municipality in 2018 and 2021. Through an analysis of the concepts of the temporary art installations, changes in public attitudes can be established and trends for future development on the subject can be summarized. From the recently held public discussions, it is clear that the site and the undergrounds in the heart of Sofia are objects with architectural, museum and artistic potential, which the Sofia Municipality is about to breathe new life into.

Key words: *reconstruction, mausoleum, urban design*

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1. INTRODUCTION

In the attitude of the Bulgarian people to the Mausoleum of Georgi Dimitrov over the years, a process can be traced in which the events of history are objectified and transformed. Although deleted from the urban terrain, it ghostly continues to be present through its undergrounds. Between these two realities, above and below, is his site - a thin partition on which the transformation of Bulgarian society continues to take place, in the direction in which it decided to develop. As a result of the possibility of political, cultural and historical factors, which even today have an impact on the issue of the architectural heritage of socialism in Bulgaria, it can be assumed that the Mausoleum remains a dialogical topic and in this sense – an open topic, free for transformation and interpretations to the present moment.

2. RESEARCH AND ANALYSIS OF SOURCES FOR THE HISTORY AND FUNCTIONS OF THE MAUSOLEUM OF DIMITROV

The Mausoleum of Georgi Dimitrov is not among the objects about which much information can be found. In fact, it turns out to be the second modern mausoleum in the world containing an embalmed body, built after Lenin's in Moscow. The main source for its construction and functions is the monograph of the last commandant of the Mausoleum from 1980 to 1989, Georgi Gergov, which was published a year after its destruction [1]. In the following lines, a brief facts shared by Gergov regarding the creation of the Mausoleum will be presented. After the Prime Minister of Bulgaria died on July 2, 1949, the cult of his personality created during his lifetime reached its culmination. The Central Committee of the Bulgarian Communist Party and the government decided that his body would be laid in a mausoleum on July 10 at the "9th of September" Square (now "Knyaz Aleksandar I" Square). In one night, the plan was developed by the Central Architectural Design Organization with chief architect Georgi Ovcharov. Architect Nedelcho Paskalev is the author of the monograph [2], which is a valuable source for understanding the meaning and contribution of Geogri Ovcharov to modern Bulgarian architecture.

Georgi Ovcharov (1889-1953) from an early age showed an attitude to develop in the bosom of fine arts. He graduated in Architecture at the Technical University of Munich in 1912. The following years were a time of self-study and disciplined work, as a result he deservedly won the international competition for the building of the Faculty of Agronomy in 1924. Ovcharov's biographer considers this project as the birth of the monumental image of the public building in Bulgaria, achieved through the means of classical architectural approaches. In the Faculty of Agronomy, he realized the first example of unity of exterior and interior. The happy combination of artist and architect forms the basis of a creatively rich design process. In the period 1923-1930, a large number of projects were carried out through the Ovcharov-Popov architectural studio, and Georgi Ovcharov was described as the first expressionist in Bulgarian architecture. He designed many emblematic public buildings such as the Workers' Hospital in 1930-1935, the House of Labor in 1935, the Ministry of the Interior in 1936 and many others. The characteristic of these projects remains the large monumental form and plastic, and the free play with the architectural classics. His urban planning, projects for the architectural layout of monuments, public parks, etc. are numerous. All these monuments and complexes can be seen today, clearly standing out with their stylistic unity and uniqueness among the city ensemble, and the Mausoleum of Dimitrov is one of the most famous works of architect Ovcharov.

Gergov reports that the Central Committee of the Bulgarian Communist Party and the Council of Ministers approve the project of Georgi Ovcharov and assign the implementation to the Main Directorate of Labor - Sofia Construction District. Together with the laborers, brigades of architects, engineers, technicians, sculptors, artists and workers of various specialties (600 people) are distributed in 4 shifts of 6 working hours. Simultaneously with the construction, the plumbing, electrical and special air-conditioning installation are placed. On July 10, the Mausoleum is almost ready and decorated. The project planned for the building to be completed in 170 hours, but the builders managed it in a record 138 hours. The building is a pure cubic volume with a classical order, 12 m high, with walls 1.2 m thick, and occupies 560 m^2, including the tribune. The building consists of two chambers connected to each other. An air conditioning system is placed between them. The inner hall has a volume of 1000 m^3, surrounded by an insulating corridor, about 2 m wide. The outer walls are 1.20 m thick. In the middle of the hall, in a niche slightly below the level of the square, a coffin for the body is placed on a pedestal. Four spotlights illuminate the center of this space. The air conditioning system maintains a microclimate with a temperature of around 16° at a humidity of 75%. Gergov describes in detail the building and its service rooms, whose main function is to support the embalming process. He provides information that its visible part occupies only 1/3 of the volume, while the greater part is located on two levels underground (fig.1) [3].

The totalitarian cult of Georgi Dimitrov developed similarly to that of Lenin and was nurtured by similar rituals and teams of specialists. A guard sentry is placed in front of the Mausoleum, whose ritual resembles the present-day one in front of the Presidency in Sofia. Gergov reports that for decades foreign delegations have been paying tribute by laying wreaths, and the party-state leadership has been accepting parades and manifestations on public holidays from his tribune. Gergov reports that from 1949 to 1989, the Mausoleum was visited by 18 million people.

Figure 1. The Mausoleum of Georgi Dimitrov. A look from 1950s, http://www.stara-sofia.com/mavzolei2.jpg

RESEARCH AND ANALYSIS OF ARCHIVES REGARDING THE DESTRUCTION OF THE MAUSOLEUM

After the end of the socialist regime, by decision of the Council of Ministers, No. 148/17.07.1990 for the burial of Dimitrov's body, the Mausoleum emptied its contents. The Bulgarian society has yet to make a decision on what to do with the building. In this connection, materials from the Scientific Documentary Archive for
3. Immovable Cultural Heritage, RIM-Sofia, were studied, which will be presented here in a summary [4]. A commission was formed, which includes representatives of the main political forces, scientists and intellectuals, chairmen of unions and organizations, and specialists from the Sofia City People's Council. The commission is assigned to conduct the necessary studies, consult with experts and submit a motivated proposal to be sent to the Council of Ministers. It is also suggested that the entire public be involved with suggestions. In July 1990, 45 proposals from private individuals and civil organizations were submitted to the "Commission on Proposals for the Fate of the Mausoleum". 3 of them propose demolishing the Mausoleum, 6 proposals are for using the Mausoleum as a Museum of the Battle Flags of Bulgaria, there are also 6 proposals for turning the building into a Georgi Dimitrov Museum. Most of the proposals appeal for the establishment of a Pantheon or a Memorial to the national heroes of Bulgaria. At the same time, the Federation of the Bulgarian Socialist Youth organized a "Signature for the transformation of the Mausoleum into a Memorial to the work of G. Dimitrov and all Bulgarian anti-fascists", which collected 13,710 signatures, attached to the archive of Immovable Cultural Heritage, RIM-Sofia. After the completion of the commission's work on the future functions of the Mausoleum, the following decisions were published:

1. The Commission believes that the building of the until recently mausoleum should be preserved, due to the fact that it represents an indisputable architectural, artistic and material value.

2. The commission recommends the Sofia City People's Council to announce, and the Union of Architects in Bulgaria and the Union of Bulgarian Artists to organize a national competition among all architects, artists, sculptors and public figures for a functional rethinking of the building of the former mausoleum and its adjacent spaces, as and of their humanization to reflect the coming societal changes. Until August 15 of this year the conditions for participation in the contest to be announced to our public.

3. All available materials and opinions of individuals and organizations to be provided to the contest organizers.

4. The Commission proposes to the Sofia City People's Council to take rapid measures to create a temporary change of character in the square in front of the mausoleum.

The commission's decisions were partially implemented, the building was preserved until 1999, but it was never functionally rethought. In the following years, the controversy surrounding its fate continued. In February 1992, a meeting of the Sofia Municipal Council was held, where the "Report on the former mausoleum of Georgi Dimitrov" was discussed, with the mayor of Sofia, Prof. Alexander Yanchulev, as the submitter. The report proposes the following solution:

"Assigns the mayor of the Greater Metropolitan Municipality to carry out the necessary procedures for the preparation of a project and its implementation for the

removal of the mausoleum or parts of it, through an auction, including the sale of the property located in it." [5]

A debate was held on the report, polarized along political lines. Speaking members of the Union of Democratic Forces fully support the removal of the Mausoleum as "one of the symbols of a dark age", which has no artistic and architectural value, but if it remains it will remind generations of the past. Members of the Bulgarian Socialist Party believe the opposite, that the building is a monument of architectural and cultural significance and should not be demolished because it is part of the city's history. The solution proposed by Mayor Yanchulev was put to a vote and was approved with 54 votes "for", 19 "against" and 3 "abstentions". Meanwhile, proposals for the reconstruction of the Mausoleum continue to arrive: a proposal for a Memorial/Pantheon of Bulgarian Military Glory, a proposal to provide the building for the needs of the National Art Gallery, as well as a proposal from the First Bulgarian Stock Exchange to preserve it. From 1992 to 1999, the institutions continued to debate the fate of the Mausoleum, while the building gradually became derelict and acquired graffiti, became a place for open-air opera, happenings, a film set, etc. At the end of August 1999, the Mausoleum was demolished by order of the minister of Regional Development and Public Works of the Government of the Union of Democratic Forces. As a result of an official inquiry to the State Agency "Archives", the experts did not find any documents related to the implementation of the decision to demolish the Mausoleum. An empty platform remains in its place, but the underground levels of the building pass into the possession of the Sofia Municipality with municipal property Act No. 993/29.11.2016 [6]. For the Mausoleum site, the time has come for many random ideas for urban design: landscape projects, summer cinemas, trade shows, beer gardens, bazaars, art actions, etc.

4. TRANSFORMATION OF THE MAUSOLEUM SITE INTO AN INTERACTIVE ART SPACE

In the circles of art critics, the opinions regarding the Mausoleum destruction continue to this day to be divided into those who blame and others who support its removal. In the last two decades, the question of turning the Mausoleum site into an interactive art space continues to open up to the Bulgarian artists. The lack of an adequate solution for the future of the site in the heart of Sofia naturally attracts many of them. The first institutionally supported work at the Mausoleum site was organized jointly with the Austrian Embassy and the Sofia Municipality with the "Bronze House" project (fig.2) by the artist Plamen Deyanoff in honor of the Bulgarian Presidency of the Council of the European Union in 2018 [7]. Contrary to the expectations stated by the Sofia Municipality, even during the preparation of the project, the "Bronze House" became a polemical center of public attention with disputes regarding the choice and specifics for exhibiting contemporary art in a public environment, the deadlines for implementation, etc.

Figure 2. Bronze House, https://artsofia.bg/bg/bronzehouse/

As a result of the controversial experience with the "Bronze House", caused by the inconsistency between procedures, stated intentions and obtained results, the Sofia Municipality promptly decided to rethink and transform its policy for the formation of an interactive art space at the Mausoleum site. In 2018 and 2021, the Sofia Municipality through the "Culture" Directorate announces open sessions of the "Outside" Program to support temporary art installations at the Mausoleum site [8]. The program was adopted in implementation of the "Sofia - creative capital" strategy, financially supporting the realization of innovative works of contemporary visual arts in the public area, which will support the creation of new publics and an open discourse for meeting art. The Creative Commission of the "Culture" Directorate of the Sofia Municipality, composed of experts in the field of visual arts and urban planning, evaluates the submitted competition proposals. The leading requirements for the works are: high artistic value and innovation, which will contribute to greater diversity and dynamics in the cultural life of Sofia.

In 2019, the installation "One Man" by Venelin Shurelov was chosen to be installed at the Mausoleum site. The installation is a 13-meter figure built from a modular steel truss structure and two-sided LED screens (fig.3). Dynamic content is fed to the screens, which is generated by a specially designed algorithm in two modes. "One Man" was installed and officially opened at the end of November 2020, remaining at Sofia until the end of April 2022. The author's design is revealed in the most favorable way in weaker lighting, when it stands out through its lighting effects. The surrounding urban environment, saturated with architectural landmarks and the proximity of busy street traffic along the boulevard, largely absorb the idea of the ambitious project.

The next competition for temporary artistic interventions at the Mausoleum site was carried out by the Sofia Municipality in 2021. Projects should allow presentation in an urban environment with free access; to be secured; not require targeted security and not provide for any form of advertising on the installations or their temporary fencing during the period of exposure. The Creative Commission propose to the Sofia Municipality that in 2022 the work of Krassimir Terziev be exhibited in the Mausoleum site, with the title "Between the Past Which is about to Happen and the Future Which has Already Been" [9]. The temporary art installation is composed of volumetric double-sided illuminated letters, inscribed in a circle with an outer diameter of 12 m, height and depth of the letter 50 cm - dimensions that allow the installation to be inhabited and visitors to stay in the space of the circle (fig.4). The horizontal solution of the installation can be perceived as an attempt to calm the passions and accordingly democratize the space. The question is whether the art installation will be able to stand out topologically by turning the Mausoleum site into a lived-in urban space. With Decision No. 999/15.12.2022 of the Sofia Municipal Council, consent was given to extend the deadlines for the implementation of the project and transfer the amount approved by Decision No. 594/21.07.22 for targeted financing of the project for 2023 [10].

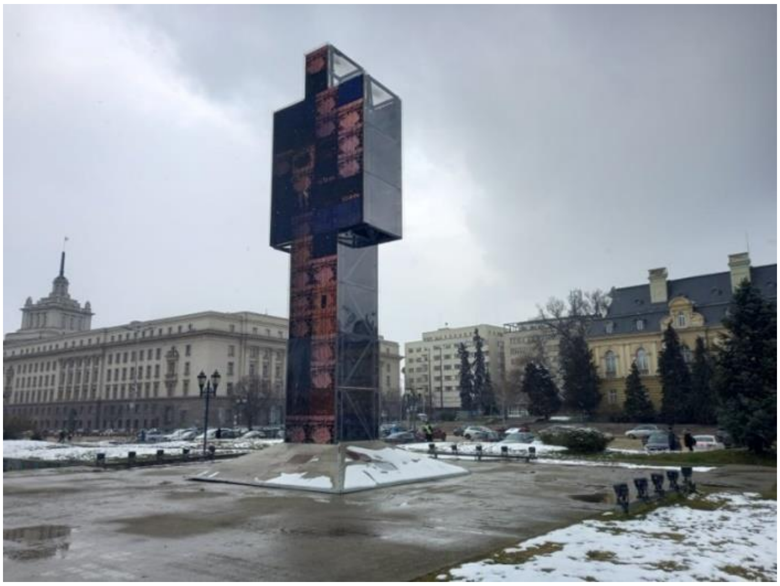

Figure 3. “One Man”, author’s photo.

Figure 4. "Between the Past Which is about to Happen and the Future Which has Already Been", https://artsofia.bg/files/pictures/2022-02/17466/original.jpg

RESULTS OF THE RESEARCH

For the purposes of the present study, here is presented a brief overview of the different artistic approaches to the temporary art interventions at the Mausoleum site and the number of submitted projects in the two competition sessions. The detailed analysis of the projects is presented in the author's monographic study on the subject [11].

5. QUALITATIVE ANALYSIS

The comparison between the competitions held by the Sofia Municipality in 2019 and 2022 aims to explore the meaning and role that the memory of the Mausoleum plays in modern society. The analysis of the conceptual ideas and visualizations of
5.1. the competition projects gives us reason to divide them into two groups related to the relevance of this memory. In the first group, the authors share the desire for the space to preserve the idea of historical continuity and convey to the public a certain message aimed at making sense of the past and developing future policies and civil debates on the subject. The second group includes projects that are inspired by contemporary ethical, social or artistic problems.

Session 2018-2019

5.1.1. The first group includes 7 projects, the inspiration of which comes from the historical events related to the Mausoleum, respectively with the memory of the previous political regime. The second group includes 11 projects in which the authors emphasize concepts related to the need to affirm universal human values or aim for harmony with the cultural and aesthetic ideas of contemporary society. What they have in common is the request for distance from any historical and political references to the site's past.

5.1.2. Session 2021-2022

In this session, the project whose inspiration derives from specific historical and political events related to the past of the Mausoleum site is only one. The remaining seven projects are aimed at the purely visual, spatial and sensory perception of artistic interventions by the public. The expected or spontaneous effect of communication with the works is realized through various visual stimuli such as mirror surfaces, movement, color, change of scale, etc., which provoke free play with the objects.

6. The comparison between the number of submitted projects for the temporary artistic interventions in the two competition sessions of the "Outside" Program shows a drop in the activity of artists in the second session. In 2019, 18 participate, while in 2021 there are only 8 submitted projects, under the same application conditions.

DISCUSSION

From the presented analysis of the projects for artistic interventions of established authors in the competitions of the "Outside" Program, it is clear that the desire to invest creative energy in this urban and, first of all, social experiment is decreasing with time. The analysis of the themes of the projects from the two sessions leads to the conclusion that their concepts gradually lost the weight and intensity of their connection with the Mausoleum. From here follows the need to revise the formula for working conditions and algorithm of art competitions. It can at least be renewed and adapted to changing attitudes in public and, in particular, artistic circles.

Nowadays, the undergrounds of the Mausoleum in turn become the subject of constructive public discussions. Urbanist Zdravko Petrov commented that under the capital there are many facilities of different sizes and purposes, some of which date back to before the Second World War [12]. According to many sources, there is an underground city under Sofia, which connected the most important buildings of power during socialist regime. This information is also confirmed by Georgi Gergov, who mentions a tunnel connecting the Mausoleum with the Party House, for the purpose of evacuation in crisis situation. Over the past years, the undergrounds have been completely abandoned and severely compromised by time (fig.5-6). After the building was destroyed in 1999 by a series of controlled explosions, parts of the undergrounds were collapsed or filled with earth mass. There are a number of structural and supporting equipment defects. Gergov mentions reconstruction and repair in 1974-1975 under difficult conditions, given the presence of an underground river under the Mausoleum. After 1999, only emergency strengthening activities were carried out, which were not sufficient to secure the site, given the extremely high humidity of the underground and the continuing shifts of the ground masses. A part of the interior and specific objects went to the Museum of Socialist Art and the Museum of Sofia, but the more voluminous ones, such as the hoist and embalming bed, electric generators, installations and other technical equipment, were left underground.

As the owner of the site, in 2023 the Sofia Municipality initiated public discussions in order to find an adequate solution for a new function of the undergrounds of the Mausoleum. In this regard, the Municipality of Sofia held discussions among three focus groups of experts - artists, architects and historians to study their attitudes regarding the fate of the underground building and the author of the present study took part in the expert group of artists. Each focus group met for a specialized discussion of the issue, after which the three groups held a general meeting in which the main conclusions and suggestions were summarized. Regarding the functions of the space, the prevailing opinions of the experts are in the direction of creating a "place of historical memory" that will tell about the time of the totalitarian regime. Here the experts are divided into two: some of them insist on a broader narrative about the regime, since the period has not been understood and experienced by society. Another part of the experts offers a narrative focused on one emphasis - "The cult of personality", aggravating with the risk of blurring the topic, as well as taking into account the limited area of the space of 1461 m². Regarding the means of presenting the functions of the place, the majority of experts offer an objective narrative without rehabilitation when exhibiting selected artifacts with more narrative. As such, the laboratory, the embalming bed with the hoist, the control desk, etc., are considered. The possibility of continuing the practice of exhibiting contemporary art as a metaphor for the duality: "above-contemporary" and "below-past" was discussed at the Mausoleum site. In summary, it is proposed to prepare an assignment for a competition for a visionary architectural project with an interdisciplinary team to carry out an analysis of the history and the environment, and to present an author's view of what and how to preserve, and what to change at the undergrounds.

Figure 5. Mausoleum undergrounds, author's photos

7.

Figure 6. Mausoleum undergrounds, author's photos

CONCLUSION

The history of the Bulgarian mausoleum is marked by many vicissitudes and contradictory attitudes in society towards its fate. There is no doubt that the presence of the Mausoleum is a traumatic fact for many people, but its demolition has not succeeded in erasing the physical and mental trauma of its presence and subsequent destruction. The research takes into account the fact that collective memory is related to dynamically ongoing political, cultural and social processes, therefore, by analyzing the concepts of artistic interventions proposed for realization at the Mausoleum site, changes in public attitudes can be established and trends can be summarized for future developments on the subject. Raising the issue of the state of the Mausoleum's underground can engage the public and experts, with a view to uncovering potential resources for the development of the urban environment. There is a real opportunity for the Bulgarian society to recognize the undergrounds as a potential for building a place of historical memory. According to experts, they can be used functionally and become an attractive tourist site, combining a museum underground with a space for contemporary art above. If this happens, a hard-to-assimilate page of Bulgarian history will be turned over and perhaps the trauma of the socialist past will be revised.

ACKNOWLEDGMENTS

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LABORATORY TESTS OF CONCRETE CYLINDERS CONFINED WITH INOVATIVE MATERIALS

Artur Roshi[1], Golubka Nechevska-Cvetanovska[2], Julijana Bojadjieva[3], Jordan Bojadjiev[4]

Abstract

The need for repair and strengthening of RC buildings and their structural elements occurs when their elements do not possess sufficient strength, stiffness and/or ductility out of different reasons or due to slighter or more severe damages most frequently caused by earthquakes. Within the frames of this paper, special emphasis will be put on RC buildings where, during construction, the built-in concrete has not achieved the designed concrete class and/or buildings that cannot satisfy the required strength, stiffness and deformation characteristics particularly in earthquake conditions due to built additional storeys or enlargements. In these cases, it is necessary to take measures for repair and strengthening using traditional or Innovative Materials. In this paper, focus will be given on technology of strengthening of RC columns with innovative materials as well as characteristics and types of these material will be introduced.

To present the possibilities and the benefits of use of these innovative construction materials in strengthening of structural elements of buildings and integral building structures, ample laboratory research for definition of the characteristics of these materials with different technologies of strengthening by CFRP (Carbon Fiber Reinforced Polymers) materials are carried out at the Institute of earthquake Engineering and Engineering Seismology – IZIIS, Skopje. Results from laboratory research and experimental investigations of RC concrete specimens-cylinders with different technologies of strengthening by CFRP are presented.

Key words: *Repair and Strengthening, Innovative Materials, compressive strength, elasticity module, CFRP*

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1. INTRODUCTION

Behaviour of structures constructed and built of reinforced concrete during their serviceability period as well as during earthquakes depends on many factors. On one hand, there are the external factors, i.e., loads acting upon the structures (in addition to the main loads, there are also additional loads as well as effects caused by possible explosions, fires, earthquakes), while on the other hand, there are the factors that directly depend on the very structure of the buildings (structural system, type, quality and quantity of material used for the construction of the structure, the number of storeys, the mode of foundation etc.). All these factors directly affect the strength and deformation characteristics of the individual structural elements and the structural system as a whole.

It has been a usual practice to perform repair and strengthening of structures by application of traditional methods (most frequently, jacketing of elements), but lately, new innovative materials with a special technology of construction and repair have increasingly been applied. The application of these materials is still the subject of a large number of investigations worldwide, particularly in the field of application of these materials in seismically active regions.

In this paper, at first detailed explanation of characteristics and types of innovative materials for strengthening of RC columns is made. Then, results are given from laboratory research of concrete speciments-cylinders strengthened by CFRP with different technologies of strengthening by CFRP (Carbon Fiber Reinforced Polymers) materials.

2. REPAIR AND STRENGTHENING OF BUILDINGS USING INNOVATIVE MATERIALS

2.1. Fiber reinforced polymers (frp)

FRP composites comprise fibers of high tensile strength within a polymer matrix. The fibers are generally carbon or glass, in a matrix such as vinylester or epoxy. These materials are manufactured to form plates under factory conditions, generally by a pultrusion process.

Reinforcement fibers are qualified in three main families of glass, aramid and carbon. There are other fibers, but they are relatively insignificant. The most important property of the fibers is their elastic modulus, and the fibres must be significantly stiffer than the matrix which allows them to carry most of the stress, [1]. Consequently, they must also be of high strength. Reinforcements are available in a variety of configurations of which there are three main categories:

- unidirectional, in which all the fibers lie in one direction.
- bidirectional, in which the fibres lie at 90° to one another. This is achieved either by use of woven fabric, non-woven fabric or by use of separate layers of fibres each unidirectionally, but successively laid at 90°.
- random, in which the fibers are randomly distributed and are in-plane.

Stress-strain fiber behaviour is different for every type of fiber (Figure 1). Different FRP shapes (Figure 2) and Different material properties are given in Table 1.

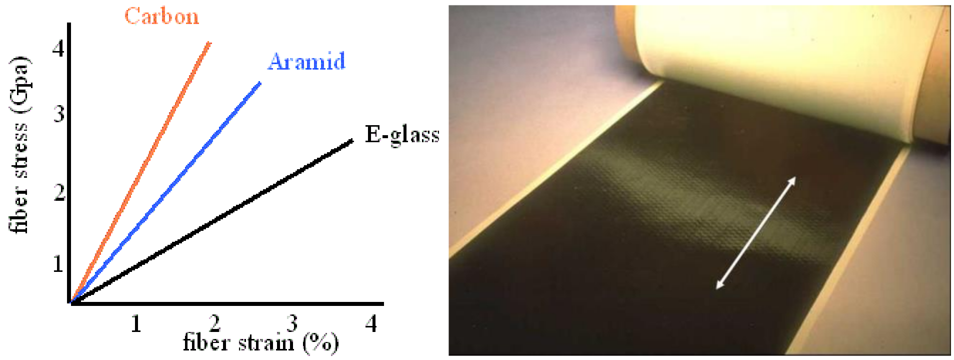

Figure 1. Stress- strain fiber behavior and a) sheet,(A. Prota, [2])

b) c)

Figure 2. Different FRP shapes b) bars c) pre cured laminate,(A. Prota, [2])

Table 1. FRP materials - Fiber comparison

	Strength	Modulus	Moisture and chemical resistance	Cost
Carbon	High	High	Excellent	High
Aramid	High	Intermediate	Good	High
E-Glass	High	Low	Low	Low

2.2. Confinement strengthening

Confinement strengthening (Figure 3) consists of:

(1) Cleaning and repair
(2) Primer
(3) Adhesive
(4) FRP strips
(5) Last adhesive layer

Figure 3. Confinement strengthening (Di Ludovico M.[3])

Fiber polymer fabrics that can be used to improve bending, shear and axial capacities of the columns and beams may be manufactured from various materials such as carbon, glass and aramid without an increase in the volume of the strengthened member, significant improvements can be achieved in the capacity and ductility characteristics of the element.

These materials may practically be used for numerous purposes such as enhancement of the flexural capacity of floor slabs and improvement of shear capacity of beams, columns, joints and shear walls.

3. LABORATORY TESTS ON MATERIALS BUILT-IN MODELS FOR EXPERIMENTAL RESEARCH CARRIED OUT AT UKIM-IZIIS

To realize the experimental quasi-static tests, two models were designed and constructed, namely Model M1 and Model M2. The models were with identical proportions (supporting beam proportioned 50/50/116 cm and a column proportioned 30/30/200 cm), constructed to the scale of 1:1[4].

For the purpose of easier incorporation of the CFRP materials, it was decided to build the models in vertical position [5].

During concreting of the models, three trial specimens- concrete cubes proportioned 15/15/15 were taken from the supports - beams and three trial cubes proportioned 15/15/15 were taken from the columns, in addition to the nine (9) cylinders proportioned 15/30 cm (Figure 4). To define compressive strength and concrete class, laboratory tests were performed at stock holding company-GIM-Skopje (for the cubes) and ZIM –Skopje (for the cylinders), while the tests for definition of the modulus of elasticity of the built-in concrete were done at ZIM – Skopje, Macedonia [4].

Figure 4. Photos of taken trial concrete specimens from Model M1 and Model M2

Using the trial concrete specimens – cylinders, three series of tests of compressive strength and tests for definition of the modulus of elasticity of the built-in concrete were carried out as follows:

- Series 0- concrete cylinders without FRP- plain concrete
- Series 1- concrete cylinders wrapped with 1 (one) FRP layer
- Series 2- concrete cylinders wrapped with 2 (two) FRP layers

Presented further are photos and results taken during laboratory tests for definition of compressive strength of concrete for the three series (Figure 5 and Figure 6). It must be pointed out that the collapse of the models from the first and the second series was explosive, with big crushing of concrete wrapped with FRP. This was particularly pronounced in Series 2 where concrete was wrapped with two FRP layers.

Figure 5. Preparation of strain gauges on concrete cylinders.

Figure 6. Testing of compressive strength of concrete for the three series

RESULTS FROM TESTS FOR OBTAINING THE COMPRESSIVE STRENGTH OF CONCRETE CYLINDERS

4. Parallel with the performed tests on the three series, the obtained results on failure forces and the results from computation of compressive strength of all three series of concrete cylinders were recorded in special tables (Table 2).

Table 2. Compressive strength of three series of concrete cylinders.

Date of casting: 04.10.2019 Date of testing: 15.11.2019 Concrete cylinders CC (3 series) 15/30 cm					
Series			***Proportions H/D [cm]***	***Failure force [kN]***	***Compressive strength [MPa]***
Specimens	*0*	*Cylinders without CFRP*	*30/15*	*296.0*	*16.8*
	1	*Cylinders with one CFRP layer*	*30/15*	*670.0*	*37.9*
	2	*Cylinders with two CFRP layers*	*30/15*	*955.0*	*54.1*

From the results obtained, it can be concluded that the force inducing failure of concrete cylinders without CFRP amounts to 296.0 kN. For the cylinder with one CFRP layer, it amounts to 670.0 kN., while for the cylinder with two CFRP layers, it amounts to 955.0 kN. The compressive strength amounts to 16.8 Mpa, 37.0 Mpa and 54.1 Mpa, for all three series, respectively (Figure 7).

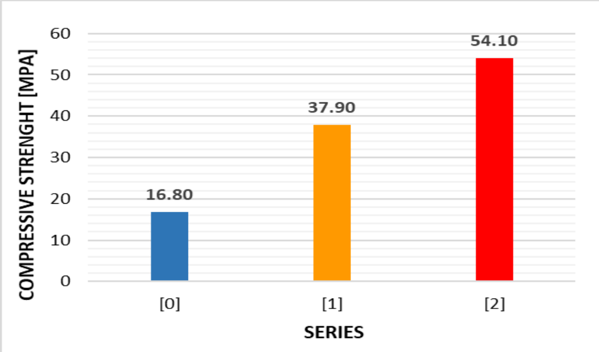

Figure 7. Testing of the compressive strength of all three series.

In general, it can be concluded that the compressive strength is higher with the number of CFRP layers.

Results from Tests for Obtaining the Elasticity Modulus

Testing of the static modulus of elasticity for each series (0, 1, 2) of built-in
4. concrete was also done in the laboratory of the Institute for Testing Materials – ZIM – Skopje AD. The tests for obtaining the static modulus of elasticity under pressure were performed according to MKS U.M1.025. The most relevant for estimation of the static modulus of elasticity was the mean value of the recorded entries of the strain gages, after dissolution in the last cycle.

Presented further are some of the photos taken during the tests on the three series of concrete cylinders (Figure 8).

Figure 8. Testing of the static modulus of elasticity of all three series.

In general, it can be concluded that the Modulus of elasticity becomes higher with the increase of the number of FRP layers. The graphic presentations of the elasticity modulus obtained by labaratory tests are presented in Figure 9.

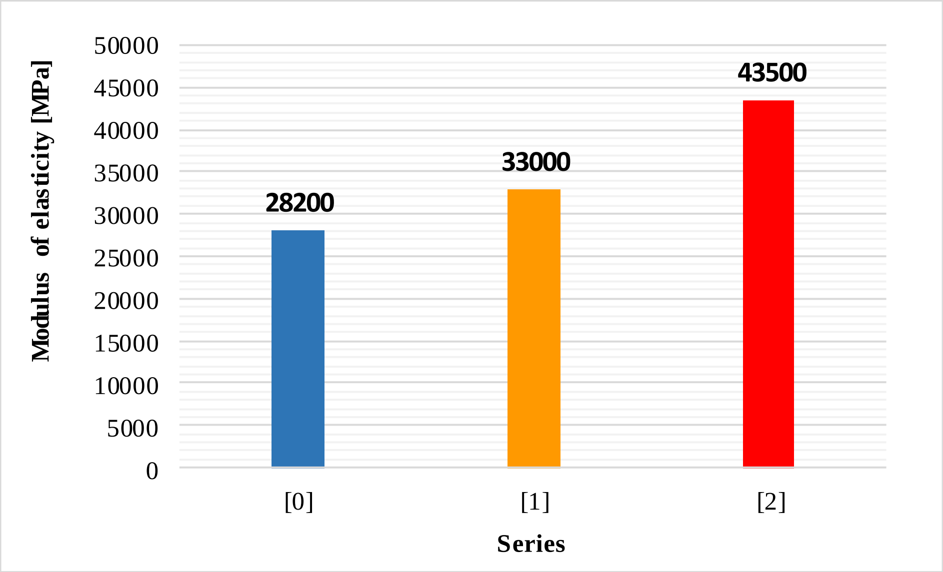

Figure 9. Testing of the static modulus of elasticity of all three series.

Generally, it can be concluded that the obtained values for the concrete cylinders with one and two CFRP layers are higher than the values obtained for the concrete cylinders without CFRP.

5. CONCLUSIONS

In the paper part of the analytical, laboratory and experimental investigations of designed models of RC columns strengthened with CFRP were presented. Based on the experimental investigations the following conclusions can be outlined:

- The force inducing failure of concrete cylinders without FRP amounts to 29.6 t, i.e., 296 KN. For the cylinder with one FRP layer, it amounts to 67.0 t, i.e., 670 KN, while for the cylinder with two FRP layers, it amounts to 95.5, i.e., 955 KN. The compressive strength amounts to 16.8 Mpa, 37.0 Mpa and 54.1 Mpa, for all three series, respectively.
- In general it can be concluded that the compressive strength and Module of elasticity is higher with the number of FRP layers.
- Obtained values for the concrete cylinders with one and two CFRP layers are higher than the values obtained for the concrete cylinders without CFRP.
- These tests are good basis for further analytical and numerical investigations which can provide additional conclusions.

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GEOTECHNICAL CONDITIONS IN EXPERIMENTAL TESTING OF CLAYEY SOIL SUBJECTED TO CHEMICAL–ELECTROKINETIC TREATMENT

Zoran Bonić[1], Elefterija Zlatanović[2], Nemanja Marinković[3], Snežana Djorić-Veljković[4], Dragan Djordjević[5], Nikola Romić[6], Branimir Stanković[7]

Abstract

The paper gives a concise description of the experimental part of the scientific–research project "A New Concept in Improvement of Geotechnical Properties of Ground – Chemical Electrokinetic Treatment of Soils (ElectroSoil)". The experiment involves the stage of laboratory tests of the physical–mechanical properties of the soil before and after the chemical treatment and the chemical–electrokinetic treatment, as well as the stage of field experiments at the pilot-project scale. Clayey soil from the Crvena Reka borrow pit, along the route of the E-80 Niš–Dimitrovgrad Highway, was used for the experimental tests. During the construction of the highway, a landslide was triggered at this location. The designed remediation measures included a support structure in the form of a curtain of piles. Samples of clayey soil for the aforementioned laboratory experiments were taken during the construction of bored piles, from the depth at which the sliding surface was registered. A special emphasis in the paper is given to the geotechnical conditions in which the laboratory experimental tests were performed.

Key words: *Geotechnical conditions, Clay, Chemical–electrokinetic treatment, Laboratory experiment*

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1. INTRODUCTION

Instability of terrain and the appearance of landslides occur, among other things, due to heavy rainfall, which has become more extreme recently as a result of global climate change. Predictions are such that we can expect more and more extreme events in terms of intensity and amount of precipitation. This will lead to more and more frequent floods and landslides, which will have inevitable consequences on the servicing and maintenance of the existing infrastructure. The problem is further aggravated by the trend of progressive urbanization, which will be present in the future as well.

The mentioned unfavorable weather conditions lead to an increase in soil water content, which results in an increase of pore water pressure, a decrease of effective stresses, an increase in soil weight, as well as a reduction in shear strength. All this leads to the occurrence of terrain instability, the formation of sliding surfaces on the slopes and the occurrence of landslides. In such conditions, it is very important to choose such remediation measures that would restore human settlements and infrastructure to a functional state in a fast, efficient and reliable manner, at a low cost.

The method of remediating landslides, which meets the aforementioned requirements, is the application of electrokinetic chemical soil treatment. This method also enables preventive action in places of recorded potential landslides by improving the physical and mechanical properties of the soil. The formation of sliding surfaces most often occurs in fine-grained soils that are the most susceptible to the change of water content and the resulting change in soil properties, which is the most common cause of landslides. In this regard, the possibility of improving the properties of fine-grained soils by electrokinetic chemical stabilization, considering both well-known stabilizers and new stabilizing materials, should be investigated. Injection of a stabilizer into the soil and its movement through the soil takes place under the influence of direct current, whereas the stabilization mechanism can be explained by the principles of chemical stabilization.

The combination of complex electrochemical processes under the influence of an electric field and with the presence of appropriate chemical agents leads to soil modification and improvement of soil physical and mechanical properties. The advantages of this method would be financial efficiency, the implementation of equipment that is quickly set up and easy to handle, relatively short duration of the treatment and the possibility of its implementation under existing structures without causing noise and disturbance to the environment.

Bearing these facts in mind, the Department of Civil Engineering Geotechnics of the Faculty of Civil Engineering and Architecture of Niš, in cooperation with the Department of Chemistry of the Faculty of Sciences and Mathematics of Niš and the Faculty of Civil Engineering of Subotica, applied for and received a project within the Program "Ideas" of the Science Fund of the Republic of Serbia, for the period 2022–2025. The name of the project is "A New Concept in Improvement of Geotechnical Properties of Ground – Chemical Electrokinetic Treatment of Soils (*ElectroSoil*)".

2. THEORETICAL BACKGROUND OF EXPERIMENTAL RESEARCH

Fine-grained soils are particularly sensitive to changes in water content. For this reason, it is planned this research to be aimed at the application of the technique of chemical electrokinetic stabilization on fine-grained soils and examining the possibility of improving their geotechnical properties by this technique. The concept of chemical electrokinetic soil stabilization is based on the electrokinetic treatment of soil, by passing a low direct current (DC) through the soil between two types of previously inserted electrodes (anodes and cathodes), along with the addition of suitable chemical agents.

From a theoretical and practical aspect, the effects of both the chemical soil stabilization technique and the electrokinetic soil treatment technique have been determined.

The chemical soil stabilization technique [1], [2], [3], [4], on the one hand, implies mechanical mixing of the selected stabilizer and the surface layer of the soil, which contributes to the improvement of physical, chemical and mechanical properties of the treated soil; however, due to the methodology of its application, it can be used only in surficial, easily accessible soil layers (Figure 1), which excludes its application in particularly important geotechnical problems such as slope stabilization, increasing the bearing capacity of the foundation soil, as well as reducing the moisture content and settlements of the soil beneath existing structures.

Figure 1. The chemical soil stabilization technique

Unlike the chemical stabilization technique, the electrokinetic soil treatment [5], [6], [7], on the other hand, can be carried out at greater soil depths and below existing structures; however, the effects of such treatment are not permanent.

A graphical interpretation of the principal processes that take place in fine-grained clayey soil under electrokinetic soil treatment is shown in Figure 2. By passing a direct current through the soil, the process of electro-osmotic flow of water in the soil from the anode (positively charged electrode) towards the cathode (negatively charged electrode) occurs.

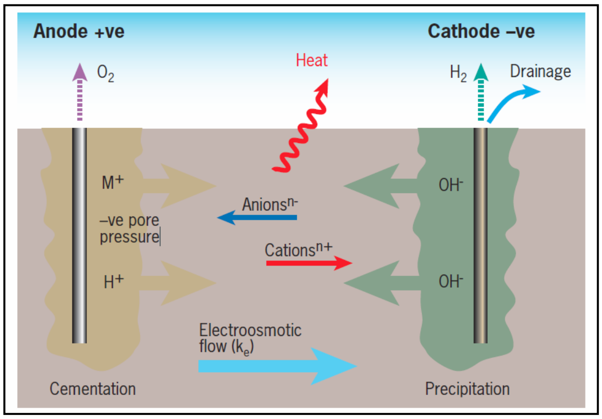

Figure 2. Principal processes active in a section of clayey soil under the elektrokinetic treatment [8]

The result of this process is a decrease in soil moisture content, which begins in the anode zone and then spreads into the surrounding soil (Figure 3), thus resulting in a decrease in pore pressure, an increase in effective stresses in the soil and improved physical and mechanical properties of the soil.

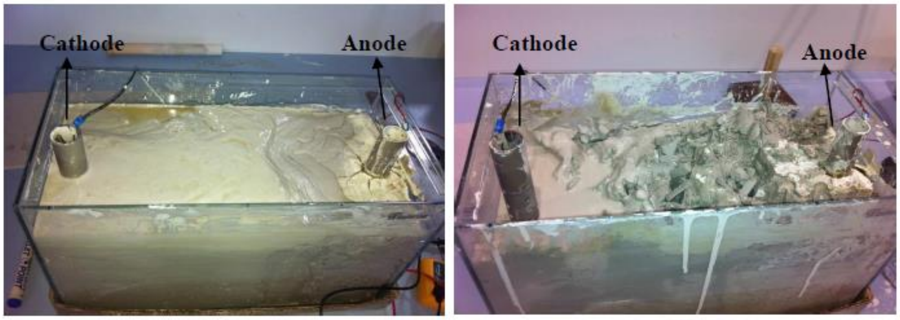

Figure 3. Electro-osmotic flow from the anode towards the cathode: a) early period after the electrokinetic treatment of kaolinite; b) 10 days after the electrokinetic treatment of kaolinite [9]

Chemical electrokinetic soil stabilization, which is the focus of the proposed research, is a technique that overcomes the shortcomings of the aforementioned soil stabilization procedures. Namely, the technique of chemical electrokinetic soil stabilization is an enhancement of the technique of electrokinetic soil treatment using chemical agents (stabilizers), where the injection and movement through the soil of stabilizing agents takes place under the influence of a direct current, whereby the mechanism of stabilization itself can be explained by the principles of chemical stabilization. The combination of complex electrochemical processes under the influence of an electric field and in the presence of appropriate chemical agents should lead to a permanent improvement of the soil in terms of physico–chemical characteristics, and in particular the mechanical properties of fine-grained soil, which are of paramount importance in geotechnical engineering. Moreover, its advantage is that it can be applied to crucial geotechnical problems such as stabilization of slopes and landslides, increasing the bearing capacity of the foundation soil, reducing the soil moisture content under existing structures, as well as stabilizing the ground for construction of deep foundation excavations, tunnels, and other underground structures.

Electrokinetic treatment of fine-grained soils in combination with chemical stabilisers has, to a very limited extent, been the subject of scientific research in the world over the past period [10], [11], [12], [13]. The application of chemical stabilizers mainly on the basis of chlorides has been evaluated, mostly on soil samples tested in laboratory conditions, and without considering the time effect in terms of controlling the achievement of permanent improvement of the properties of the treated soil. All these facts indicate the necessity for detailed experimental research to better understand the nature, effects, efficiency and scope of application of this soil stabilization technology, as well as with the aim of considering the possibility of applying new chemical agents that would contribute to the stabilization effect of a permanent character, which is of elementary importance in geotechnical engineering, and therefore the primary goal of the proposed research within Project "ElectroSoil".

3. METHODOLOGY OF EXPERIMENTAL TESTING

The first part of the planned research activities is related to modelling natural conditions in a laboratory environment. In the second part of the research, data recorded and analyzed during the laboratory experiment stage will be tested at the pilot-project scale (testing the effects of the proposed stabilization technique on slope stability, as well as on ultimate bearing capacity and settlement of foundation soil).

3.1. Laboratory testing

The planned laboratory research will be carried out by a series of laboratory experiments on clay samples, with two variants being considered as chemical stabilizers in combination with electrokinetic treatment: lime [14] (whose effects have not been sufficiently tested by applying the electrokinetic stabilization to fine-grained soils, in particular from the viewpoint of physico–mechanical soil properties), and materials such as magnesium carbonate $MgCO_3$ and water glass Na_2SiO_3, whose influence on soil geomechanical properties has not been investigated to date.

1) In the first stage of laboratory testings, the physico–chemical and mechanical characteristics of natural clay, that will undergo the chemical electrokinetic treatment, will first be determined.

   Clayey soil from the Crvena Reka borrow pit, along the route of the E-80 Niš–Dimitrovgrad Highway (Figure 4), was used for the experimental tests. During the construction of the highway, a landslide was triggered at this location. The designed remediation measures included a support structure in the form of a curtain of piles. Samples of clayey soil for the aforementioned laboratory experiments were taken during the construction of bored piles, from the depth at which the sliding surface was registered.

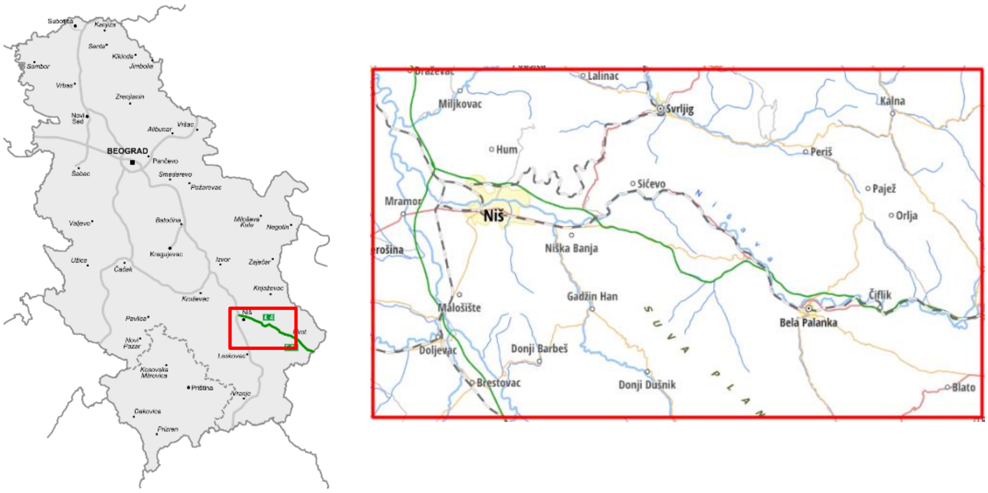

Figure 4. The location of the landslide from where the clay for testing was taken

2) In the second stage of laboratory tests, mechanical mixing of clay in its natural state with the provided chemical stabilizers will be performed. In this way, chemical stabilization of the soil is achieved, the effects of which should be determined through a modification (i.e., improvement) of the physical and mechanical properties of the clay treated with chemical stabilizers in relation to the properties of the clay in its natural state. The obtained values of physical and mechanical properties of chemically treated clay will represent reference values with which the corresponding values, obtained after the combined electrokinetic and chemical treatment, will be compared.
3) The third stage of laboratory testing will include conducting of the research on experimental models, a schematic illustration of which is presented in Figure 5. The clay to be tested is embedded in a pre-prepared testing box of appropriate dimensions, into which the hollow stainless steel electrodes are inserted. The electrodes possess some drilled holes through their walls in order to allow the chemical stabilizer to be injected into the soil sample. The water accumulated in the cathode zone during this process is being collected in a vessel, whereby the amount of the collected amount of water represents a measure of the effect of the electrokinetic treatment on soil drainage (dewatering).
4) In the last stage of laboratory testing, representative samples of treated soil, taken from locations at different distances from the anode and at a variety of depths in the testing box, will be subjected to a series of corresponding tests (direct shear test, oedometer test, triaxial compression test, moisture content, water permeability, consistency limits, …) aimed at determining the physico–mechanical properties of the soil after the chemical electrokinetic treatment. In addition, the effects of the chemical electrokinetic treatment of soil with respect to a modification of the chemical and mineralogical composition of the clay will also be determined. Moreover, the taken samples will be cured over time, with an aim of examining the durability of the achieved stabilizing effects of the proposed technique on the properties of the treated soil by conducting a series of tests at different time intervals after the treatment. In addition to static conditions, laboratory testing of clayey soil samples would include testing of soil properties under dynamic conditions as well.

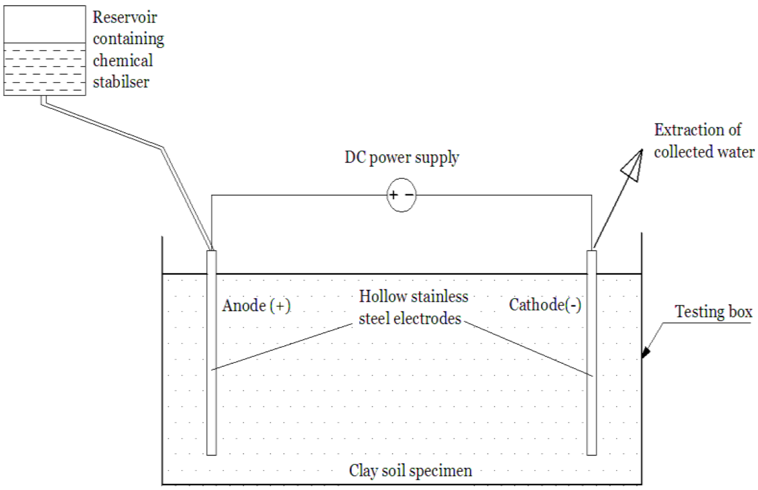

Figure 5. Chemical electrokinetic stabilization testing model

Pilot projects

3.2. In the second part of the proposed research, the research activities are planned to be scaled up from the experimental to a higher level - the pilot scale. A pilot project of slope (Figure 6) and a pilot project of foundation with foundation soil will be done, in cooperation with a construction company, referring to testing the effects of the proposed chemical electrokinetic stabilization technique on slope stability, ultimate bearing capacity of foundation soil, as well as foundation-soil settlements.

Figure 6. A pilot project of slope [15]

The effects of chemical electrokinetic soil treatment, as a considered new technique of fine-grained soil stabilization, will be examined by comparing the physico–mechanical properties of the clay in its natural state determined by the laboratory testing before applying the stabilization technique (the first stage of laboratory testing) with the corresponding physico–mechanical properties of the clay estimated after mechanical mixing with chemical stabilizers (the second stage of laboratory tests) and after its treatment by the proposed combined electrokinetic and chemical stabilization technique (the fourth stage of laboratory testing).

The evaluation of the proposed chemical electrokinetic soil treatment will be performed through a quantitative consideration of the effects of the treatment on the improvement of physical and mechanical properties of the tested soil, such as the soil shear resistance parameters (cohesion (c) and internal friction angle (φ)) and compressibility modulus (M_v). Improving the soil parameters c and φ contributes to increasing the stability of the slope (by increasing the safety factor (F_s)), increasing the bearing capacity of the foundation soil (q_a) and reducing the settlement of the foundation soil (s) (by increasing the compressibility modulus of the soil (M_v)). One of the most important effects of the proposed stabilization procedure will also be considered - the effect of permanent reduction of water permeability of the treated soil through determination of the water permeability coefficient (k), which permanently improves the stated physical and mechanical properties of soil.

4. CONCLUDING REMARKS

The soil stabilization method described in the paper is an improvement of the technique of electrokinetic soil treatment using chemical agents (stabilizers), whereby the injection and movement of stabilizing agents through the soil takes place under the influence of direct current, while the stabilization mechanism itself can be explained by the principles of chemical stabilization. The method of chemical electrokinetic soil stabilization, which is presented in the paper, represents a technique that overcomes the shortcomings of the chemical stabilization technique and the technique of electrokinetic soil treatment. It is expected that the laboratory and field experiments foreseen by the project will confirm the assumption that the proposed soil stabilization technique contributes to the permanent improvement of the physical and mechanical properties of the soil, such as cohesion, angle of internal friction, compressibility and water permeability, which are of particular importance in geotechnical engineering.

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UNFAVOURABLE GEOLOGICAL CONDITIONS AND ASSOCIATED RISKS IN TUNNELLING

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Abstract

Contemporary methods of tunnel construction imply the application of very complex construction technologies. The complexity of the process itself brings with it a number of potential problems and risks, which would have to be assessed in an adequate and systematic way, in order to prevent unforeseen incident situations or reduce them to the lowest possible level. The paper gives a brief overview of possible risks in the stages of contracting, design, and construction of a tunnel, with a special reference to the risks associated with unfavourable geological conditions and the forms of tunnel instability caused by them. A detailed investigation of the geological structure and composition of the terrain through which the tunnel is to be built is of huge significance, as, among the variety of construction technologies (excavation and supporting system), it allows selecting the one that will result in minimal risk.

Key words: *Tunnelling, Risks, Geological conditions, Construction technology*

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ON HAZARDS, RISKS, RISK ANALYSIS, RISK ASSESSMENT, AND RISK MANAGEMENT IN TUNNEL ENGINEERING

Underground construction and tunnelling projects involve a variety of complex and complicated tasks. These projects require a high level of expertise and precision in order to ensure safety and efficiency. The construction process itself consists of excavating and supporting the excavated contour, thereby creating underground
1. space that can serve for various purposes, such as transportation, utility systems, and storage facilities. Accordingly, the construction of tunnels necessitates advanced engineering and geotechnical knowledge, as well as the use of specialised equipment and machinery. It is a challenging but crucial aspect of contemporary infrastructure construction and development.

Given the possibility of unforeseen obstacles and unexpected challenges, especially due to the diverse and complex nature of ground and groundwater conditions, the success of any project is never guaranteed. Yet, with appropriate planning, effective communication, and the ability to adapt to changing circumstances, it is possible to increase the likelihood of success. In doing so, special attention should be paid to establishing clear goals and objectives, identifying potential risks and opportunities, and allocating resources adequately. In order to achieve the desired outcome, it is not uncommon to need to adjust the timeline, budget, or scope of the project.

Tunnel construction work can be a demanding and challenging task, in particular when it comes to tunnels located in congested urban areas. These types of projects require a great deal of planning, in order to ensure that the work is carried out safely and efficiently.

Risk reduction goals can include both general objectives and objectives that are specifically related to each risk category. The general objectives of a construction risk policy may be to identify potential *hazards*, which represent expected occurrence of future unwanted events.

After identifying potential hazards, it is necessary to determine the best ways to eliminate/reduce the *risk*, which stands for expected consequences of future undesirable events. As a result of the previous activities, the implementation of these strategies is put into practice when it makes sense financially or when required by health and safety regulations or certain risk objectives.

Risk analysis actually represents a methodical approach that accurately indicates the probability and potential outcomes of hazards that may arise as a result of working on a specific facility or during certain activities. The risk analysis process consists of three basic steps: planning, risk assessment, and risk treatment. In contrast, *risk assessment* involves evaluating the results of the risk analysis process against certain decision parameters and acceptable criteria.

Risk management is a comprehensive process of systematically applying policies, procedures, and management practices to the tasks of identification, analysis, assessment, treatment, and monitoring of risk. Simply said, risk management is the use of available mechanisms to identify hazards and assess risks to individuals, property, and the environment. It includes deciding whether to accept known risks or to implement measures to reduce unacceptable risks to an adequate level [1]. One of the main goals is to define the so-called acceptable (tolerable) level of risk. In relation to this level, the other levels (classes) can be determined and the necessary measures can be determined accordingly (Table 2).

Table 1. Example of risk classification and actions (measures) [2]

Risk classification	Example of actions that should be carried out for each class
Unacceptable	The risk shall be reduced at least to Unwanted regardless of the cost.
Unwanted	Risk mitigation measures shall be identified. The measures shall be implemented as long as the costs of the measures are not disproportionate with the risk reduction obtained (ALARP principle – As Low As Reasonably Practicable) .
Acceptable	The hazards shall be managed throughout the project. Consideration of risk mitigation is not required.
Negligible	No further consideration of risks or hazards is needed.

Risk management during the design of a tunnel from the early stages of planning to the start of construction work covers the following aspects [3]:

- Stage 1 – Early design stage (feasibility and conceptual design):
  - Establishing a risk policy;
  - Defining risk acceptability criteria;
  - Providing a qualitative assessment of the project risks;
  - Conducting detailed analysis of areas of particular interest or concern.
- Stage 2 – Tender and contract negotiations:
  - Definition of requirements in the tender documentation;
  - Assessing risk in tender evaluation;
  - Specification of risk clauses in the contract.
- Stage 3 – Construction stage:
  - Management of contractor's risk,
  - Management of investor's risk,
  - Management of joint risk between an investor and a contractor.

By analysing all three stages of risk management, the conclusion that could be drawn is that in the first stage, all responsibility in the risk management process rests with the investor, in the second stage, the potential contractor receives instructions related to the tender, but all responsibility is still in the hands of the investor. In the third stage, the responsibility is assumed by the contractor, but for successful risk management, cooperation between the investor and the contractor is necessary because the common goal is to reduce risk to a minimum and to successfully assess and manage risks.

For all the above given reasons, careful risk analysis is of huge importance in mining and tunnelling projects in order to prevent potential accidents at work.

2. AN OVERVIEW OF POSSIBLE RISKS IN TUNNEL CONSTRUCTION

Depending on where they are built, tunnels are often subject to unpredictable ground conditions and varying groundwater levels. As a consequence of the above, there is a possibility that various types of incidents, such as fire, landslides, and floods, may occur during the construction of the tunnel, which may lead to delays, environmental concerns, and the risk of cost overruns. In addition, there may be a risk of public complaints that tunnel construction projects affect the public in any way, which could ultimately have a significant impact on project progress.

Incidents that occur in construction are closely related to geology and are classified as major hazards, for example, excavation instability. If the works are not performed adequately and the necessary measures are not taken properly and on time, these instabilities can threaten the stability of the ground and reach the breaking point.

During work on tunnel construction projects, it is necessary to familiarise yourself with the possible types of incidents that may occur. The following problems are ranked among the main risks of tunnel construction [4]:

- loss of tunnel face stability;
- portal collapse;
- collapse of tunnel ceiling (ground arch) at the heading, resulting potentially in:
  - excessive excavation,
  - ceiling collapse up to the ground surface;
- face fall-out on tunnel;
- low stability of tunnel face;
- tunnel bottom growth, lining penetration into soft subsoil;
- excessive growth of convergences – tunnel profile squeezing, primary lining deformations;
- excessive ground water inflow into the tunnel;
- sudden water/mud/runny sand breakthrough into the tunnel;
- dangerous gas or radiation bursts into the tunnel from:
  - methane,
  - natural gas from ruptured piping,
  - CO_2;
- occurrence of stray currents;
- excessive surface sinking above the tunnel and related impacts on surface structures, and power and service utility lines;
- drawdown, destruction of water wells around the tunnel;
- damage and destruction of water courses near the tunnel by mine water discharges that may have substantially changed their chemistry (for example, concrete extracts);
- 2.1. damage due to pressure grouting compacting the rock massif or due to anchor grouting (damages to power and service utility lines, surface swelling);
- improperly selected and implemented tunnel waterproofing and water infiltration into the tunnel.

Types of undesirable events in tunnelling

It is necessary to identify and classify the types of events that can occur during tunnel construction. Based on the collected data on past events [5], the main observed accidents are presented in subsequent subsections**.** They can cause loss of live, equipment damage, and damage to the tunnel structure that may lead to a collapse. Fire and explosions are probably the most common type of accidents during the operation of tunnels, but are less frequent during construction.

Falling of stones and rocks

Landslides or rockslides are common types of landslides that can move at high speeds and can greatly threaten the safety of tunnel construction. Unfavourable geological conditions are the main reason for falling stones and rocks. It is crucial to predict the probability of landslide occurrence in order to ensure the safety of the tunnel construction and the normal operation of the tunnel after its completion.

2.1.1. Collapse of the tunnel structure

During the construction of the tunnel, the tunnel structure is damaged, but these damages do not reach the surface itself. The largest number of tunnel damages (face and/or roof) occurs in the header area. The second, much smaller number, occurs behind the face of the tunnel.

2.1.2.

Damage that creates an opening in the tunnel structure (daylight collapse)

2.1.3.

This type of damage causes openings in the structure itself and allows sunlight to enter the tunnel. The damage breaks through to the surface creating a crater. This could be of a great danger, in particular if the tunnel is built in urban areas. Damages of this type are the most represented in the literature, because they are most likely those with more serious consequences on the construction process, the safety of workers, and people and structures on the surface.

2.1.4. Flood / Large inflow of water

Groundwater inflow into the tunnel can affect the tunnel design and construction process, especially for open cut methods. During tunnel construction, large water inflows can cause ground subsidence, as well as soil property changes or damage to building foundations and utility services. All these facts can affect unpredictable delays in the construction process.

2.1.5.

Rockburst / Spalling

This type of damage occurs when the stresses developed in the ground exceed the local strength of the material. As a result of the increase in tension in the ground, cracking or, in the worst case, sudden and violent disintegration of the solid rock mass may occur. Rockfalls can occur suddenly and can cause serious, and often fatal, injuries. They often occur under seismic activities. They are conditioned by the stress on the rock, which increases with increasing depth.

2.1.6.

2.1.7. Excessive deformation

Cases in which there is a deformation that is significantly greater than expected, but does not cause damage to the structure itself. It appears as a consequence of a wrongly chosen design solution, due to construction defects and errors, and/or due to a special type of terrain that was not foreseen in the design stage.

Collapses on certain locations (portals, shafts)

This type of collapse most often occurs in locations where soil resistance is lower, which can be related to stress concentration and which can also be an independent factor for collapse. These locations are most often portals and connections with shafts. It often happens that if the construction of the entrance part of the tunnel does not meet the requirements of the project, the stability of the tunnel structure is reduced and the tunnel is damaged by collapse.

2.1.6. Other

Other types of collapse that include slope failures, etc.

2.2. Tunnel construction method

The selection of tunnel construction method (New Austrian Tunneling Method (NATM), Tunnel Boring Machine (TBM), cut-and-cover method, etc.) depends on a number of factors such as soil conditions, groundwater, tunnel length and diameter, transportation, tunnel depth, production costs, and risk management.

3. UNFAVOURABLE GEOLOGICAL CONDITIONS AS ONE OF THE MOST PRONOUNCED RISKS IN TUNNELLING

In order to minimise the risk of tunnelling projects, a complete understanding of the ground conditions through detailed investigation is required. Geological substrates contain data on the types of rocks found in a certain area and their properties (genesis, spatial position, layering, water permeability, etc.), which are presented through a written report, geological maps, and geological profiles.

Based on the evaluation of the ground conditions for the needs of tunnel construction, the forms of expected tunnel instabilities can be:

- Instability due to unfavourable geological composition of rock mass (failure controlled by the rock structure and gravity);
- Instability due to low strength of rock mass in relation to stress (failure caused by stresses and gravity);
- Instability due to heavy weathering or swelling of rocks;
- Instability due to high pressure or water flow.

3.1. Instability due to unfavourable geological structure

When there are one or more dominant discontinuities in the rock mass, in which the problem of stability is solved, they form blocks whose stability depends on the properties of the discontinuity. Under the influence of forces caused by gravity, or a change in the state of stress caused by the loading of the rock mass or excavation, the blocks fall out from the roof or slide from the side walls of the tunnel opening along the discontinuities. This unstable state is called *structurally caused instability*.

These blocks are formed by the intersection of structural elements, such as planes and joints that separate the rock mass into discrete but interconnected fragments. When a tunnel contour is created by excavating the opening, one or more of these blocks may fall or slide into the tunnel profile if the rock joints are continuous or the stone bridges along the discontinuity are broken. If adequate steps are not taken to prevent the collapse of the inner parts of the tunnel, the situation may become worse.

Figure 1 shows examples of tunnel instability due to unfavourable geological composition. Heavily cracked rocks (Fig. 1a) will show instability at low stresses in the form of small wedge-shaped blocks falling out along the contour of the excavation. Fracture can extend deep into the rock mass if not controlled. Massive rocks (Fig. 1b) will deform elastically under low stresses and fracture of the rock will generally not occur. Cracked rocks (Fig. 1c) will show instability under low stresses in the form of falling or sliding blocks under the action of gravity.

Movement along the joints must be minimised to prevent collapse of the rock material, which means that the support system must provide adequate response to the rock movement (Fig. 2).

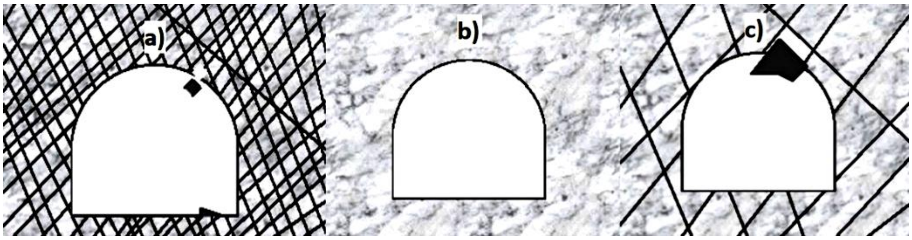

Figure 1. Examples of tunnel instability due to unfavourable geological structure [6]

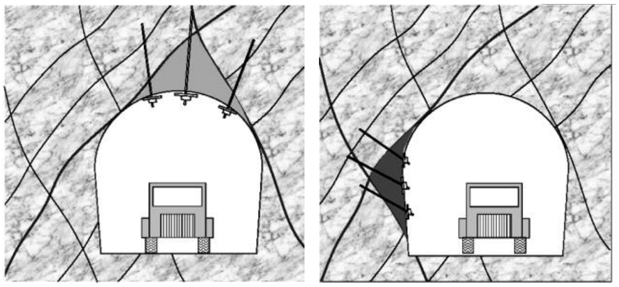

Figure 2. Preventing unstable wedges from falling out by installing a support (rock bolting) [6]

3.2. Instability due to low strength of rock mass

When the rock mass is homogeneous, which is very rare, or when there are so many discontinuities that it is completely fractured, so it can be considered conditionally homogeneous (quasi-homogeneous), unstable conditions usually occur when, due to a change in the state of stress caused by a change in load or excavation stress, they exceed the strength of the rock mass. In this case it is a *stress induced instability*. Fracture in the rock mass can occur due to exceeding one or more forms of strength - compressive, tensile, or shear, and that of the rock or discontinuity.

Figure 3 shows examples of instability due to low tensile strength of rock mass.

High stress concentration on the contour of the excavation in the cracked rock mass (Fig. 3a) will cause fractures in the form of sliding along discontinuities and crushing and splitting of individual blocks. A high stress concentration on the contour of the excavation in the heavy cracked rock mass will cause sliding along discontinuities and crushing of individual blocks. A profile closure due to floor heave and block movement towards the opening are typical results of this type of failure (Fig. 3b).High stress concentration on the contour of the excavation in the massive rock mass (Fig. 3c) will result in spalling, slabbing, and crushing.

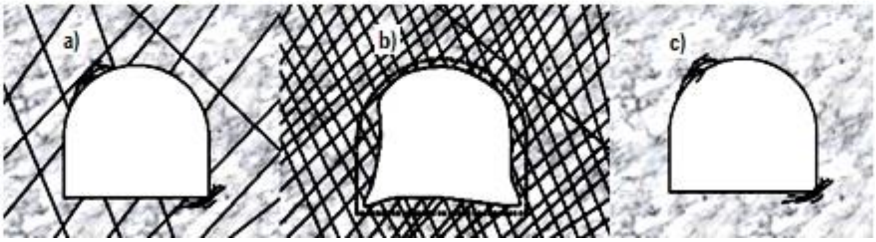

Figure 3. Examples of instability due to low tensile strength of rock mass [6]

Rocks rich in clay minerals in contact with water are prone to squeezing, which represents a time-dependent large deformation that occurs around the tunnel and is mostly related to creep that is a consequence of exceeding the limiting tangential stress. As a result of squeezing of the rock mass, the tunnel profile is reduced due to large deformations of the surrounding rock mass, which leads to long-term loading of a tunnel lining and its deformation and possible failure (Fig. 4). An example of solving the problem of instability due to the squeezing of the rock mass by applying the appropriate type of tunnel structure is given in Figure 5 for the case of the Gothard base tunnel.

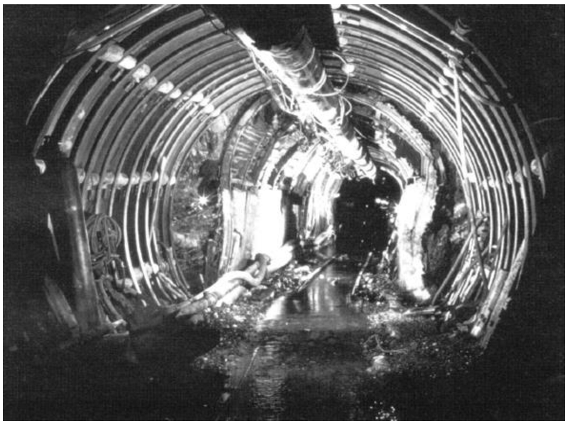

Figure 4. Deformation of a tunnel support due to squeezing of the surrounding rock mass [6]

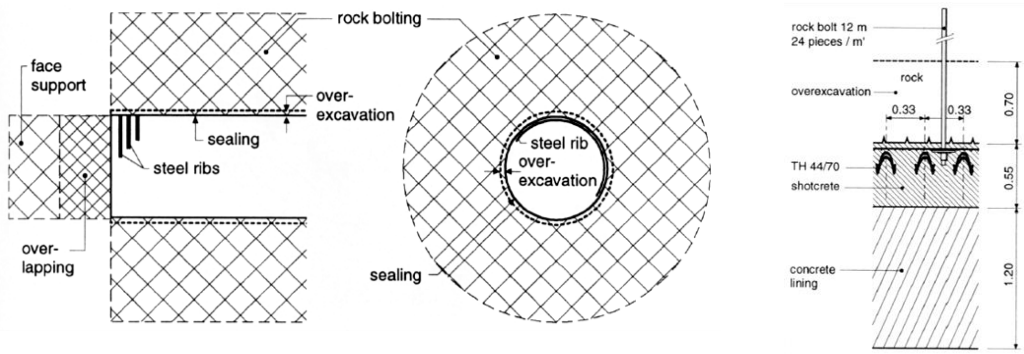

Figure 5. Tunnel support of the Gothard base tunnel in a squeezing rock mass [6]

Instability due to heavy weathering or swelling of rocks

Swelling of rock masses represents a time-dependent increase in the volume of natural ground caused by an increase in water content in the ground. Many rock types that contain clay minerals and/or anhydrite will swell or disintegrate when exposed to atmospheric cycles of wetting and drying. Although squeezing and swelling of rock masses have nothing in common in the phenomenological sense, in tunnelling they are very tightly connected, that is, the effects of swelling are regularly enhanced by the effects of squeezing. Swelling usually develops over several decades, thus seriously aggravating the long-term serviceability and stability of underground structures.

Practice shows that rock usually swells in the floor of an underground opening, for the following reasons: in the floor there is the most water (technological and/or underground), the floor is usually less secure than the calotte and sides, and the dynamic effects of transport contribute to the disintegration of the rock in the floor.

In tunnel structures, swelling manifests itself as a heaving and failure of the tunnel invert (Fig. 6). When swelling is limited by an inverted arch, pressure develops, which can damage the bottom part of the tunnel structure. The walls and crown of the tunnel structure, on the other hand, remain stable for many years.

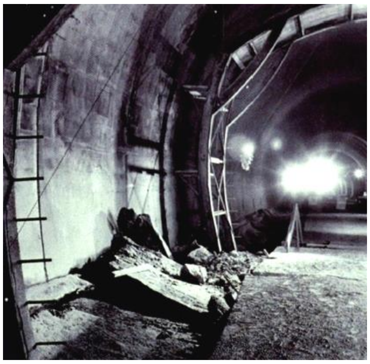

Figure 6. Heaving and failure of the tunnel invert due to swelling of the rock mass [6]

3.4. Instability due to high pressure or water inflow

Unfavourable effects of groundwater on tunnels can be multiple, both during the construction phase and during the operation phase. During the construction of a tunnel in soil that is saturated with water, water flows towards the opening (Fig. 7a), as the tunnel acts as drainage of underground water. Water can negatively affect both the stability and the deformations of the tunnel by reducing the effective stress, and thus the resistance to shearing, as well as by washing away fine particles from the surrounding ground in an erosive action. In addition, groundwater can cause chemical effect on the elements of the tunnel structure, as well as an increase in temperature in the case of thermal waters.

Experience shows that in the case of small tunnel profiles in dense soil or in soil that exhibits some cohesion, drainage alone is often sufficient to enable excavation. The technical and financial feasibility of drainage in a specific case depends on the amount of water inflow, which in some cases can be enormously large (Mon d'Or Tunnel − 10.000 *l*/s, Simplon Tunnel − 1.500 *l*/s). In most cases, in addition to drainage, the proper waterproofing should also be carried out (Fig. 7b).

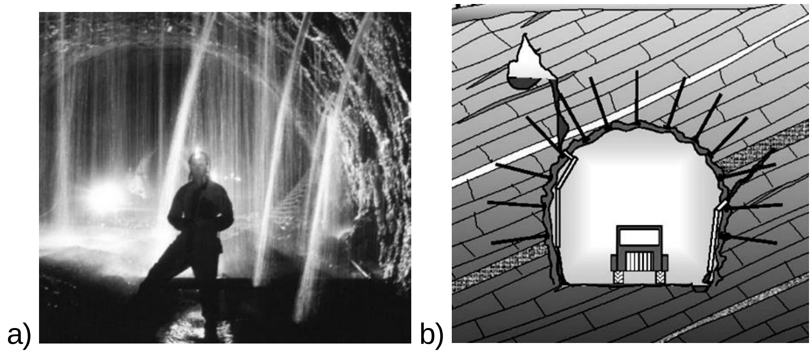

Figure 7. Water flow into the tunnel and corresponding measures against it [6]

3.5. Instabilities induced by seismic events

There are several patterns of cracking induced into the tunnel lining during an earthquake [7]. A structural or lythological modification determines unfavourable conditions and causes lining cracking and collapse. These patterns are (Fig. 8):

a) Sheared off lining (it occurs for tunnel passing through active faults);
b) Slopes failure induced tunnel collapse (it occurs when the tunnel runs parallel to slopes generating landslides passing through the lining);
c) Longitudinal cracks (it occurs when the tunnel is subjected to higher deformations due to surrounding ground);
d) Traverse cracks (it occurs when the tunnel has weak joints);
e) Inclined cracks (it occurs for a combination of longitudinal and transversal cracks);
f) Extended cracks (it occurs when there is the partial collapse of linings for seismic intense deformation);
g) Spalling of lining (it occurs when the transversal section completely collapses).

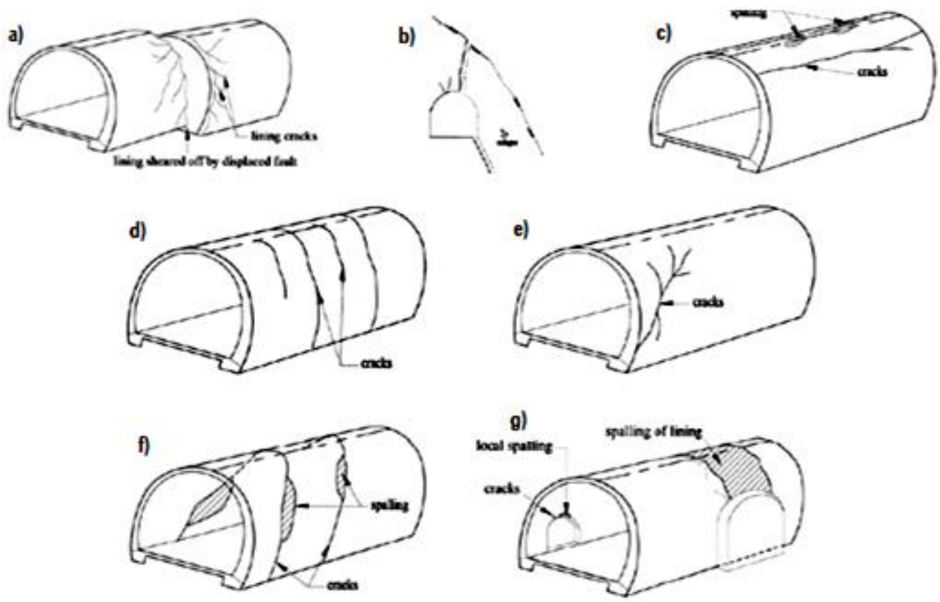

Figure 8. Example of damage to tunnel structures due to earthquake events [7]

Here follow the most extreme examples of seismically induced damage to tunnels in the recorded history (Fig. 9).

In the *1998 Mid North Iwate Earthquake, Japan* (Mw=6.1), the fault rupture extended over 880 m crossing an outlet tunnel of the hydropower station. The tunnel cracked and separated into several blocks, one of which completely collapsed, causing the soil with boulders (30–50 cm) to enter into the tunnel (Fig. 9a) [8].

A railway tunnel crossing the White Wolf Fault (reverse and strike slip, amplitude 1.3m) was seriously damaged during the *1952 Kern County Earthquake, USA* (Mw=7.5) associated with this fault. After the earthquake, both a compressive and a lateral component of displacement were detected on the ground surface along the WWF: rails, both inside and at the entrance of the tunnel, were bent, while locally the displaced rail was thrust by the 46-cm-thick tunnel lining, showing that the tunnel wall was lifted up and the bent rail slid underneath (Fig. 9b) [9].

In the *1999 Chi-Chi Earthquake in Taiwan* (Mw=7.6) several highway tunnels were located within the zone heavily affected by the earthquake. The main damage occurred at tunnel portals due to slope instability as illustrated in Figure 9c. There were nine severely damaged tunnels and six moderate damaged tunnels induced by portal landslide. Minor cracking and spalling was observed in some tunnel linings. One tunnel passing through the fault was shut down because of a 4-m fault movement [10].

A strike-slip fault appeared in the *1970 Off Izu Oshima Earthquake* (M 7.0) across railway tunnel. The northeastern half of the tunnel was pushed about 0.85 m seaside, whereas its western part was pushed about 0.2 m towards mountains. The tunnel was most seriously deformed at around the point, where the tunnel was cut by the fault. The example given in Figure 9d shows that a tunnel can keep its cross-section almost intact even after experiencing some larger fault dislocations reaching about 1.0 m. These cross-sections were all pushed slightly out of shape. As a consequence, its crown was bent up against the soil, and some block joints broke up into flakes. One of the side concrete blocks was thrust in the tunnel, and some invert concrete blocks were pushed up. However, the greater part of the cracked pieces of lining stayed at their locations, and fortunately the tunnel cross-section was kept almost intact [11].

The 3.2-km-long Bolu twin tunnels between Istanbul and Ankara in Turkey are part of a 1.5 billion dollar project and were constructed using the New Austrian Tunneling Method (NATM). Construction has been unusually challenging because the alignment crosses several minor faults parallel to the North Anatolian Fault (strike slip), along a 200–300 m wide shear zone consisting of highly plastic clay of poor strength. The squeezing of this weak rock mass and extreme deformation up to 720 mm were observed during the opening of the tunnel. The August 17, 1999 earthquake was reported to have had minimal impact on the Bolu tunnels. However, the *November 12, 1999 Duzce Earthquake* (Mw=7.2) caused the collapse of both tunnels. At the time of the earthquake, an 800-m section had been excavated and a 300-m section of unreinforced concrete lining had been completed. The collapse took place in clay material in the unfinished section of the tunnel. The section was covered with shotcrete (sprayed concrete) 25 cm thick and had bolt anchors 6 to 9 m long. Figure 9e [12] shows a section of the collapsed tunnel after it has been re-excavated (reducing the tunnel profile up to 0.5–1.0 m, cracking of the sprayed concrete support, and bending and breaking of reinforcing bars). Several mechanisms have been proposed for explaining the collapse of the tunnel. These mechanisms include strong ground motion, displacement across the clayey material, and landslide.

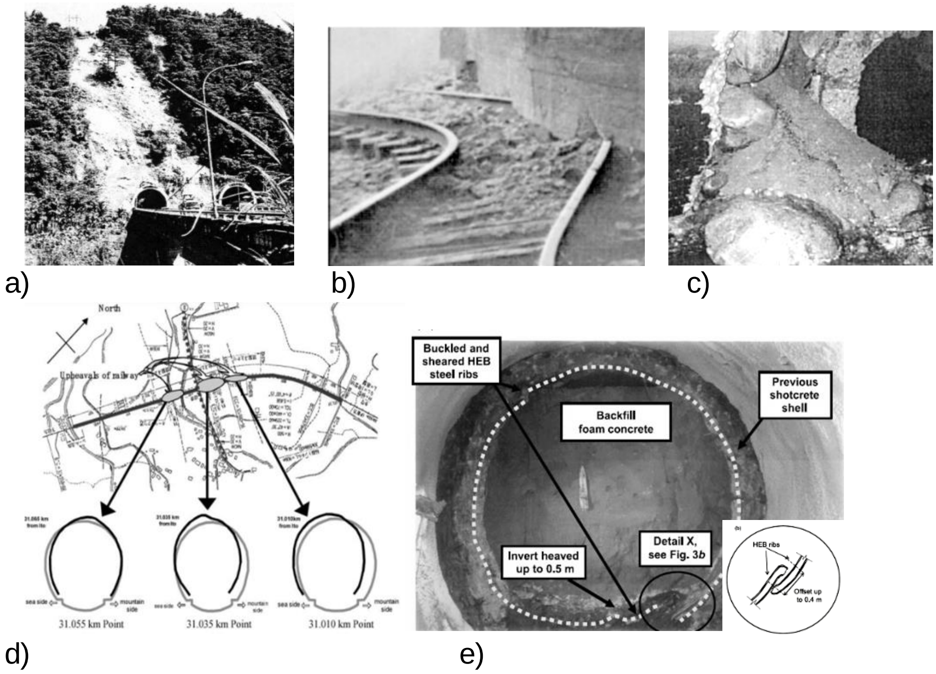

Figure 9. Some of the most extreme cases of seismically induced damage to tunnels

4. CONCLUDING REMARKS

Tunnel construction projects are a specialised and complicated field of several engineering sciences, characterised by significant risks that exist even after the completion of the project, and the risks during the operation and maintenance stage are especially represented. To effectively manage risks, tunnel maintenance professionals must create a risk management plan that includes gathering information about past incidents. This information is necessary to establish appropriate operational strategies as soon as possible.

In order to ensure maximum preparedness for any potential incident during tunnel construction and operation, the first step is to identify all possible types of instabilities. Once this is achieved, the most relevant design parameters can be determined. If the rock mass behaves isotropically, which is very rare, then the parameters of the rock mass itself are taken into account. However, if the rock mass behaves anisotropically, which is found in the largest number of cases, then the characteristics of all the discontinuities it exhibits take precedence. By applying these proposals, it is possible to evaluate the principles for the selection of appropriate support measures and their basic dimensioning based on the behaviour of the ground and the predicted mode of failure. The accuracy of these classifications and support systems can be directly monitored and managed through continuous tunnel monitoring.

ACKNOWLEDGMENTS

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APPLICATION OF THE TROMBE WALL SYSTEM IN THE FORM OF FACADE PANELS OF PREFABRICATED OBJECTS: A CASE STUDY

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Abstract

The concept of sustainable development in architecture and construction is a modern approach that aims to meet the needs of humans by utilizing available resources and innovative technology while promoting the longevity of buildings and preserving natural systems and the environment. Building Energy Performance Simulation of prefabricated buildings provides the best passive design options by analyzing the efficiency of passive design strategies in contextual climatic circumstances to calculate potential energy savings in heating and cooling. Through a detailed case study, the research paper aims to provide insights into the feasibility, effectiveness, and practicality of applying the Trombe wall System in prefabricated constructions. This research paper aims to investigate the impact of passive design strategies on the prefabricated building envelope, assess the effectiveness of such strategies, and develop guidelines for comparative analysis of various Trombe wall types to increase energy efficiency. The study's findings highlight the possibility of identifying and providing viable solutions to problems in reducing energy usage.

Keywords: *Sustainable development, Trombe wall, Energy efficiency, Passive design, Prefabricated objects*

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INTRODUCTION

The necessity for the sensible use of energy emerged internationally for the first time during the 1973 oil crisis, which resulted in soaring energy costs. Several nations enacted stringent measures to decrease energy usage during this period, including the earliest building thermal protection standards. Shortly after the stability of energy costs, there was a decline in interest in the energy efficiency of buildings.
1. However, this topic has regained importance due to the detrimental impact of energy use on climate change. The thermal energy consumption per square meter in Serbian houses is far greater than the EU average, with some exceeding this already high amount. This gives a chance for building owners to investigate energy-saving and energy-efficient improvements. It is imperative to prioritize green construction to significantly reduce harmful gas emissions, particularly within the building sector. Architects face a challenge when designing energy-efficient buildings that incorporate passive solar design. Passive design systems can effectively aid this pursuit [1], [2].

The Trombe wall (TW) System is a passive solution commonly used in building design. It involves the integration of a massive, thermally absorbent wall located on the south-facing facade of a building. This wall collects and stores solar energy during the day, which is then slowly released into the interior at night, maintaining a more stable and comfortable indoor temperature [3], [4]. The effectiveness of the TW is influenced by its three components: vents, ventilation, and insulation [5]. The accumulation of solar energy aids in heating and improving thermal comfort within the building [6]–[8].

The research investigates the potential benefits of incorporating this passive system into pre-built structures using TW panels as facade elements in prefabricated objects. Through a detailed case study, the research paper aims to provide insights into the feasibility, effectiveness, and practicality of applying the TW System in prefabricated constructions. Such an approach enhances the thermal performance of these prefabricated objects and reduces their reliance on conventional heating
2. and cooling systems, reducing energy consumption and carbon footprint.

ARCHITECTURAL MODEL SETTINGS - INPUT PARAMETERS

Various forms of TWs include the Classic TW, Zigzag TW, Water TW, Solar Transwall, Solar Hybrid wall, TW with phase-change material, Composite TW, Fluidized TW, and Photovoltaic (PV) TW [9]. Vents, ventilation, and insulation are
2.1. three essential components that significantly impact the TW's effectiveness, contributing to improved thermal comfort inside the building.

When modeling a TW, it is important to consider key input parameters such as local climate data, wall orientation, thermal mass material, glazing type, ventilation strategy, building design, insulation, internal heat gains, and simulation software.

Meteorological characteristics of the location

The effectiveness of passive solar design strategies depends largely on meteorological factors, so architects must understand climatic factors well. The efficiency of the TW system can fluctuate depending on climate, time of day, and outside temperature [10].

The modeled hall is situated in Niš, Serbia, which has a moderate-continental climate and averages 11.4°C. July averages 21.3°C, while January averages -0.2°C. Niš averages 1993 hours of annual insolation. The Rulebook on Energy Efficiency classifies Niš as zone A since its external design temperature is -14.5°C. The condensation period lasts 60 days (with an average monthly insolation of over 250 hours) and is calculated using the external air's temperature of -5°C, relative humidity of 90%, and indoor air's relative humidity and temperature of 55%. December averages 52 hours of insolation.

Data on the materialization of the building's thermal envelope

Materials with high heat capacity, such as concrete, stone, soil, and water, are ideal for constructing TWs [9]. While concrete and steel are great at storing heat, steel is not significantly better than concrete when considering convection effects [11]. Concrete, terracotta, and limestone are the most favorable inertial materials due to their high heat storage capacity, low production energy consumption, and affordable price [12]. Walls made of concrete, stone, or brick can accumulate heat during the day when facing the sun and release it into rooms during colder nights. This transfer can occur naturally through the properties of air, where warmer air rises and colder air descends. The position of thermal insulation can greatly influence heating and cooling needs, with insulation jacketed around thermal mass on the inside providing the greatest benefits [13].

The facade walls of the analyzed hall are constructed with Trimoterm or an equivalent insulated sandwich panel with a 120-minute fire resistance certificate. The panels are mounted onto a thermal insulation layer and fastened with PVC dowels and steel screws. A vapor-permeable waterproof film is also installed over the stone wool panels to ensure optimal protection. The Pan-X cassette system covers canopies and other facade elements in the same finish as the facade and ceiling elements. The hall's facade surfaces facing north, east, and west was built with a thermal break system of aluminum profiles, such as the ALUMIL M50 or an equivalent. The facade comprises vertical and horizontal self-supporting aluminum profiles, 50 mm wide inside, with a cover cap of vertical and horizontal profiles, with a width of 50 mm outside. The same elements connecting the facade to the exterior surfaces are covered with aluminum cladding. The glazing used on the facade consists of low-emission safety glass with a preliminary configuration package. The roof is single-gable, flat, and impassable. It has a three-layer structure with plasticized steel sheet, vapor barrier, and stone wool. The system also has a waterproof PVC membrane and PLUVIA for drainage, while the finish is with an FPO sheet and polyurethane grout.

The most effective thickness of a TW structure in South Europe would depend on various factors such as the specific climate conditions, solar exposure, and the thermal requirements of the building. Although, as a general guideline, the thickness of a TW typically ranges from about 20 centimeters to about 40 centimeters, in regions with milder winters and moderate solar exposure, a thinner TW might be sufficient to capture and store solar energy effectively. On the other hand, in areas with harsher winters and higher solar exposure, a thicker TW with more thermal mass can help retain and release heat more efficiently, contributing to better thermal performance during colder periods.

Modeled TW system (Figure 1) comprises a massive thermo-accumulation wall and glazing with an air gap. The massive thermo-accumulation construction is made of concrete, while the projected width of the intermediate space is 0.10m. The concrete thermal storage construction has a thermal conductivity of 2.04 W/m/K, a density of 2400 kg/m3, and a specific heat of 840 J/kg/K, while the thickness of the concrete layer is 0.15 m.

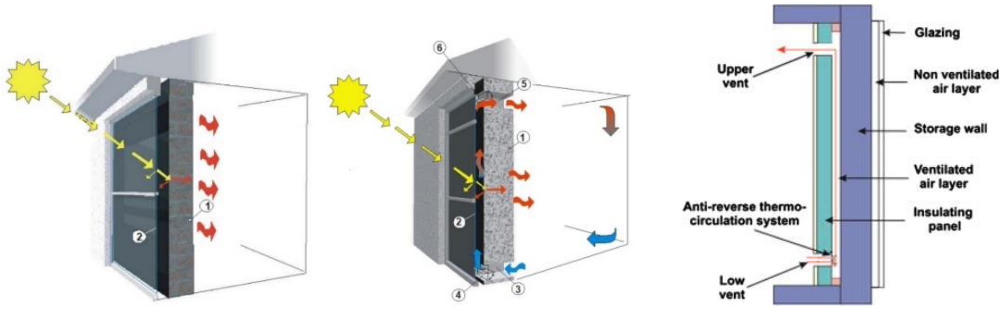


Figure 1. - The way the TW functions (left) and the section of the tested TW construction (right) [9]

3. ENERGY SIMULATION SOFTWARE

Numerous modern software for energy simulation enables the modeling of the TW, primarily BLAST, DOE-2, TRNSYS, SUNREL, ESP-r, and EnergyPlus. Even though experimental research on these constructions is the most reliable way to get the facts and knowledge about the functioning of the TW system, in practice, experiential or intuitive design of these systems often prevails. With the appearance and development of modern software, this problem has been overcome, and it is increasingly easier and more certain to obtain data and have reliable assumptions related to future projects.

One of the most popular programs for energy simulation is certainly EnergyPlus. In his thesis, Peter Graham Ellis develops and validates the TW model in the EnergyPlus program. This software enables a comprehensive analysis with the inclusion of various factors such as precisely defined climatic characteristics, construction, presence of people, lighting, thermal mass, electrical devices, time of use, the influence of solar radiation, shading, wind, infiltration, all for a precisely defined period. In this way, it is possible to vary the physical parameters and optimal design. The TW model in the EnergyPlus software implies the inclusion of all the mentioned phenomena for walls and windows, which has been validated and experimentally confirmed in practice [14]. The TW model is based on the heat balance method, where heat is accumulated in the air space between the glass and the massive wall structure and stored in the thermal mass. This method operates under several assumptions: uniform temperatures of internal surfaces, diffuse surface radiation, instant mixing of entering air with existing air, uniform air temperature throughout the room, and one-dimensional heat transfer. Heat transfer plays a vital role in the research of these systems, and its complexity increases when considering factors such as conduction through the wall, transfer of solar energy through the glass, exchange of long waves by radiation, and heat loss.

The EnergyPlus program simulates heating, cooling, lighting, ventilation, and other energy flows in the built environment. With this software, energy use can be modeled in architecturally diverse buildings. The program considers all factors that affect thermal loads in the building, such as electrical devices, lighting, pipes, and wind. This program allows designers to simulate the energy behavior of buildings over a certain period and suggests ways to save energy. The geometry of the model used in energy plus is created in Google SketchUp using the OpenStudio plug-in. Creating the model's geometry can be very complicated, depending on the complexity of the object whose model is being created. With more complicated buildings, various problems can arise while making the model, so sometimes it is necessary to simplify it. Applying different components allows us to see their interdependence and solve this complex problem. Finding the best combinations of applied interventions from the point of view of reducing the required energy for heating and cooling modeled buildings is possible only by applying parametric analysis. In this way, the impact of changing the value of the selected parameters of the formed models on energy consumption for heating and cooling can be determined.

In simulations of the energy performance of buildings, an ideal HVAC system[6] was used to determine the required energy for heating and cooling annually without defining a specific type of fuel or energy processing and transmission system. An internal design temperature of 26°C was adopted for the cooling period, while a temperature of 18°C was foreseen for the heating period. In order to prevent excessive temperature fluctuations in the building, in periods when employees and students are not present, if the temperature drops below 12°C, the heating system is turned on, and if the internal temperature rises above 30°C, the cooling system is turned on.

3.1. Energy model settings - input parameters

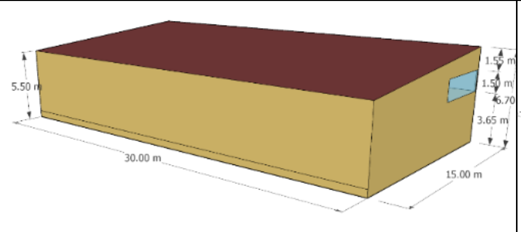
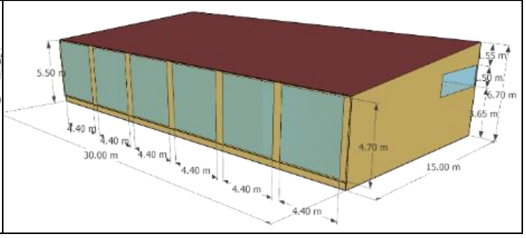
Choosing energy-efficient renovations for industrial buildings is not easy, as there is no universal algorithm to follow. While multiple measures can be more effective, they must be appropriately sized to avoid conflicts. Therefore, selecting measures that holistically reduce energy requirements for heating and cooling in buildings is essential.

Energy model settings for a TW should include parameters like the wall's orientation and tilt, thermal mass material properties, glazing type and properties, ventilation strategy, building insulation levels, internal heat gains, and choice of simulation software.

The conceptual object of the industrial hall is a free-standing production facility on the territory of the city of Niš. The purpose of the main facility could be the production and design of electronic modules, including all components and related processes for the automotive, industrial, or any other market. The total area of the building is 450m^2, while the dimensions of the energy model are shown in Table 1. The maximum height of the building is 6.70m.

[6]An ideal HVAC system is not connected to the central air system but delivers cooling or heating air in a quantity sufficient to cover the heat load of the zone or to its limits, if specified.

Table 1. Dimensions of the hall models; M_0 - without the TW system implemented; M_1 - with the TW system implemented

Model without implemented construction of TW	Model with implemented construction of the TW
	

In this research, a TW structure is positioned on the south-facing side of a building to maximize solar exposure, allowing the TW to capture and store solar energy efficiently. While a south-facing orientation is generally the most effective, the TW system can still provide benefits in other orientations. For instance, east- and west-facing TWs can help moderate indoor temperatures during morning and evening hours. However, the solar exposure and energy gain will be lower than a south-facing wall. Nine variants - sets of measures - were singled out (Table 2), and the obtained results of the conducted simulations were compared with each other for each simulation model for orientation 0°, +30°, and -30° relative to absolute north. Due to the glass's properties that allow short-wave solar radiation to pass through while retaining long-wave radiation (otherwise the main carrier of heat), the TW is functionally based on the greenhouse effect. Three types of glazing with U-coefficient values of 3.0 W/m²K; 1.5 W/m²K; 0.7 W/m²K were also varied; while the heat gain coefficient (g) value is 0.71; 0.61; 0.48, respectively.

Table 2. - Descriptions of applied measures

Label	Descriptions of applied measures
V_0	Baseline model
V_1	With the implemented TW system with double, transparent glazing without a thermal insulation layer on the inside of the thermal mass
V_2	With implemented TW system with double, low-emission glazing, without a thermal insulation layer on the inside of the thermal mass [m]
V_3	With an implemented TW system with triple, low-emission glazing without a thermal insulation layer on the inside of the thermal mass
V_4	With the implemented TW system with double, transparent glazing, with a thermal insulation layer on the inside of the thermal mass with a thickness of 0.05 m
V_5	With the implemented TW system with double, low-emission glazing, with a thermal insulation layer on the inner side of the thermal mass with a thickness of 0.05 m
V_6	With the implemented TW system with triple, low-emission glazing, with a thermal insulation layer on the inside of the thermal mass with a thickness of 0.05 m
V_7	With the implemented TW system with double, transparent glazing, with a thermal insulation layer on the inside of the thermal mass with a thickness of 0.10 m
V_8	With an implemented TW system with double, low-emission glazing, with a thermal insulation layer on the inside of the thermal mass with a thickness of 0.10 m
V_9	With the implemented TW system with triple, low-emission glazing, with a thermal insulation layer on the inner side of the thermal mass with a thickness of 0.10 m

RESULTS AND DISCUSSION

A large number of papers indicate the effectiveness of the application of the TW system. Simulations for the prediction of energy consumption contribute to the definition of guidelines for the design and implementation of this system in order to save energy [15]. Table 3 presents the energy savings of modeled hall for heating and cooling compared to the reference model.

4.

Table 3 - Energy savings for heating and cooling compared to the reference model

Serial number	Applied measures	Object Orientation [°]	Type of TW glazing[7]-	Thermal insulation Thickness [m]	HEATING [KWh/m²]	COOLING [KWh/m²]	Savings for heating [%]	Cooling savings [%]
1	V_0	0°	/	/	105.32	29.03	0%	0%
2	V_1		Window 1		80.44	24.55	24%	15%
3	V_2		Window 2	0.00	76.27	24.73	28%	15%
4	V_3		Window 3		75.33	24.59	28%	15%
5	V_4		Window 1		89.52	26.24	15%	10%
6	V_5	0°	Window 2	0.05	88.04	26.16	16%	10%
7	V_6		Window 3		88.91	25.95	16%	11%
8	V_7		Window 1		92.53	25.82	12%	11%
9	V_8		Window 2	0.10	91.68	25.74	13%	11%
10	V_9		Window 3		92.74	25.58	12%	12%
11	V_0	-30°	/	/	105.15	31.88	0%	0%
12	V_1		Window 1		84.49	27.27	20%	14%
13	V_2		Window 2	0.00	80.90	27.47	23%	14%
14	V_3		Window 3		80.09	27.31	24%	14%
15	V_4		Window 1		92.11	29.13	12%	9%
16	V_5	-30°	Window 2	0.05	90.80	29.05	14%	9%
17	V_6		Window 3		91.51	28.81	13%	10%
18	V_7		Window 1		94.58	28.68	10%	10%
19	V_8		Window 2	0.10	93.82	28.60	11%	10%
20	V_9		Window 3		94.66	28.43	10%	11%
21	V_0	30°	/	/	105.07	29.07	0%	0%
22	V_1		Window 1		75.24	24.72	28%	15%
3	V_2		Window 2	0.00	67.78	25.39	35%	13%
24	V_3		Window 3		62.60	25.76	40%	11%
25	V_4		Window 1		81.25	27.24	23%	6%
26	V_5	30°	Window 2	0.05	75.55	27.61	28%	5%
27	V_6		Window 3		71.63	27.80	32%	4%
28	V_7		Window 1		84.17	26.78	20%	8%
29	V_8		Window 2	0.10	79.43	27.03	24%	7%
30	V_9		Window 3		76.27	27.14	27%	7%

Window 1: double, transparent, 4-12-4 mm, glass heat transfer coefficient Ug≤3.0W/m2/K, g=0.71.

Window 2: double, low-emission, 4-16-4 mm (air), glass heat transfer coefficient Ug=1.5W/m2/K, g=0.61.

Window 3: triple, low-emission, 4-8-4-8-4 mm (Kr), glass heat transfer coefficient Ug=0.7W/m2/K, g=0.48.

Designing the TW system can use solar gains well and decrease the energy needed for building heating. According to Saadatian et al. [9], when the coverage of the southern facade is increased with the TW system, heating energy decreases proportionally. The simulation results indicate that using a concrete TW system with double transparent glazing and shading can reduce the energy required for heating and cooling buildings.

The TW system is highly recommended for regions that experience significant temperature fluctuations between day and night. However, it is important to note that transmission losses may occur during periods of cloudy weather, which can affect the efficiency of thermo-accumulation construction. Research shows that cooling premises during the summer may be more challenging than reducing the required heating energy during the winter, which is consistent with the studies conducted by Gan [16] and Saadatian et al. [9]. Additionally, simulation results demonstrate that massive concrete TW systems work effectively in various geographic locations, including the climatic conditions of Serbia [17].

The following figures show the energy needed for the heating and cooling a building for the applied measures V_1 to V_9. For each of the applied variants, the impact of changing the orientation of the building by 30° to the east and 30° to the west was checked.

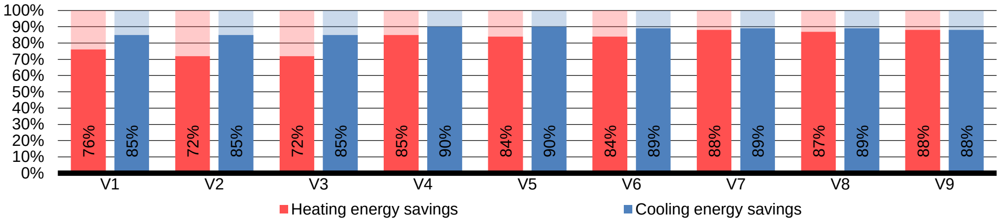


Figure 2 - Graphic representation of energy savings for heating and cooling for orientation 0° relative to absolute north (V_1-V_9)

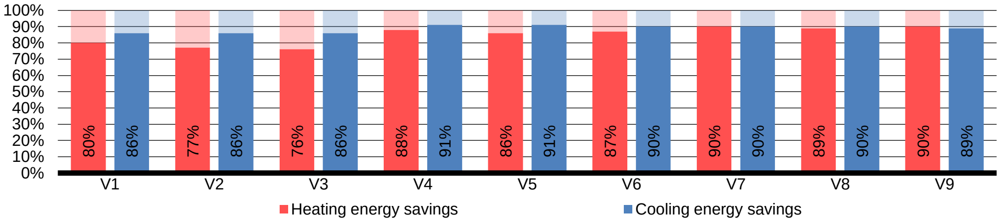


Figure 3 - Graphic representation of energy savings for heating and cooling for orientation -30° relative to absolute north (V_1-V_9)

Figure 4 - Graphic representation of energy savings for heating and cooling for orientation 30° relative to absolute north (V_1-V_9)

The following table discusses the energy savings for heating and cooling of a building for the applied measures V_1 to V_9.

Table 4 - Tabular discussion of energy savings for heating and cooling compared to the reference model

Label	Energy savings for heating and cooling compared to the reference model
V_1	The implementation of the TW system with double, transparent glazing, with shading, without a thermal insulation layer on the inside of the thermal mass leads to a saving in the required energy for heating by about 24%, while the saving in the required energy for cooling is about 15% compared to the basic model.
V_2	The implementation of the TW system with double, low-emission glazing, with shading, without a thermal insulation layer on the inside of the thermal mass leads to a saving in the required energy for heating by about 28%, while the saving in the required energy for cooling is about 15% compared to the basic model.
V_3	The implementation of the TW system with triple, low-emission glazing, with shading, without a thermal insulation layer on the inside of the thermal mass leads to a saving in the required energy for heating by about 28%, while the saving in the required energy for cooling is about 15% compared to the basic model.
V_4	The implementation of the TW system with double, transparent glazing and shading, with a thermal insulation layer on the inside of the thermal mass with a thickness of 0.05 m, leads to a saving in the required energy for heating by about 15%, while the saving in the required energy for cooling is about 10% compared to the basic model.
V_5	The implementation of the TW system with double, low-emission glazing and shading, with a thermal insulation layer on the inside of the thermal mass with a thickness of 0.05 m, leads to a saving in the required energy for heating by about 16%, while the saving in the required energy for cooling is about 10% compared to the basic model.
V_6	The implementation of the TW system with triple, low-emission glazing and shading, with a thermal insulation layer on the inside of the thermal mass with a thickness of 0.05 m, leads to a saving in the required energy for heating by about 16%, while the saving in the required energy for cooling is about 11% compared to the basic model.
V_7	The implementation of the TW system with double, transparent glazing and shading, with a thermal insulation layer on the inside of the thermal mass with a thickness of 0.10 m, leads to a saving in the required energy for heating by about 12%, while the saving in the required energy for cooling is about 11% compared to the basic model.
V_8	The implementation of the TW system with double, low-emission glazing and shading, with a thermal insulation layer on the inside of the thermal mass with a thickness of 0.10 m, leads to a saving in the required energy for heating by about 13%, while the saving in the required energy for cooling is about 11% compared to the basic model.
V_9	The implementation of the TW system with triple, low-emission glazing and shading, with a thermal insulation layer on the inside of the thermal mass with a thickness of 0.10 m, leads to a saving in the required energy for heating by about 12%, while the saving in the required energy for cooling is about 12% compared to the basic model.

5.

CONCLUSIONS

Conducted simulations have identified the most effective ways to save energy for heating and cooling in modeled buildings. The energy savings achieved depend on the specific measures implemented. The variants of the model with the implemented TW system with triple, low-emission glazing, without a thermal insulation layer on the inside of the thermal mass, were singled out as the best. Based on the conducted simulations of the energy performance of buildings, it can be concluded that the application of variants with the implemented system of the TW is justified.

Shading techniques in architectural design are often underestimated, but research shows they are directly linked to reduced cooling energy consumption. Jaber and Ajib [18] recommend the use of blinds in order to prevent the penetration of solar radiation into the building, as well as insulating curtains between the glass and the wall, which would avoid the transfer of heat into the building during the summer. The aesthetic aspect can sometimes influence investors and the decision whether to implement this system or not [19]. While compromises may be necessary, it is important to prioritize natural light, pleasant views, and comfortable surroundings.

In order to fully comprehend the construction of a TW, it is imperative to analyze its thermodynamic properties and temperature changes. It is highly recommended to confirm any obtained results experimentally. However, external climatic conditions, such as high summer temperatures, can limit the benefits achieved in the winter, while cloudy weather can lead to additional transmission heat losses. Due to the low thermal resistance of this system, predicting gains can be challenging due to increased heat flux. Raising environmental awareness and promoting responsible building user behavior can significantly impact final energy consumption. Building users can also implement systems that do not require additional energy consumption while improving building comfort, making them part of the solution to this problem.

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PRESERVING THE MEMORY_FROM AN ARCHITECTURAL ANECDOTE TO A COMMERCIAL END

Alexandra Ioana Radu[1]

Abstract

The Romanian coastline along the Black Sea hosted a powerful modernist playground since before the early 60`s well into the 70`s. The newly founded resorts were a political statement, as well as an architectural one. The study is centered around leisure programs, such as commercial buildings and restaurants, which through their clean lines and pavilion structures came to be appreciated internationally and helped the resorts sustain outside tourism.

These experimental places sustained the illusion of a rich nation, being filled with expensive products and addressed to a clientele set to spend money on entertainment during their well-deserved holiday. Everything was a sparkly image of political propaganda, both on the postal cards and in the field. This architectural scenography, completed with an adequate urban planning was set to change after the fall of communism in the late 80`s.

In the present, the set presents itself in a totally different image. The last thirty years brought along some changes that no one could predict. Commercial centers from Eforie, Neptun, or even Mamaia, have been damaged to a point of almost no return. So it is the case for some restaurant from the same destinations, that peaked in construction technology at the time. Moreover, this damage stands at the hands of man, and not at the ones of time. With new partitions being made, inadequate material used to replace the old ones, architectural elements wiped away and a total misuse of space, these objects seem like a lost cause. What is the future of their usage, as they are placed in the center of the resorts and contribute to the degrading image of the national tourism? With plans lost and no interest from the authorities for the urban heritage, the search remains for the professionals.

Key words: *commercial center, restaurant, seaside, socialism, urban heritage, leisure*

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INTRODUCTION

The aim of this paper is to follow a particular modernist architectural program, which was developed in its experimental form at the beginning of the 1960`s, through its rise and eventual fall, after the events of the year 1989. Settled in an almost perfect context – given the fact that the coastline was mostly a barren land- the entertainment facilities (or the so called *social-cultural* ones, according to *Revista*
1. *Arhitectura RPR*) were some of the most exquisite buildings contained in those pre-planned resorts.

The first part of the paper will be focused on the original period, from setting the time frame of the events, to the case studies in question. One commercial center, as well as one iconic restaurant, are going to be critically discussed, in matters of architectural expression, form and shape, as well as, political meaning and representation of that time. The information comes from a collection of that time articles, archive work and even modern text on this subject. Their initial state, which is to be presented with photographs from that period and their initials plans, is put alongside their current one. Given the fact that one of these locations is still in use, even close to its initial purpose, this kind of mirror image is more than necessary. The present state of the buildings is described after thorough field research and on-site documentation over a period of four years, with photographers and experiences from there, all in aid to describe and comprehend the actual state of being for the programs in question.

In the last part of the paper the question will be around the future of this kind of establishments. Given their current state, it would be a safe bet to see them demolished. Yet, due to the original planning of the resorts, they still hold a valuable position there, whether in the very center and if not so, even better, close to the sea. While the material and aesthetic degradation is more than present, an economical value still resides, making them suitable for a debate regarding what should be next.

The main goal of this research is to establish a certain architectural appeal over these functions, as regardless of their value, they are still under no protection and badly exploited. Moreover, finding a few guidelines for their future usage could prevent their ultimate demolition and to propose a more sensible way of using the
2. space without washing away the cultural memory of the place.

2.1.

THE OLD ANECDOTE

The Setting

At the beginning of the last century, the coastal area grows in popularity for the general public, the high interested being acknowledged by an architectural competition for a piece of land belonging to Movila-Tekir-Ghiol Society [1], a place today known as Eforie Sud (former Carmen Sylva). The beautiful surroundings, fields going down to the shore, were to host in-between the wars the work of the most famous Romanian modernist architects.

The shape of the coast-line that we know today resides in one ample project of the former socialist regime, that started in the mid 1950`s, going well into the 70`s. In 1955, Cezar Lazarescu, a character that marked the architectural story of the Romanian seaside, was in charge of the first strip from Midia (North of Constanta) to Tuzla (way down to the South). Due to a series of economic concerns, this starting point was concentrated on expanding and valuing the existing fabric [2].

In Eforie, the resort that holds the second case study, the architectural treatment, as well as the urbanistic concerns applied, are rather honest to the surrounding environment. Over time, the perception changes from the shore to the access road by inserting the new vacation complex Eforie I, and a year later, Eforie II (1959). Overall, looking at the general context, we can say that the projects of this first period have this common characteristic, yet there also were some important buildings, some of them still recognizable today (Perla Hotel, Victoria Restaurant in Mamaia, Sea Pearl Restaurant in Eforie Nord).

The architects working on the seaside were in search of a utopia, by creating a set with an aestival appeal, optimistic, good for entertainment a rest [3], even more potent by a coherent modernist expression, under the influence of international practice. In the year 1967 the National Tourism Office (referred as O.N.T) starts working as an administrative entity which would coordinate from then on, the actions along the coastline and impose the state agenda [2].

2.2. Architecture and the New Citizen

The events formerly described, taken place inside a socialist regime, also involved a pour of ideology over the citizen, by responding to some social and representation necessities. The image of an other-worldly seaside completed the propaganda speech, both in the professional area, as well as in the public one [1]. Supported by architecture, the successful image of the new regime is spread towards the people, even so after the year 1961, when the country opens to the West which now has access. This kind of synchronicity with the architectural movement was highly regarded by the political party, as the material possibility and the overall success could be show-cased [2].

In the same period of time, the terminology changes (from the working people – expression that had been used until then) to citizens or tourists. There is an illusion of a more inclusive society, one that accepts more than the working class [4].

2.3. Critical Acclaim

An internal source, although still hard to be found objective, is *Revista Arhitectura RPR*, the main architectural magazine of the period. In the articles presented there, the ways of expressing were rather limited, as it was customary during that time. Most of the descriptions are neutral and concern more the technical aspects of the buildings.

After the opening year 1961, the Romanian architectural projects are well received outside its borders. G.E. Kidder Smith, formerly an architect, but also a photographer, talks in his book *The New Architecture in Europe*, about the well-developed modernist aesthetic from the coastline, making reference to projects in Mangalia, Mamaia and of course, Eforie [2]. A year later, an article from Architectural Forum (*Communism`s New Looke. The Surprising Architecture of Four East-European Nations)*, corelates the architectural work with the political ideological intent, yet also praising some experimental project from the same resorts mentioned above.

CASE STUDY 1 – MAMAIA COMMERCIAL CENTER

Early Mamaia

In the year 1958, Mamaia was a wild strip of land, with an aspect unsuitable for the touristic expectations of that time. As a result, the Institute for design starts working on a project comprised of a series of alveolars open to the sea [1]. In the same year, a permanent camping for tents is set up, a hotel for 120 people and the
3. work is going on for two assemblies, both not very tall, one for suitable for 1000
3.1 people and one for O.N.T. double in size [1].

The year 1960 marks the beginning of a very ambitious project, the planning of the rest resort that was meant to host 10.000 beds. Cezar Lazarescu, the architect we already talked about, joined by his large team, was in charge of the buildings. During one year`s time, there is a new city rising up, on an area of 70ha, the first priority being the North-South direction (from Midia Navodari, coming South to the city of Constanta, with the new developments along the street, facing the sea). The straight lines of the terrain lead the design, resulting in an alternate rhythm of tall hotels, lower volumes placed deeper in and other functions. Inside this free urbanism manifestation one can read the spatial equilibrium that had been sought after [5].

Architecture and Functionality

3.2. The commercial center for Mamaia resort was first presented in Arhitectura RPR (*RPR coming from Romanian People`s Republic)* in 1963, in a number devoted to commercial projects. It may not be the first of its kind on the seaside, as one of the first experiments with this function took place on smaller scale in Eforie Nord in 1960, however it is an excellent example. With a total built area of 3850 square meters and concrete beams covering the walkway five meters into the air [6], it is also joined by an open-air theatre, making it unique on the whole coastline. It is no wonder, since from the beginning, until today, Mamaia has been the largest seaside resort in Romania, and somehow, the most luxurious one.

Situated in the heart of Mamaia, as it was back-then, the commercial centre contains a series of modular shopping spaces spread across a rectangular surface. They were connected through a garden, on the inside of the permitter, a protected walkway passing across. This idea was closer to the model of the commercial street, some stylized presentation of an old bazaar [6]. This open-air circulation, brought together by nature, was motivated by the season character of the place, as in the winter months it would have been shut down. An above covered passage would also connect the shopping area with the entertainment one, inviting tourist to a whole architectural promenade.

Inside the complex, there were two types of shopping buildings. The small modules, only one story high, would be closer to the middle of the garden, or facing the shore. All is an open plan, both the ceiling of these rooms, as well as the beams outside being supported on round metal columns, set 4.80 apart. Even the furniture, which had been specially made for this project, would come in to play, as part of the room partitions. On the other side of the building, close to the street, there are set the shops that would have had a heavier traffic and needed a place to bring in the goods. They had a special service court, that was masked by the other volumes, and for their two stories structure would use concrete columns instead of the metal ones [6].

The unity of the commercial center was carried through a uniform treatment for the modules, with glass walls coming down from the ceiling to the floor (*fig.1)*. Moreover, the terrazzo pavement was unitary, both on the outside, as well as on the inside. Also, there were ceramic panels that covered some of the blank walls. A lot of care went onto the finishing details, a similar situation happening also nearby for the summer theatre.

The smaller stores were meant to respond to various customers` needs from beach accessories, souvenirs, a tourism agency, a train ticket office and a bookshop (*fig.2)*. In the two story pavilions, one could find a decent market, a tobacco shop, and other functions, even a library and an exposition space [6]. It is no wonder that in a clash between an event area and a free roaming market, they went on to call them social-cultural designs (in introduction it is mentioned that this term had been misused during that period in Arhitectura RPR Magazine to comprise this type of commercial projects).

The commercial center in Mamaia is indeed a great example of exploratory work from that period. There are a series of smaller scale ones resembling in principles and quality, from the type of material used to the structural solutions (here are worth to be mentioned the one in Eforie and the latter one in Neptune, both works of the same architect Roxana Bernstein-Katz). Due to their temporary usage, there was the place for the extensive use of glass, the dreamy gardens that made up a shadowed passage under the hot summer sun and the fine, elongated modernist lines that blended in their environment.

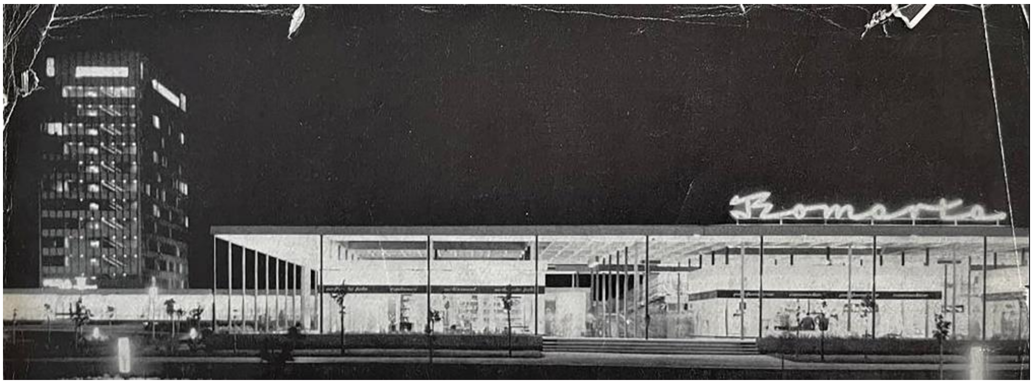

Figure 1. Mamaia Commercial Center during the Night, Arhitectura RPR magazine 6/1963

Figure 2. Inside of Mamaia Commercial Center, Arhitectura RPR magazine 6/1963

3.3. Present Day

The changes of scenery are present and harsh in the case of Mamaia commercial centre. Yet, unlike most commercial spaces along the coastline, that have been mutilated by new partitions and are hardly if not recognizable, this one fell into a fortunate compromise.

Even though the theatre near the shops have been closed for a good few years now and it has started to crumble, the commercial spaces are still in use during the summer time for the same original purposes as they once were. In an act of neglect, the original materials can be seen rotting, exfoliating or falling, as the municipality have not made a serious investment in the last thirty years. It is quite not so bad news that the vendors have not severely modified the original aspect of the modules, with plastic panels and other inadequate structures. This had been the less happy fate for the small shops designed by the same team on the beaches of the same resort. On a first glance, one can see the windows have been changed with modern and cheaper solutions, the original glass walls having been lost. The garden barely exists nowadays under the concrete beams, while one looks up might bring into perspective the exterior AC units, a poor choice against the heating problem.

The description above is more aggravated during the winter months, when everything around is closed and the resort resembles a ghost town. In opposition, during the summer, the excessive number of tourists, no matter if it is day or night, alongside colored and flashy beach accessories hanging around blocks the eye perspective towards the building. The passing of time and the neglect of the municipality are hidden by the colored plastic wrap and the flashy lights added on top of this unprotected object..

Figure 3. Store front at Mamaia Commercial Center, personal photo November 2019

Figure 4. Inside Mamaia Commercial Center, personal photo November 2019

4. CASE STUDY 2 – NEON RESTAURANT EFORIE NORD

4.1. Two Ambitious Projects

The Neon Restaurant was part of the first large vacation complex in Eforie Nord (1957-1958), designed and built under the supervision of arch. Cezar Lazarescu and arch. A. Grunberg. It sums up twelve separate buildings able to host and cater for 1600 tourists. The general aspect is a clean one, with simple volumes, lacking the particular decorations of the socialist period prior to 1960. The creative team was set to establish a new architecture, closer to contemporary fashion, that would transmit the holiday spirit, alongside a note of optimism [5]. This particular project established a new way of designs, and sets a clear distinction in time.

The next vacation complex, which even strongly supported this change in direction, is Eforie II, completed just a year later. The team was led by arch. Cezar Lazarescu and arch. L. Popovici and even managed to obtain the State praise for
4.2. their results on this project [5]. In this case, the assemble, was in a strong relationship with the nature around, having hotel rooms oriented either to the sea, as to the lake Techirghiol. One of the most distinguished buildings contained is Sea Pearl Restaurant, that displayed very well the aesthetic sought after, with lean vertical elements, soft horizontal lines and overall glass walls.

Architecture and Functionality

Neon Restaurant, also known as Building D, or as Club-Restaurant Neon was by far intended to be the most spectacular program of the whole vacation complex. Its large size facilitated the serving spaces for 750, such as the restaurant-cafeteria, the club and the bar, the small shops and also some technical rooms for the central heating unit, ice factory, the sweets laboratory and some general storage [7]. It had function both during the day, catering meals for the visitors, as well as during the night for entertainment purposes, having the restaurant open, as well as the bar area, where people could dance and enjoy their holiday.

The architects` team were on a special mission to reach a suitable ambiance, not just to limit themselves to responding to the functional needs. Since they could not just join together fragments corresponding to each service, nor introduce long hallways in between [7], making the service distances even more problematic, they came up with a spatial solution. They seek to open the whole public area to the surrounding nature, in an attempt to make the space seem open and infinite. An interior court was introduced, and the outside passing was made along the terrace. One can see in this very case, the use of beans acting as a shelter from the sun, sustained by some round pillars, just like in the case of the commercial center in Mamaia. By doing so, the journey of passing through the restaurant, or the bar, was transformed into something of an architectural value.

The restaurant on the upper floor, as well as the bar on the ground floor are facing the sea and are connected by two impressive stairs (*fig.5)*, one on the South side, near an open plaza, while the other being placed on the East side. These two staircases are individually two beautiful architecture objects, with a special technical solution. They are made out of thin floors of concrete, stacked on a central beam – also a visible element. For the one on the East side, it lays on two separate columns, while the one o the South side (that is a little bit shorter due to a level difference) is held by a V cast in concrete. Their surprising aspect announces the visitor about the experimental journey, he or she embarks in. Needless to say, a similar type of staircase was used a year later for the Sea Peral Restaurant. The spaces related to preparing the meals are set on the upper floor, while downstairs, on the South side, there were a series of shops [7] such as a hair saloon for men and women, a pharmacy and a tobacco shop that also carried newspapers and magazines. The other technical spaces that serve the place are set in the back, away from the visitors` passage.

The structural solutions are novelties for that place in time. Long thin concrete slabs were used to cover the large opening above the upper floor, while the dining hall that looks to the sea is covered with prefabricated elements resembling the waves. There is a partition between this roof and the wall toward the service spaces made up of glass, thus creating the impression of a floating element. The thin concrete slabs came in as a solution for the hall facing South, reaching an impressive length of 17.2 meters [7]. There was little to no masonry used for the walls, as most of them are sliding glass panels (*fig.7)* for the club and the restaurant while the kitchen had concrete linings with sliding metal windows.

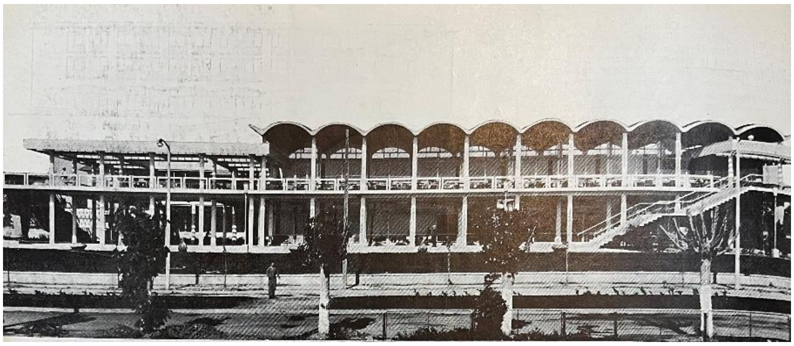

Figure 5. Neon Restaurant seen from East,
Arhitectura RPR magazine 8-9/1958

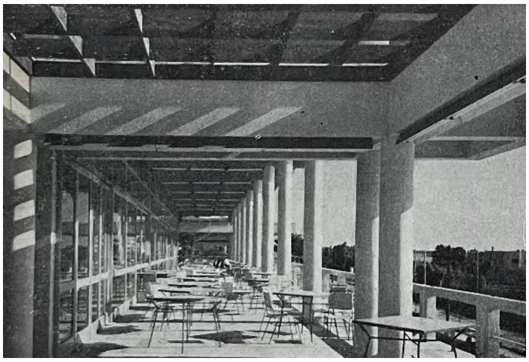

Figure 6. The Balcony facing the Sea,
Arhitectura RPR magazine 8-9/1958

4.3. Present Day

The current state for the Neon Restaurant is a very unfortunate one. While most of the initials building contained in the holiday complex Eforie I are still in use today – with the improper architectural transformation to make them suitable for recent needs- Neon stands abandoned.

After 1990, most part of the hotels and entertainment facilities were bought up by their new owners. Even tough, for some years after these events the restaurant carried it on its function and continued to be searched and visited by the tourists, today, quite a good deal of time has passed since it was indefinitely closed. Since it did not reach to be in use in recent years, when the old infrastructure from Eforie has been changed by colored plastic panels and other unproper materials, its original image stands the same, frozen in time. The interior is empty, only rubbish and construction materials illegally thrown away are pilling up on the sides.

The restaurant can still be entered into by the South side, while on the East the vegetation has grown to cover the alley leading up to the stairs. Also, the place is now inhabited by stray dogs, preventing an eventual visit. Inside one can see mostly original finishing, like the terrazzo connecting the interior with the exterior, the wide windows left unchanged and even part of the commercial lightening sign. The wooden beams sewn together that protected the tourists from the sun are partly fallen, while the concrete elements are crumbling on the exposed areas. A lot of infiltration is present in the walls and other vertical elements, while the floor have different types of moss growing from the cracks.

The current state of Restaurant Neon is close to a ruin. It was one of the first true experimental projects on the Romanian Black Sea Coast, marking the beginning for all the other innovative architectural products of the 1960`s.

Figure 7. Restaurant Neon facing the Sea, personal photo, April 2022

Figure 8. The Luminous Sign Covered and the Stairs Ruined ,personal photo, April 2022

5. LEAP INTO THE FUTURE

The socialist modernist heritage is always a rather problematic topic to discuss. One can take in to account the fact that this kind of buildings, like in the case of the Romanian seaside, were projects of state propaganda. Also, there is not a big window of time since the beginning of the constructions in the mid to late 50`s up until now (less than seventy years) for the older generation to analyse them apart from their personal concerns and into an objective manner. This emotional way of interpreting and using an architectural object has been translated numerous times on the changes made to the building, as they are improper, and made to hide the original architecture as an aid to forget (we can add here the commercial center in Eforie Nord and Neptun, both mentioned above, as well as the Sea Pearl Restaurant in Eforie Nord).

The commercial center of Mamaia is set right in the middle of the resort, having an immediate access to the beach, as well as to the main road connecting the city of Constanta to the resort. This fact, altogether with the impressive size of the establishment make it a location with a strong economic value. A ray of hope can be found in the fact that the nearby theatre is going to be remodeled and put once again in to use by the local authorities [8], creating a precedent that in the near future, something of sorts would be also possible for the shopping area. Unfortunately, neither the theatre nor the commercial center ranks up on a heritage preservation list, making room for the construction works to be on the destructive side and not aligned to the original architecture. On the other hand, Neptun Restaurant is privately owned, putting its fate in the very hands of the owner who left it emptied, even though its location is as good in the resort of Eforie, if not better than the one for the case study in Mamaia.

A strong factor necessarily to take into account is structural one given the harsh environment they were set in. At a special technical analysis, would the concrete and the metal structure pass in order to uphold for years to come the buildings and the heavy summer traffic; probably not. If one can see columns and beams crumbling, exterior elements exfoliating and slowly turning into pieces after so many winters with strong winds, some searches should be made whether to keep the original material or to build again.

Another aspect that might be missed is the actual utility for these places in today`s world given their size and current offer. Only part of the commercial center in Mamaia is still in use, selling cheap beach toys made out of plastic which do not correspond with the principles of an environmentally friendly tourism. Moreover, there are other supermarkets in the nearby area, even two chain stores along the principal road; not to mention that in a digital world an actual library and a bookshop are some farfetched ideals, especially looking at the profile of the regular tourist visiting the resort. On the same note, the size is rather improper also in the case of Neon Restaurant, as it is hard to manage in both matters of service and profit. One can look at the example of the Sea Pearl Restaurant that is still in use, yet only on the ground floor, the upper part which is actually the most spectacular one, is closed. Moreover, even in Eforie, which is not a big resort in comparison with Mamaia, there are plenty of options for the holidayers to choose from when it comes to restaurants.

Given the description above regarding the consumers` taste and the way the resorts work today, probably the best way to save these pieces of architecture is to find multiple purposes and functions that respond to the actual needs of the people visiting.

6. CONCLUSION

On an overall look over the entertainment buildings that once made the Romanian seaside internationally famous, it comes easy to say that they represent a part of an endangered heritage. They reflect a particular use of the modernist style in a socialist country and are witness of that period. Unfortunately, without the proper regulations to facilitate their keeping and proper use, they are doom to fall apart.

Looking at each and every resort from North to South along the coastline, it is simple for one to see that their current image is far from the utopian dream they once promoted. Starting with bad services, improper new architecture, up to general facilities for this kind of places, the area lacks them altogether. It is an important thing to preserve them, more than thirty years after the fall of socialism as it could instill an example of good architecture practice that would inspire future developments inside the resorts. On a small scale, treating them like symbolical objects for an old narrative, one can compare the general state of the coastal region, the whole gross picture derived from years of greedy exploitation, to them. They came to be representative of the new reality based on unethically economic and touristic values.

The time frame left is a very short one, leaving little space for professionals and people in charge to make up their mind about these objects of the past. The general public should shift its perception about the socialist architecture in this particular case and make a change for better in the collective memory of those places. The need to remodel them to be compatible with the present day while preserving as much of their original architecture can change the whole look and function of today`s resorts. Until then, there might be hope, otherwise all is left are shady concrete ruins.

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GEOGRID-REINFORCED FLEXIBLE PAVEMENT ON CORRIDOR X IN SERBIA

Milan Draganović[1], Dragana Turnić[2], Biljana Mladenović[3], Srđan Živković[4], Marija Spasojević-Šurdilović[5]

Abstract

Previous researches have shown that usage of geogrid in pavement contributes of durability and increases pavement resistance of formation cracks, ruts and other damage. In this work we analyzed usage of geogrid on wrong place what had bad effect on pavement in exploitation period.

In pavement design on south fork of corridor X, on section Caricina dolina – tunnel Manajle, it was geogrid-reinforced pavement, geogrid was installed between the last layer of binder course and surface course (SMA). After 2 years of using this highway on that section on some location semicircular cracks were formed. Samples were taken from that section because of laboratory testing. It was necessery to determin the reason for the appearence of semicircular cracks, and to find the most effective solution for the rehabilitation of pavement damage.

The purpose of this research was finding the most effective solution based on the analysis of the laboratory results, which we got from samples taken from section where semicircular cracks were formed, and finding reasons for the pavement damage.

Key words: *flexibile pavement, reinforced pavement, geogrid, cracks, sample, rehabilitation.*

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INTRODUCTION

Traffic has increased on our roads, while highways are under unprecedented pressure, with increased use and reduced maintenance budgets [1]. Also, a simple renewal is only a temporary solution. When flexible pavement structures are under repeated cyclic loading, rutting, potholes and fatigue cracking can occur [2]. Also, with the increase in the number of vehicles and the axle load, this problem can
1. worsen significantly.

The goal of the construction and maintenance of each road is to postpone the appearance of damage to the pavement for a minimum expected period of time, which may depend on the amount of currently available investment, the amount of planned financial savings on future road maintenance, the reduction of traffic interruptions caused by future maintenance and the definition of the minimum duration of the new asphalt pavement [3].

There are two known ways to delay the appearance of a reflected crack, namely:

- Installation of the SAMI layer (Stress Absorbing Membrane Interlayer), which when it comes to geosynthetics is achieved with a thicker layer of non-woven geotextile soaked in bitumen emulsion and
- Installation of a geogrid with multiple positive effects. The geogrid distributes the load over a larger area and reduces the stresses that come from the tops of the existing cracks, slowing down their propagation, while at the same time introducing a normal load on the crack surfaces, improving the clamping of the asphalt mixture grains and increasing the shear resistance between them [4].

The disadvantage is that there is no standardized way to calculate the minimum required tensile strength that the geogrid would have to have, and the reason for this is the large number of variables that would have to be included in the calculation. However, fortunately, the geogrid has been used since the beginning of the 70s of the last century, so it is possible to choose a geogrid based on previous experience and available literature [5]. There is a wide variety of geogrids on the market made from different raw materials such as glass, polyester (PET), carbon fiber, polyvinyl alcohol (PVA), polypropylene (PP), etc [6].

There are several guidelines that significantly affect the success of geogrid application for asphalt reinforcement:

The quality of the adhesion between the geogrid and asphalt strains is one of the key characteristics [7]

- In research [7], the property quantified as adhesion stiffness, which he determined by pulling tests of the embedded product from the cores. PET geogrids with bitumen coating had a much higher value compared to the other tested materials.
- The fact that PET and asphalts have very close thermal shrinkage coefficients, so PET does not represent a "foreign body" in the asphalt mixture, is in favor of the application of PET geogrids, in a similar way concrete and reinforcement work together [8].
- It is necessary to know the resistance to damage when installing the selected geogrid. The value that gives a true picture of the resistance is the % of tensile strength remaining in the sample after installation compared to the tensile strength of the intact sample [8].

• Selection of a product that exists and is used significantly longer than the minimum period of time until which the pavement should last. Of course, new products need to be given a chance because they can prove their performance only through the projects they were built on, but this proving period should be left to financially better off markets with a much longer tradition of using asphalt reinforcement materials and clear regulations.

In addition to all this, if the geogrid is installed on a scraped surface, it is necessary to check whether the manufacturer approves installation on such a surface, as well as what depth of grooves is acceptable. Installation directly over the concrete pavement is another case that requires special attention and to establish with certainty that the material is intended for it. It may seem like an unnecessary remark, but there are products that are recommended for both installation in the ground and installation in asphalt, and their application in asphalt should not be considered. Different materials require different installation conditions, but they all have in common that they should not be installed on a wet surface, that it is not allowed to use diesel or diesel-based products for cleaning equipment, and that the best installed material is to cover it with a new layer of asphalt on the same day.

The behavior of the material embedded in the new layer of asphalt depends a lot on the quality of the installation. Products that require a smaller amount of residual bitumen from the bitumen emulsion to ensure adhesion to the substrate can be successfully installed [4]. For this reason, a very thin layer of non-woven geotextile is usually added to the geogrid, which serves only to provide the adhesion required during the installation period, especially during the paver's supply as well as its movement. The use of rivets or other metal means for anchoring the geogrid to the lower layer of asphalt is not recommended at all, because stress concentration and the appearance of mesh cracks occur in these places.

The main advantages of using geogrids in pavement construction are: affordable price, wide range of use, convenient transportation, high strength, reduction of pavement construction thickness (by 20%), increasing the maximum possible transport load, simple and high-quality installation in all weather conditions, fast construction, longer road life, etc. [9].

2. USING GEOGRID AS REINFORCEMENT IN FLEXIBLE PAVEMENT

The topic of this research is the analysis of problems arising from the rehabilitation of a part of the road after the appearance of cracks in the asphalt layer. Works are executed on highway E75 section Caricina dolina – tunnel Manajle. Within this project, construction company “Ogranak Integral Inženjering Niš” was one of the contractors, more precisely, they were in charge of the construction of asphalt layers on that section of the highway. The first design stipulated that the asphalt layers on that section should be made in two or three layers, depending on the design solution (driving, overtaking and emergency lanes). After detailed analysis, it was adopted that on parts of the main route, more precisely in the driving and overtaking lanes, an asphalt layer should be additionally provided, all with the aim of extending the life of the pavement structure.

Additional strengthening included the application of a thermostable reinforcing mesh for reinforcing asphalt layers, at the contact between the wearing layer of asphalt mixture SMA 0/11mm (thickness 4cm) and the bearing layer of asphalt mixture BNS22sA (thickness 8cm), all with the aim of extending the life of the road surface with a project period of 20 years. The control laboratory for the quality control of the layers and the installation of the reinforcing mesh was a laboratory of construction company "Ogranak Integral Inženjering Niš". At every moment during the installation, the works were strictly and according to the rules controlled and all the results of the laboratory testing of the asphalt layers were satisfactory. Figure 1 shows a detailed schematic representation of the pavement strip solution by layers.

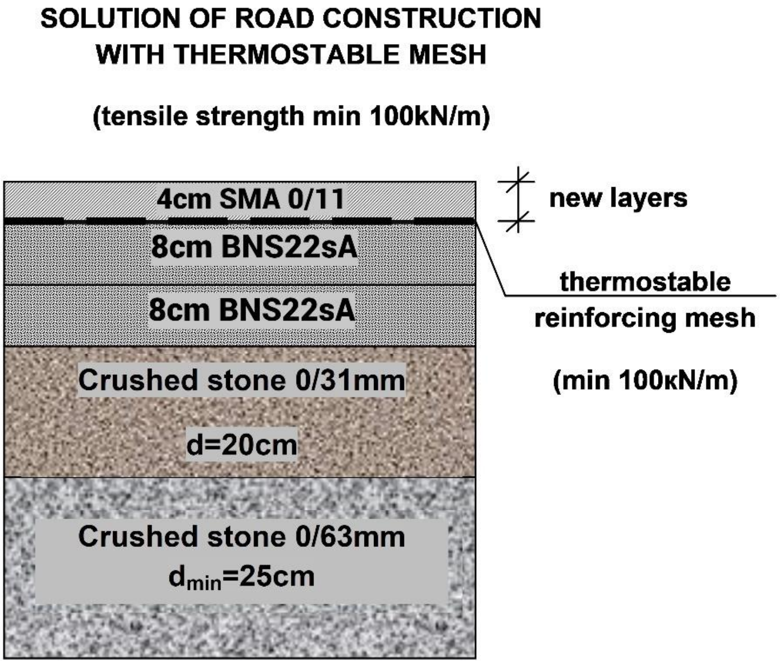


Figure 1 - Schematic representation of the pavement strip solution by layers [10]

In the calculation of the pavement structure, the total traffic load of 80 kN was adopted from the design and it amounts to

$$ECO_{20\ years} = 23{,}6 \times 10^6 \text{ of standard axles of 80 kN.}$$

2.1.

$ECO_{20\ years}$ - equivalent traffic load of standard axles of 80 kN for 20 years

Problems that have occurred

Work on the asphalt layers on this section was carried out in 2018, and already in the middle of 2020, damage to the surface of the pavement curtain was observed (semi-circular cracks caused by sliding on the upper layer). The first visual inspection, which was carried out in mid-2020, revealed semicircular cracks on the road surface. In accordance with the current road load standard [SRPS U.C4.010 and SRPS U.C4.012], a detailed control was carried out, which included measuring and stationing the location with semicircular damage. The obtained measurement results are shown in Table 1 and refer to the locations where the mentioned damages occurred.

Table 1 - Locations of semi-circular cracks

Item	Chainage	Side
1	890+217	Left
2	890+032	
3	890+019	
4	889+983	
5	889+926	
6	889+389	
7	889+366	
8	889+330	
9	886+815	
10	886+755	
11	889+145	Right
12	889+213	
13	889+293	
14	890+533	

The resulting damage was precisely measured and documented with photographs showing the surface damage at the mentioned locations.

Figure 2 - Surface damage to the pavement [10]

As we can see in Figure 2, semicircular cracks have appeared, which are caused by sliding between the layers. Slippage of layers occurs when the shear (sliding) stress is greater than the adhesion stress at the contact between the layers. Bad contact, or blindness, between the layers results in a redistribution of stress and deformation in pavement , and is one of the key reasons that lead to the loss of bearing capacity and a shorter life of the pavement structure, and this is especially pronounced in the case of bad contact between asphalt layers. The loss of connection between the asphalt layers is mainly the result of the appearance of semicircular cracks, as well as the difficult compaction of the asphalt mixture [10].

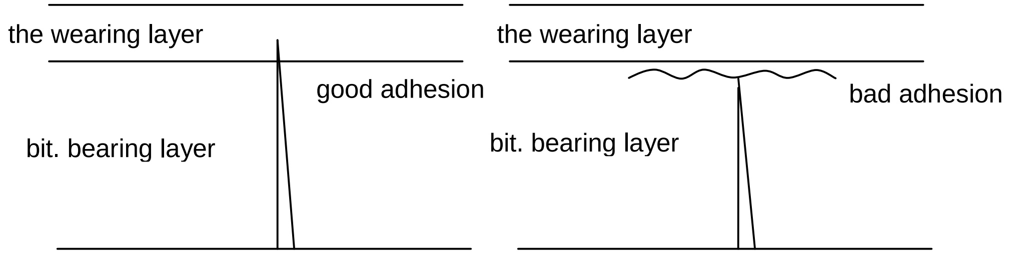


Figure 3 - Schematic representation of crack development for the case of good/poor adhesion between asphalt layers [10]

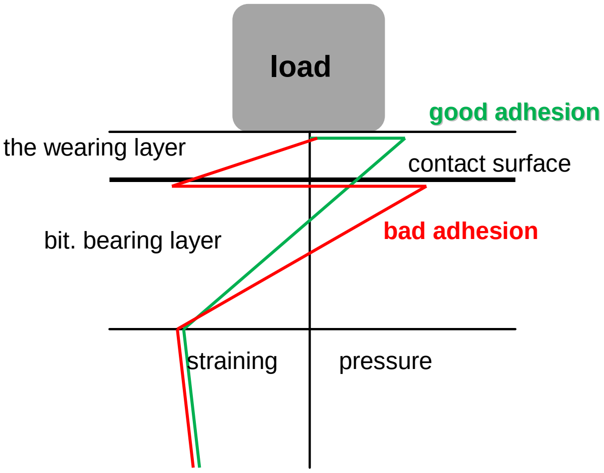


Figure 4 - Schematic representation of the redistribution of horizontal stresses due to sliding between asphalt layers [10]

Figure 3 shows a schematic representation of crack development for the case of good or bad adhesion between asphalt layers, and Figure 4 shows the redistribution of horizontal stresses due to slippage between asphalt layers.

3. LABORATORY TESTS

In order to test of asphalt samples from the pavement where semi-circular cracks were observed in the middle of 2020, coring of asphalt samples was carried out, the testing was carried out by the “IMS” Institute from Belgrade, and the dimensioning and adhesion of asphalt layers was done according to Leutner.

According to the sampling plan, asphalt cores with a diameter of 150 mm were extracted two in the profile (at 4.8 and 6.6 m from the dividing belt). Samples were taken from 121 locations in order to control the thickness of the asphalt layers, their compactness and the quality of the contact between the wearing SMA0/11 and the upper bearing layer BNS22sA (according to Leutner)..

The required specific adhesion according to the Technical Specifications of PE Roads of Serbia [11] from 2012 for the highway is $\beta_{ZS} \geq 0.85$N/mm2. A comparative view of the established thicknesses and adhesion of asphalt layers in the research cores is shown in the following pictures.

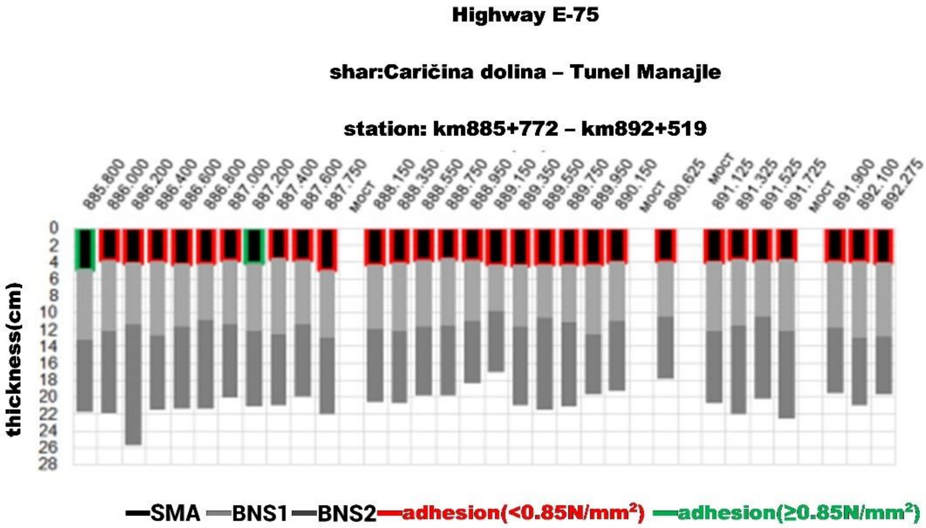


Figure 5 - thickness/adhesion of asphalt layers - right lane [10]

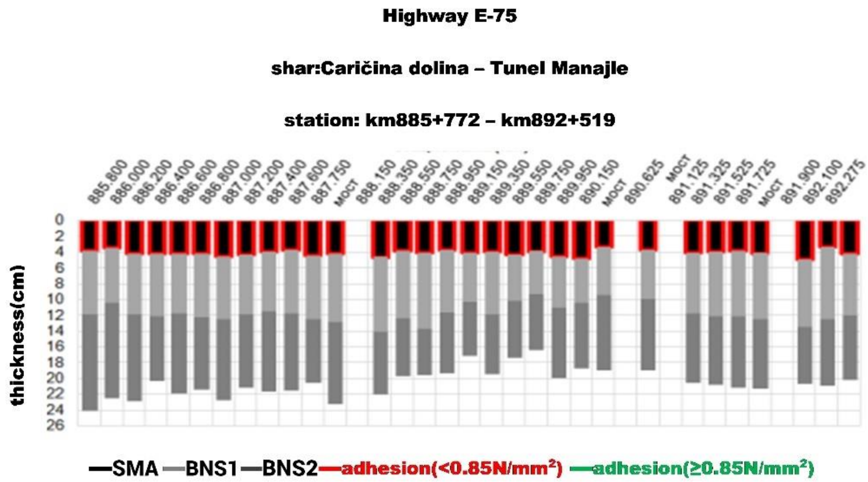
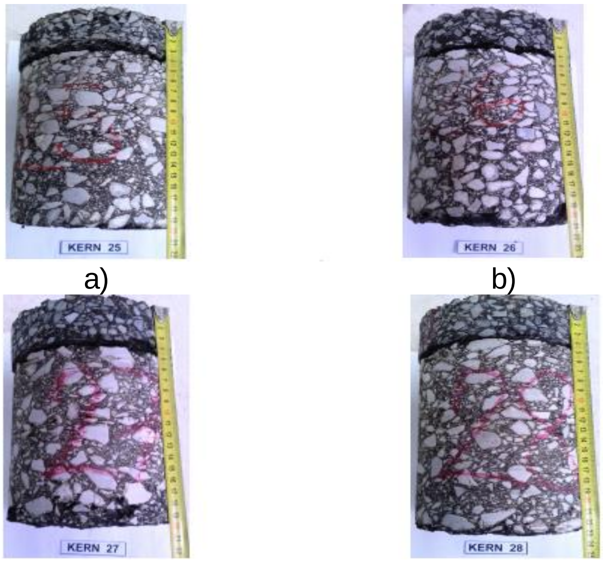


Figure 6 - thickness/adhesion of asphalt layers - left lane [10]

Based on these values, the following can be concluded:

- Total average thickness of asphalt layers amount d_{SMA}=4.1cm (15% value 3.8cm), d_{BNS-1}=7.7cm (15% value 6.3cm) I d_{BNS-2}=8.8cm (15% value 7.2cm)
- Adhesion between the wearing SMA 0/11 and the upper bearing layer BNS22sA is expressed by the specific adhesion β_{zs} (according to Leutner) does not meet the criteria according to the Technical Specifications of PE Roads of Serbia from 2012.

In the following pictures, we can see the asphalt cores from the section in question.



a) b)

c) d)

Figure 7 - Asphalt samples Ø 150 mm, with 887+000 km from the left and right lanes; a) right traffic lane, 6,6 km from the dividing line; b) right traffic lane, 4,8 km from the dividing line; c) left traffic lane, 4,8km from the dividing line c) left traffic lane, 6,6 km from the dividing line [10]

In Table 2 we can see results of the laboratory test of the adhesion on the contact surface of the cores, from km 887+000 from both driving lanes, between the wearing SMA0/11 and the upper bearing layer BNS22sA according to Leutner. According to the Technical Specifications of PE Roads of Serbia from 2012 shear force must be $F_{qmax} \geqslant 15$ and specific adhesion of layers must be $\beta_{ZS} \geqslant 0.85$ [11].

Table 2 - The results of the laboratory test of the adhesion on the contact surface of the cores between the wearing SMa0/11 and the upper bearing layer BNS22sA according to Leutner

No samples	*Location in cross section*	*Chainage*	*The area of the contact surface between the layers mm*	*Shear force Fqmax kN*	*Specific adhesion of layers βZS N/mm2*
Sample 25	*6.6 from dividing section*	*887+000, RHS, driving lane*	*153.1*	*0.00*	*0.00*
Sample 26	*4.8 from dividing section*		*153.2*	*0.00*	*0.00*
Sample 27	*4.8 from dividing section*	*887+000, LHS, driving lane*	*153.3*	*0.00*	*0.00*
Sample 28	*6.6 from dividing section*		*153.2*	*0.00*	*0.00*

As we can see in Table 2, the values of shear force and specific adhesion of layers for all samples at the chainage of km 887+000 are 0.0, which means that there is no adhesion between the layers, these layers on these samples act as separated layers without any adhesion between them. Based on all this, it can be concluded that it is necessary to rehabilitate this section as soon as possible.

4. PAVEMENT REHABILITATION

Deflections, as an indicator of the condition of the structure determined by a non-destructive method, were measured with a heavy deflectometer with a falling load in June 2020. A force of approximately 50 kN was applied to a circular plate with a diameter of 300 mm, which was placed on the road surface, and the contact load was approximately 560 kPa. At each measuring point, 3 blows were made, while the deflection measurement during the blow was performed with geophones at the following distances from the center of the crown of the plate: 0mm, 200mm, 300mm, 450mm, 600mm, 900mm, 1200mm, 1500mm and 1800mm. The measurements were monitored via a processor and computer, based on these data we obtained a characteristic deflection basin.

Based on the data on the deflection basin and the pavement structure, the modulus of elasticity of the pavement and subbase were determined using the BAKFAA/2.1.0.1 software package. On the basis of the deflection basin and the thickness of the layers, with the solution according to the linear theory of elasticity for multi-layer systems, the modulus of elasticity for the layers of the pavement structure at the relevant annual temperature of the asphalt layer (20^0 C) was defined. The pavement structure was viewed as a three-layer elastic system, consisting of a wearing layer (d=4cm), a bituminizing bearing layer (d=16cm) and unbound stone aggregate material. In relation to the simulation model, a poor contact between the wear layer and the bituminizing base layer was assumed. The values of the layer modulus for pavement construction are given in the table 3.

Table 3 - Values of modulus E by layers

Side	*Layer*	*E (MPa)*
Left	*SMA 0/11*	*3590*
	BNS	*6900*
	Subbase	*186*
Right	*SMA 0/11*	*3470*
	BNS	*9110*
	Subbase	*171*

During the execution of the works, after the completion of the bituminized base layer, the surface of the upper layer of BNS22sA was used for construction site traffic (about 6 months). Based on the control coring of the asphalt cores by the IMS Belgrade Institute during 2020, we can conclude that the surface of the upper bearing layer was not properly prepared for the production of the wearing layer SMA 0/11, i.e. that the dirt on the contact of BNS and SMA has not been removed.

In addition to the visual inspection, sampling of asphalt cores also determined that there are special weak spots in the construction, on a longer stretch or locally, which were caused by poor adhesion/contact between the wearing and bearing asphalt layer. Bearing in mind that there are spatial limitations (preservation of the existing leveling elevations of the constructed asphalt wearing layer) as the type I cause of damage, the project solution of corrective maintenance should be sought precisely in the restoration of the curtain, i.e. the replacement of the wearing layer, which would increase the life of the pavement by at least 50% . Given that there is no need to remove one of the base layers (BNS), alternative corrective maintenance solutions should not be considered, but the replacement of the wearing layer itself represents the desired design solution. Taking into account the time constraints for the completion of the works on the rehabilitation of the existing curtain, the design solution excludes the reuse of the thermostable mesh for reinforcing the asphalt layers.

The restoration of the pavement structure, i.e. the replacement of the wearing layer (thickness 4.5 cm) in the carriageway and overtaking lane (width 8.0 m) represents the basic measure of road rehabilitation that is planned for this section, in accordance with the forecasted exploitation conditions, with appropriate preparatory works.

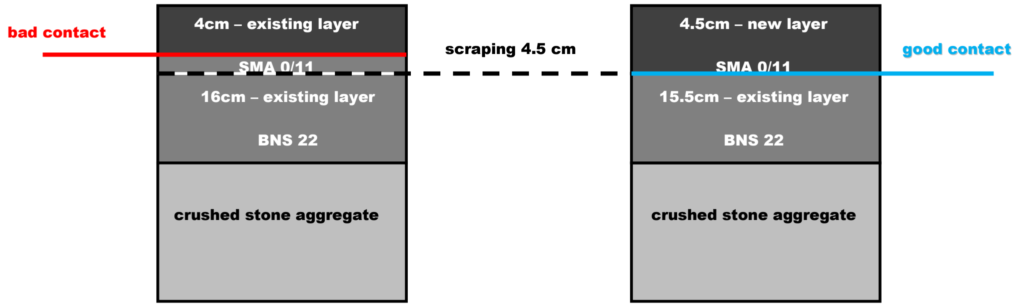


Figure 8 - Cross-sectional profile of the solution proposal for rehabilitation (corrective maintenance) of the pavement structure

After scraping and before making new asphalt layers, the asphalt surface must be completely cleaned of all dirt, and all pavement damage in the form of cracks must be repaired or rehabilitated beforehand. It should also be noted that the coring of asphalt samples and the testing of the quality of the contact between the wear layer and the bituminizing carrier layer were not performed in the emergency lane. So, if during the coring of asphalt samples and testing the quality of contact in the emergency lane, it is found that the asphalt layers are insufficiently sealed, it is necessary to apply the same type of remedial measures as in the driving and overtaking lanes. All positions must be done according to technical conditions, so that the damage does not happen again in the near future.

The results of the calculation of the deformation and the calculated durability (lifetime) of the pavement structure after rehabilitation, expressed by the number of transitions of standard axles of 80kN, are shown in Table 4

Table 4 - Durability of pavement structure - SHELL method

Calculated tensile expansion of the bottom fiber of the asphalt layer (μstrain)	*The number of transitions of standard axles from 80kN*		*Computational durability (years)*
	Calculated	*Designed (20 years)*	
εxx=84.9	*16.7 x 106*	*23.6 x 106*	14

5. CONCLUSION AND RECOMMENDATIONS

Research has shown that depending on the quality (blindness) of the contact and its position in the construction, the life of the pavement structure can be shortened by 20% when it comes to medium contact quality between the wearing layer and the bearing layer, i.e. by 50% when the contact is poor. When it comes to the contact between the bearing and bonding asphalt layer, the life of the pavement structure is reduced by 60% [11].

Also, before installing the geogrid on this section, it was necessary to check:

The type of geogrid that will be used and how the manufacturer recommends installation (in the asphalt layer, between asphalt layers or in the ground) [12]

- Check the condition of the pavement before installation, i.e. is it scratched, is there any damage, is it dirty, is it wet
- Prepare the base for installing the geogrid in the prescribed manner
- Lay the asphalt layer on the same day as the geotextile is installed
- Check how the geogrid was stored and transported, i.e. in which condition the geogrid was delivered to the construction site
- Check the resistance to damage during installation
- Install the geogrid with a very thin layer of non-woven geotextile [13]

Also, before installation, it would be desirable to make a trial section with a geogrid and take an asphalt core from it in order to laboratory test the adhesion of the layers, the technology of installation as well as the economic profitability of installing the selected geogrid.

Also this topic should has an economic analysis, which will be the topic of some of our next research.

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A CASE STUDY OF RECONSTRUCTION OF A RESIDENTIAL MASONRY BUILDING: DOES UPGRADING A BUILDING ADVERSELY AFFECTS ITS EARTHQUAKE PERFORMANCE?

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Abstract

Earthquakes in the vicinity of urban areas affect a large number of buildings, of different vulnerability classes, built over a long period of time and in accordance with the building codes of that period. Most often, these are masonry or concrete family and multi-storey residential buildings, a large part of which does not have sufficient earthquake resistance in accordance with the current building codes i.e., EN1998-1. When inspecting damaged buildings after earthquakes, it is usually observed that the damage grade is greater than expected considering the year of construction. One of the reasons is additions to the existing building structure, such as the expansion and/or elevation of the building. Building owners mostly do this without design, while not being aware of how they affect the earthquake behaviour of the building. Using a masonry multi-story residential building as a case study, the assessment of the earthquake behaviour of the building using a non-linear static pushover method is performed, considering the possibility of adding additional storeys to the building, with the condition of not affecting the earthquake resistance in any harmful way.

Key words: *residential masonry building; reconstruction; building upgrading; nonlinear static analysis; earthquake performance*

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1. INTRODUCTION

The Balkan Peninsula, in particularly its south, is historically exposed to high seismicity with over approx. 1750 earthquakes of M_L≥5.0 (I_{MCS}≥VI), 200 earthquakes of M_L≥6.0 (I_{MCS}≥VI), and 20 earthquakes of M_L≥7.0 (I_{MCS}≥VIII), including the south of Italy, island of Sicily, and Izmir region in Turkey, in compliance with the USGS Earthquake Catalogue.

A more recent example of surveys of damage after earthquakes M_L5.5 Zagreb and M_L6.2 Petrinja, Croatia [1–4], M_L6.4 2019 Durres, Albania [5,6] and M_L5.5 2010 Kraljevo, Serbia [7], in the region revealed a different vulnerability (fragility) of masonry buildings (stone or brick) w.r.t. time period of their construction. In general, they could be classified as pre- and post-1964 construction with reference to M_L6.9 1963 Skopje, North Macedonia earthquake, and the enactment of the building code [8]. However, after 1979 M_L7.0 Montenegro earthquake the building codes [9] were enacted and used till 1999 when [10,11] were introduced, which were superseded by [12,13] in 2013, by which the earthquake protection is increased. Therefore, even if the building code requirements of the period of construction are met (discrepancies are often observed), there is an effort needed to reduce the earthquake vulnerability of the building when compared to current building codes [12,13]. Such awareness is increased for buildings in existing urban areas by experiencing the consequences of recent earthquakes.

The upgrading of existing buildings provides a potential with regard to the planning of land use in urban areas, but it also highlights the differences in building's time period of construction and the current code demands. The long-term upgrading (or reconstruction) is not carefully regulated as it is for the new buildings. The presented case study is referring to planned activity of residential masonry building upgrading by considering the current earthquake resistant design criteria that differ from those of the time period of the construction of the building. The complete details of the study can be found in [14].

2. CASE STUDY BUILDING

The residential and commercial two-story unreinforced clay block masonry building of dimensions 15.45 m by 11.20 m in plan, and total height of 5.90 m, was used as a case study, Figure . The storey height is equal to 300 cm with the clear height of 280 cm. Masonry walls were built using clay blocks laid in cement-lime mortar, without vertical confining elements (in compliance with the building code of the time period and the prescribed medium seismicity zone i.e. I_{MCS}=VII). Only horizontal confining elements were built at floor levels and lintels above the openings. The floor slabs were made of reinforced concrete of 15 cm thickness. The clay block masonry walls are 25 cm thick, except staircase walls, made of solid bricks, which are 38 cm thick. The partition solid brick walls are 12cm thick. Building is located on soil category B, and the class of the building is II, in compliance with [11].

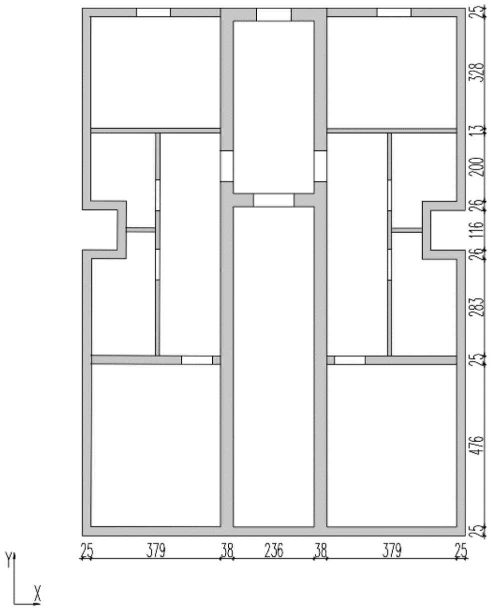


Figure 1 Building plan (measures in cm)

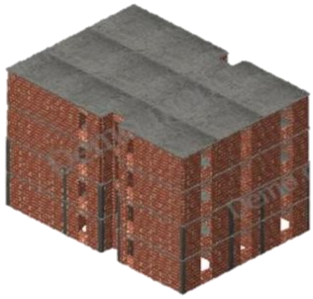
The following different cases i.e. building upgrade (reconstruction) possibilities were considered (see Tables 1-3):

- model 1: existing building without tie columns, with masonry "Porotherm Profi" blocks sealed with mortar;
- model 2: existing building with tie columns, with masonry "Porotherm Profi" blocks sealed with mortar, addition (upgrade) of two storeys with masonry "Porotherm Profi" blocks sealed with mortar, without vertical confining elements
- model 3: existing building, with masonry "Porotherm Profi" blocks sealed with mortar, with addition of two storeys, with seismic blocks "Porotherm S" sealed with mortar M5, with vertical confining elements (cross-sectional dimensions 25*25cm or 38*38cm; long. reinforcement 4Ø14 and stirrups Ø6/15, concrete C25/30).

Table 1 View on the Model 1 including volume and mass of elements

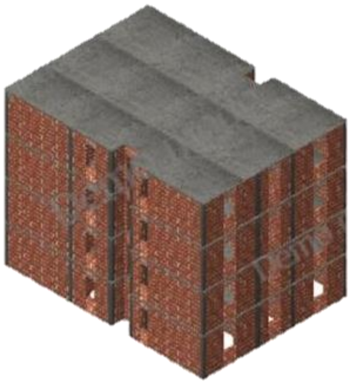
	Model 1	*Volume [m³]*	*Mass [kg]*
	*wall 38*	*44.477*	*33708.684*
	wall 25	*70.561*	*56166.556*
	wall 12	*12.721*	*8185.658*
	confined beam 25x25	*5.600*	*14000.000*
	confined beam 38x38	*4.043*	*10108.000*
	confined beam 25x38	*0.532*	*1330.000*
	lintel 25	*1.265*	*3162.500*
	lintel 38	*0.471*	*1178.000*

Table 2 View on the Model 2 including volume and mass of elements



Model 2	*Volume [m³]*	*Mass [kg]*
wall 38	*74.485*	*56451.476*
wall 25	*152.963*	*121758.548*
confined beam 25x25	*5.600*	*14000.000*
confined beam 38x38	*4.043*	*10108.000*
confined beam 25x38	*0.532*	*1330.000*
lintel 25	*2.635*	*6587.500*
lintel 38	*0.806*	*2014.000*

Table 3 View on the Model 3 including volume and mass of elements



Model 3	*Volume [m³]*	*Mass [kg]*
Seismic wall 25	*75.598*	*68038.200*
Seismic wall 38	*27.582*	*22138.132*
wall 25 non-bearing	*70.219*	*55894.324*
wall 38 non-bearing	*44.819*	*33967.884*
confined beam 25x25	*11.900*	*29750.000*
confined beam 25x38	*0.532*	*1330.000*
confined beam 38x38	*7.278*	*18194.400*
lintel 25	*2.635*	*6587.500*
lintel 38	*0.806*	*2014.000*

The dead load for ground floor was taken as 3.75 kN/m^2, and 1.5 kN/m^2 for the first storey, while live load was 2 kN/m^2 for both. Additional live load is taken in account for the roof 0.5 kN/m^2, together with the snow load of 1 kN/m^2 in compliance with Serbian National Annex of [15]. The dead and live loads on the added stories were taken the same as for the first storey of the existing building (residential purposes).

The above stated cases were analysed under seismic and static actions. For seismic action representation, selected was the response spectrum of Type 1 (earthquake magnitude greater than M>5.5), for seismic hazard with a return period of 475 years. Building is located in medium seismicity zone I_{MCS}=VII with corresponding peak ground acceleration (PGA) of 0.1g i.e. 1 m/s^2.

The properties of materials of construction are given in Tables 4 – 6 [11].

Table 4 Mechanical characteristics of masonry walls

Wall	Porotherm 25 Profi	Wall	Porotherm 38 Profi	Wall	Porotherm 11.5 Profi
partition wall:	No	partition wall:	No	partition wall:	Yes
f_k [MPa]:	3.869	f_k [MPa]:	3.869	f_k [MPa]:	4.101
f_{vk0} [MPa]:	0.300	f_{vk0} [MPa]:	0.300	f_{vk0} [MPa]:	0.300
f_{vlt} [MPa]:	0.517	f_{vlt} [MPa]:	0.517	f_{vlt} [MPa]:	0.562
f_{xk1} [MPa]:	0.000	f_{xk1} [MPa]:	0.000	f_{xk1} [MPa]:	0.000
f_{xk2} [MPa]:	0.000	f_{xk2} [MPa]:	0.000	f_{xk2} [MPa]:	0.000
ρ_n:	0.750	ρ_n:	0.750	ρ_n:	0.750
ρ_t:	1.000	ρ_t:	1.000	ρ_t:	1.000
ε_{mu}:	-0.00200	ε_{mu}:	-0.00200	ε_{mu}:	-0.00200
ε_m:	-0.00100	ε_m:	-0.00100	ε_m:	-0.00100
Mortar:	Dry-fix	Mortar:	Dry-fix	Mortar:	Dry-fix
f_{kh} [MPa]:	0.569	f_{kh} [MPa]:	0.569	f_{kh} [MPa]:	0.569
E [MPa]:	3869.000	E [MPa]:	3869.000	E [MPa]:	4101.000
G [MPa]:	1547.600	G [MPa]:	1547.600	G [MPa]:	1640.400
Weight [kg/m^3]:	796.000	Weight [kg/m^3]:	757.895	Weight [kg/m^3]:	643.478
γ_M:	2.200	γ_M:	2.200	γ_M:	2.200
Scale r:	0.500	Scale r:	0.500	Scale r:	0.500
f_k / f_{mean}:	0.833	f_k / f_{mean}:	0.833	f_k / f_{mean}:	0.833
Φ_{fvk}:	0.400	Φ_{fvk}:	0.400	Φ_{fvk}:	0.400
Φ_{fvlt}:	0.000	Φ_{fvlt}:	0.000	Φ_{fvlt}:	0.000

Table 5 Mechanical characteristics of the concrete class C25/30

Tip:	C25/30	E [MPa]:	31000.000
f_{ck} [MPa]:	25.000	G [MPa]:	12917.000
f_{cvk} [MPa]:	0.450	f_{cm}:	33.000
γ_C:	1.500	Weight[kg/m3]:	2500.000
f_{cvm} [MPa]:	0.833	ε_{cu3}:	-0.00350
		ε_{c3}:	-0.00175

Table 6 Mechanical characteristics of reinforcing bars

Ø6			
Diameter [mm]:	6.000	Cross section [mm^2]:	28.274
f_{yk} [MPa]:	500.000	γ_S:	1.150
E [MPa]:	210000.000	f_{yk} / f_{ym}:	0.980
Ø12			
Diameter [mm]:	12.000	Cross section [mm^2]:	113.097
f_{yk} [MPa]:	500.000	γ_S:	1.150
E [MPa]:	210000.000	f_{yk} / f_{ym}:	0.980
Ø14			

Diameter [mm]:	14.000	Cross section [mm^2]:	153.938
f_{yk} [MPa]:	500.000	γ_S:	1.150
E [MPa]:	210000.000	f_{yk} / f_{ym}:	0.980

The seismic action parameters defined by ground characteristics, other than those defined earlier, are: dynamic amplification factor B; attenuation relationship of 5; acceleration in ULS of 0.45; ground factor (S) of 1.2; periods B, C and D of 0.15, 0.5 and 2.0, respectively.

3. STRUCTURAL ANALYSIS

Structural model of the above stated cases, for the purpose of earthquake performance evolution, were built in AmQuake computer program [16]. The analysis was performed by means of nonlinear static i.e. pushover analysis. The wall and floor limit criteria for the design are shown in Table and 8.

Table 7 Floor limit displacements

Material	*Bending displacement*	*Shift due to shear*
Walls	*0.00800*	*0.00400*
Reinforced walls	*0.00800*	*0.00400*
Reinforced concrete	*0.0110*	*0.0110*

Table 8 Floor limit displacements

Damage limitation:	*0.00500*
Damage limit (d_{lim})	*0.500*
Coef. of Cracks:	*1.000*
Importance factor (γ_I):	*Yes*
Push Over analysis	*1.500*
P_d	*0.800*
P_F	*5.000*
Load eccentricity (e_{ai}) [%]:	

The structural and non-structural components of the building were considered in the model, however, partition walls were included only through their mass distributed on the surrounding structural elements. The results of the building response analyses are given in Tables 9 and 10, and Figs. 2-4.

Table 9 Display of horizontal seismic load model response in X direction

	uniform horizontal load			triangular horizontal load		
X+, exc. pos	1	2	3	1	2	3
Targeted displ. SLS [mm]:	1,220	3,827	2,982	1,344	3,500	3,320
SLS capacity [mm]	4,642	11,879	10,014	4,624	12,532	12,079
Targ. displ. ULS x 1,50 [mm]	3,661	11,808	8,946	4,033	12,007	9,961
ULS - capacity [mm]	4,642	11,879	10,014	4,624	12,532	12,079
Safety stock DLS [%]	73,711	67,783	70,222	71,041	72,069	72,510
Safety stock ULS [%]	21,134	0,601	10,667	13,122	4,193	17,530
Max error [%]	0,308	0,368	0,444	0,284	0,393	0,364
Storey	1,0	1,0	1,0	1,0	3,0	2,0
R Shift	0,00120	0,00173	0,00164	0,00099	0,00213	0,00155
DLS Criteria	3,804	3,104	3,358	3,453	3,580	3,638
R Shift Criteria	0,241	0,347	0,328	0,199	0,426	0,310
ULS Criteria	1,268	1,006	1,119	1,151	1,044	1,213
DLS step Id	5,0	6,0	6,0	5,0	9,0	6,0
ULS step Id	5,0	6,0	6,0	5,0	9,0	6,0
Period T Norm.	0,181	0,321	0,317	0,181	0,283	0,306
Max ref. ground acc. [m/s^2]	1,141	0,904	1,007	1,036	0,926	1,091
Ductility	1,517	1,781	1,525	1,565	2,808	1,887
Factor over strength	1,743	1,595	1,719	1,835	1,366	1,831
Elastic displacement [mm]	3,347	7,266	6,860	3,543	5,687	7,982

Table 5 Display of the response of the horizontal seismic load model in the Y direction

	uniform horizontal load			triangular horizontal load		
X+, exc. pos	1	2	3	1	2	3
Targeted displ. SLS [mm]:	0,130	0,775	0,683	0,168	1,537	0,745
SLS capacity [mm]	0,445	3,154	3,162	1,637	8,650	3,162
Targ. displ. ULS x 1,50 [mm]	0,390	2,326	2,049	0,505	6,507	2,236
ULS - capacity [mm]	0,445	3,154	3,162	1,637	8,650	3,162
Safety stock DLS [%]	70,770	75,423	78,394	89,714	82,232	76,427
Safety stock ULS [%]	12,311	26,268	35,183	67,143	24,770	29,282
Max error [%]	0,386	0,441	0,399	0,362	0,285	0,399
Storey	1,0	2,0	2,0	2,0	3,0	2,0
R Shift	0,00008	0,00039	0,00039	0,00031	0,0026	0,00037
DLS Criteria	3,421	4,069	4,628	9,722	5,628	4,242
R Shift Criteria	0,018	0,077	0,079	0,0624	0,5200	0,0752
ULS Criteria	1,140	1,356	1,543	3,241	1,329	1,414
DLS step Id	3,0	3,0	3,0	3,0	5,0	3,0
ULS step Id	3,0	3,0	3,0	3,0	5,0	3,0
Period T Norm.	0,071	0,146	0,151	0,076	0,188	0,145
Max ref. ground acc. [m/s^2]	1,026	1,221	1,389	2,917	1,057	1,273
Ductility	1,098	1,115	1,066	1,225	4,765	1,274
Factor over strength	1,000	1,000	1,000	1,000	1,003	1,000
Elastic displacement [mm]	0,443	3,082	3,097	1,596	2,313	3,095

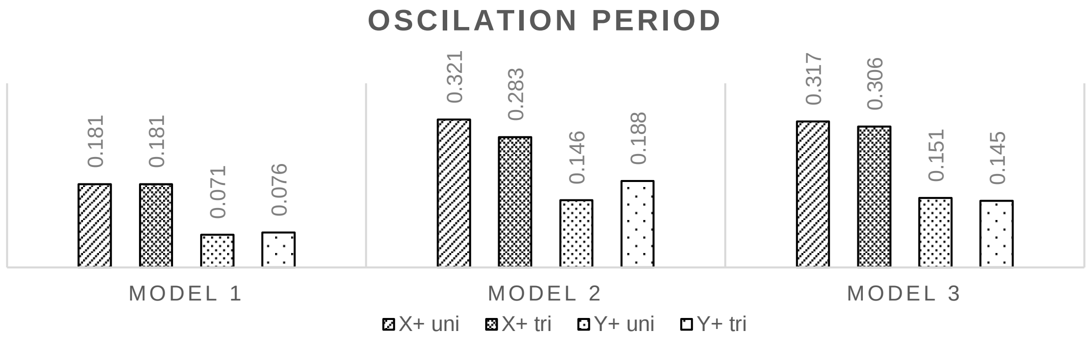


Figure 2 Oscillation period comparison

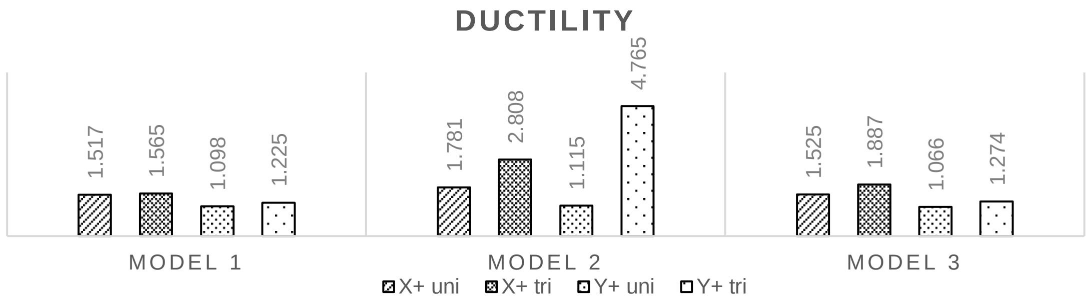


Figure 3 Ductility comparison

Figure 4 Models safety stock comparison

The comparison of the earthquake performance of the observed cases in the form of the first oscillation period, T_{NCR} (s), ductility, and safety stock, are presented in Figs. 2-4. The most critical was the ground floor.

4. CONCLUSION

The upgrade possibilities of an existing residential masonry building, built in the time period of building codes with lower earthquake demand, were analysed w.r.t. latest (improved) building codes. Depending on the specific cases considered, the following conclusions have been made:

- the addition of two stories to the building, with or without construction of vertical confining elements, increased the first oscillation period from approx. 0.2 s to approx. 0.3 s making it still in the range of the dominant periods of the earthquake excitation

- the ductility increase of the upgraded models is on the side of the model with consistent construction materials
- the safety stock is on the side of the upgraded building with vertical confining elements.

Because of variety of possibilities, each existing structure is a case for itself and must be individually approached. The premise was, that the building upgrading, if carefully designed and performed, improves its earthquake resistance.

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PROGRAM TRANSFORMATION OF URBAN VILLAS, BUILT IN THE PERIOD BETWEEN THE FIRST WORLD WAR AND THE SECOND WORLD WAR IN NOVI SAD, SERBIA

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Abstract

The urban villas built in the period between the First World War and the Second World War in Novi Sad represent some of the most valuable works of architectural heritage. Although short in time, this period was very significant due to a series of changes that occurred in the development of the city. It is characterized by the formation of a civil society constituted according to the developed countries. Due to the increased migration of the population towards the city and the influx of significant economic capital, there was a need for more construction in the city centre, but also on the outskirts of Novi Sad. The increased economic wealth of individuals caused the emergence of individual and collective residential construction, not limited by material means nor burdened by the traditionalism of the owner. The urban villa as an architectural type is significant for several reasons. It illustrates the quality architecture of a period. By researching this type of housing, one can conclude about the way of life, construction, styles, and customs, i.e., culture of a time. The urban villa is present in a certain social setting, i.e., capitalism and has to do with private property. Built in the period between the two world wars, these buildings originally had a function and spatial organization characteristic of the needs of the daily life of the investor and his family at that time. However, as the socio-economic context of Novi Sad changed during the 20th century with changes in the state structure, so did the ownership of urban villas. This paper aims to investigate original spatial-functional settings of urban villas in Novi Sad, and then the programmatic transformations that arose because of changed socio-economic factors, that inevitably led to spatial changes and different spatial relationships within the buildings.

Key words: *housing, villa, program, architecture, transformation, Novi Sad*

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1. INTRODUCTION

In every period of architecture's development, some buildings that stand out from others by their characteristics and quality and bring specific importance for the society. Within many architectural typologies, housing is always distinguished as the basic human function, especially the villa as a type of single-family residential building characteristic for the period of capitalism and private property when it appears under the influence of the overall socio-economic context.

The aim of this paper is to analyse the architecture of villas built in Novi Sad during the 20th and early 21st century. For this research, the villa as a physical structure is seen as a variable category, with all different processes and influences since its creation and development. The main part of the work is contextual analysis in relation to the phenomenon of time and place, chronological observation of changes in program transformations, and then other elements for the quality evaluation of villas and their preservation. For the purposes of research, it was necessary to identify, document, evaluate, and then present conclusions and recommendations how to preserve this type of buildings that has often program transformations from devastation and demolition. Within this paper, this problem will be analysed from the aspect of the context of the time and program of villas, but not through the criteria of protection of cultural heritage, although some of the villas have the status of a protected ones. Therefore, through their program, the way of functioning of villas that were created in response to the existential needs of people from a certain period will be examined, but also the way they have transformed over time, with changes in lifestyle, changes within society, in sociological aspects and cultural policies of the times. Therefore, the basic question is the relationship between the program's changes and the villa as a spatial unity, and its physical changes in the context of its protection and revitalization.

2. URBAN VILLA AS A TYPE OF RESIDENTIAL BUILDING

The villa is defined as the perfect and most complete form of housing since it represents the highest standard of a culture and epoch. Within the framework of the typology of residential buildings, it represents a family house built in a certain space and time context. In architectural terms, the villa reflects the harmonious unity of the urban context, interior space, and outer form. The term villa appears in ancient Rome, as a building on the land estate of wealthy Romans, in the city and in the suburbs. It is specific in the period from 15^{th} to 17^{th} century as type of houses in Italy, surrounded with a park, statues, fountains and famous for its architectural appearance with works of art, or from the 19^{th} century defined as a building outside the city surrounded by greenery [1], today also defined as a summer house, or a house built in the form of a summer house [2].

Several influential factors – social, cultural, and urban, determine the villa as an architectural type. The process of development of this type of housing, from concept to building, is conditioned by the ideology, social and economy values, and standards of society, as well as their historical, cultural, and traditional values. Family house always represents the way of life, customs, but also the individual needs, desires, and possibilities of its owners. Villa, as one of the highest quality residential architectures symbolizes the concept of elegant and harmonious living. The construction of this specific type of luxury housing is usually initiated by the social elite, while prominent representatives of the architectural profession make a great contribution to its planning and construction, striving to realize the high-quality architecture through the luxury housing program. Each family house is determined by the program as the basis for the the organization of space, as the meaning of architecture that as an artifact preserves and develops the image of time and society [3, p. 119], i.e., as a process of realization of content, an established series of requirements that the built space through the needs recognized by the client should meet [4, p. 39]. The starting point for the design of a house is a program based on human needs that can be general: biological, physiological, psycho-emotional, social, but also specific and conditioned by the program's elements defined by the owner.

Another determinant of a family house is the context – the place and time in which it arises. The house is also a reflection of socio-cultural conditions that span from the ideology of social order, economy, and social standards to the historical, cultural, and traditional values of the society. Its program, comparing with the programs of other architectural types, despite a relatively small, plays a significant role in the cultural imagination of the individual and the community [4, p. 2]. Based on contextual analysis, it can be determined how and in what way a house developed as a villa, i.e., what is the difference between these two types of homes. In the architectural sense, the villa is more luxurious than a single-family house, which has more modest character, and as Milan Rakočević states, it implies that the shape and function are transformed into the bearer of the idea of comfort, with new amenities and larger spaces, proportionally investing more material resources [5, p. 56]. The villa, unlike a family house, implies housing of a higher standard [6, p. 175], based on an extended program. As a rule, the villa is built in nature or on larger and spacious lots. Respecting the natural characteristics of the terrain, but also the created urban conditions, in accordance with the needs of the users, and according to the architect's idea, it strives for unity of interior and exterior space, to achieve a more comfortable living environment.

One of the basic criteria for differentiation between the villa and single-family house is the program. This is reflected in the project of a functionally more substantive building, which can be called a villa because the spaces intended for living, working, sleeping and hygiene are increased and enriched (separate or additional comfortable dining room with living room and with good connection to the kitchen, separate room for work, library, salon for ladies, fireplace lounge, separate bathroom in the sleeping area, parents' bath, sauna, etc.). In this way, a more comfortable interior space is formed, with adequate composition of the plan, zoning and other aspects of functional analysis and spatial concept. When considering the comfort of a house, according to Milan Rakočević, it increases in both quantitative and qualitative sense of living, including not only the size of space, but also applied materials and equipment [5, p. 55]. We can conclude that luxury and comfort are constant categories that determine the villa and that these properties affect the process of growing an ordinary family house into a villa.

DEVELOPMENT AND TRANSFORMATION OF VILLAS IN NOVI SAD, SERBIA

During its development, Novi Sad has gone through a period of dynamic socio-historical changes which have left marks on its spatial characteristics, especially through the architecture and culture of housing. The time and space framework of this research includes a period of one hundred years through which the process of
3. the emergence and development of a specific type of single-family residential buildings – villas could be followed. By the method of research based on the villa - context - continuity relations a possible system of evaluation of existing residential buildings in Novi Sad was established with contribution to the preservation of specific properties of this architectural type in the future. In addition, all the values on which villa-type buildings are based, can be applied to the design and construction of other residential buildings which can contribute to the development of urban, architectural, and aesthetic landscape of Novi Sad.

For a complete understanding of an architectural type, it is important to research the whole socio-historical context. The 20th century was chosen for the study of villas in Novi Sad, as this period enables continuous monitoring of the development of this architectural type, from the first forms to the present day. General social conditions, political circumstances, as well as the achieved level of economic, cultural, and artistic development, can be seen over three periods:

1. Period from 1918 to 1941 – the emergence of villas in Novi Sad (capitalism, private property, elite, educated architects).
2. Period from 1945 to 1990 – program and spatial transformation of existing villas (socialism, nationalization, ownership transformation as a prerequisite for program transformation, villa as type is transformed into new programs with public character).
3. Period from 1991 to 2023 – a new program transformation (capitalism, some buildings reconstructed in accordance with the new regulations, individual villas valued based on location with the idea of erecting
3.1. multifamily buildings at these locations; the question of inheritance and how to treat built heritage is raised.

The period from 1918 to 1941: the development of villas

Although short in time, the period between the two world wars, was very significant due to a series of changes that took place in the development of the city. After the end of the First World War, Novi Sad and other cities in Vojvodina decided to secede from Hungary and join Serbia [7, p. 35]. Within the newly formed Kingdom of Serbs Croats and Slovenes, which was capitalist in terms of economic and social structure, but agrarian in terms of production and technically poorly developed country, with underdeveloped construction techniques and limited use of new materials and structural systems, Novi Sad, with a population of 39,000, found itself geographically in the centre of Vojvodina. In 1929, with the change of the country's name to the Kingdom of Yugoslavia and its division into nine banovinas, Novi Sad became an administrative unit of the highest rank – the seat of the Danube Banovina. With this event started the great development of the city in the time of late capitalism. Spatial expansion of the city and urban activity, brings in 1921 the first professionally developed regulatory plan [8, p. 29]. According to Pušić, the review plan of the municipality from 1930 represents a reflection of the plan from 1921 and represents a turning point in the urban development of the city [7, p. 121]. Just before the Second World War, a Yugoslav competition for the General Urban Plan of Novi Sad was announced. The elaboration of this plan was entrusted to professor Juraj Najdhart, but these works were interrupted due to the outbreak of war. A very important document that marked this period is the adoption of the Building Law in 1931, according to which Novi Sad received the building legal code in 1938. Within the framework of legal acts, many problems related to the urban development of the city have been solved, as well as the construction of individual buildings – the area of plots, the street front, as well as other characteristics related to the characteristics of the apartment have been defined. Based on the regulations, the smallest length of the street front for villas was 18 m. Minimum height of living rooms in the basement and attic 2.5 m, on the ground floor 3.0 m, on the floors 2.8 m and for household purposes 2.25 m. According to hygiene regulations which processes buildings for housing it was defined as follows:

1. The apartment must at least have a room, kitchen, and toilet. In addition to this, in larger buildings, there may be in addition to other apartments and separate apartments (studios) that must have one room and a bathroom with a toilet.
2. Residential and workspaces and public premises where people stay shall be completely dry and equipped with installations for sufficient heating.
3. In each apartment, at least one living room must have an area of 16 m² and a width of at least 3.0 m, the kitchen minimum area of 8 m² and a width of 2.5 m, a pantry of at least 1.5m² of area and a toilet at least a width of 0.9 m and a length of 1.2m². If there is a room next to the apartment for the younger ones, then its area must be at least 6 m² [9].

Although this period was characterized by an unfavourable political and economic situation, which conditioned the emergence of an agrarian crisis, and since 1929 a general economic crisis, in the years between the two world wars, some progress has been accomplished in different fields. First, an intensive construction started in the city after the First World War and lasted continuously until 1941 (six factories were built, railway stations expanded, construction of the military airport began). During the expansion of the city, eight peripheral settlements were built (Nova Podbara, Vidovdansko naselje, Pejinovo, Detelinara, Vragova bašta, Telep, Železničarsko naselje, Veliki Liman and Mali Liman). In this period, several important public buildings were erected in the area of Mali Liman (the Health Centre, the Workers' Chamber, the Labour Exchange, the Home of Educators, the Chamber of Commerce and Industry and Crafts, the Cultural Centre, the Habag Cultural Centre, the Palace of the Danube Banovina, the Commercial Youth Centre), as well as several large-scale residential buildings (Tanurdžić Palace, Klein's Palace, the building for banovina officials in Mali Liman, etc). These buildings, as well as most of the newly built villas, were designed by a new generation of architects educated abroad, such as Đorđe Tabaković. Lazar Dunđerski, Danilo Kačanski, Filip Šmit, etc. [10].

This period characterized the formation of a civil class of society. Due to the increased migration of the population towards the city, the inflow of significant capital, there was a need for greater construction in the urban environment, but also on the outskirts. The increased wealth of individuals has created conditions in Novi Sad for the emergence of individual and collective housing construction, unlimited by material means, nor burdened by the traditionalism of the client. The capitalist system and the emergence of private property provided preconditions for the new type of housing – villas. As Donka Stančić states, after the First World War housing in the city centre was no longer as prestigious as it used to be, and the fashion of building villas not far from the old town core or in blocks along the Futoški road in the immediate vicinity of the Iodine Spa and the City Hospital, has begun. With the construction of representative family houses according to the urban rules and quality projects, these parts of the city acquired an exclusive attraction, in where successful industrialists, merchants, doctors and engineers with well-developed private practices have moved [11, p. 382]. Analysing the plans made between the two wars, three zones are observed in which the villa, as a new type of family housing, dominates. These were the zones of the former peripheries, which over time, with the spatial expansion of the city, will become part of the central zone. The construction of Mali Liman area, from the Danube to Dunavska Street and Zmaj Jovina street and borders with today's Železnička Street, and the former embankment and Mihajlo Pupin Boulevard, started in the 1920s based on the Regulatory Plan from 1921. The newly formed space had an orthogonal block structure, as well as modern residential and business multi-storey buildings. The area was specific because it represents a spatial framework for the construction for villas, whose construction begins in the 1920s, just after the regulatory plan was implemented, when parcelling was carried out and plots sold at the public auction to wealthy citizens of Novi Sad. The western direction towards Futog also became interesting, especially lots in the vicinity of the Roman Catholic cemetery and the Complex of The Iodine Spa and the Futoški Park. This area was characterized by diverse examples of individual residential typology. Several representative buildings were built at the request of well-known doctors, which was explained by the proximity of the hospital.

The main feature of the villas built in the period between the two world wars is the division into two functional units: serviced and serviceable space. The specificity of the example was reflected in the fact that each villa had a clearly separated functional unit of the serving space, always oriented towards the courtyard, and composed of a kitchen, storage room and in most cases servants' rooms. The served space of these villas, mostly ground floor, was unique whole with mixed public and private spaces. Usually, three interconnected rooms were oriented towards the street and treated in the same way. As part of the plans, certain rooms were still singled out such as hall, lounge, dining room, etc. The first form of a private zone was a room next to the bathroom with a direct connection. During the 1930s, several storey villas were built with a clearly demarcated division into public and private zones. Usually, the ground floor was a public zone with representative chambers (entrance hall, living room, lounge, hall), dining room, and cabinet. The private zone, composed of several bedrooms and bathrooms, separates a functional unit positioned upstairs. Within this zone, in the period between the two world wars, wardrobes were special rooms in some very representative villas. During this period, a developed form of a private zone occurs, which includes an apartment type, with bedroom directly connected to the bathroom through the wardrobe as a luxurious solution. Serving the space of the two-storey villas is, as with the ground floor, a separate unit with a separate – auxiliary entrance, organized on the ground floor, but also in the basement. The novelty is the rooms of the central heating system located in the basement, as well as household rooms intended for laundry [12, p. 163].

Figure 1. Characteristic villas of Novi Sad built in the period between the two world wars Gallery square (left) and Pavla Simića Street 10 (right), source: authors.

3.2. Period from 1945 to 1990: emergence of socialism – the ownership and program transformation of villas

This period is characteristic by the ideal of collectivism and the suppression of individualism and independent initiative. It excludes individual construction, valuable ambient units of individual houses were demolished, and skyscrapers and blocks of buildings for collective housing were being built [13, p. 253]. There was no place for the individual house as a private property in socialism, and it could not have the position of a worthy urban category and was on the side-track of organized social events [14, p. 42]. In this period, with the change of social relations, housing conditions and housing needs in cities were changing. A part of the housing stock that was intended for rent is socialized, and ownership with more than two apartments is expropriated. In the new context, society takes over the construction and distribution of apartments which become a concern of the community and a sign of social equalization. The city was expanding intensively, and residential typology has increased, with the construction of a series of zones dominated by the of multifamily housing (Grbavica, Liman, Detelinara, Novo Naselje). Major socio-economic and political changes stand out, among which the measures of expropriation of private property caused a series of changes within single-family housing. The new social and political context which excluded the private property, significantly influenced the development of the villa as a type of housing. In this period, the classic type of villa did not exist. Several examples that were designed by famous architects have been recorded, but these were family houses of complex program, which, due to the characteristic authorial attitude and their authentic design principle, stand out from other typical solutions. In accordance with the changes in society, reflected in the way of life, the division of space has changed comparing it to the previous period. The main difference is observed in the lounge area. It was no longer a separate functional unit, but an integral part of the served space. The kitchen as a central room was connected to the dining room, and the servants' room completely disappeared from the plan. The served space was still divided into two independent functional units: public and private. The system of passing rooms was no longer applied. Generally, the discontinuity is a characteristic of this time, and could be interpreted on two levels. Several existing villas that were owned by Jews or Germans switched from private property to state property in the process of nationalization, and thus the former housing program was replaced by various public programs. Numerous villas, especially those with several apartments built on Mali Liman, still had a residential function, but instead of private ownership, it has become the property of several persons [12, p. 70].

During this period, three types of program's transformation are clearly observed:

1. Transformation of the program of single-family housing of the villa type under the influence of lifestyle changes.
2. Transformation of single-family (villa type) into multi-family housing (transitional form between single-family to multi-family housing).
3. Transformation of housing programs into other public programs in the fields of culture, health, education, research.


Figure 2. Characteristic villas that changed the ownership and function after 1945: Health care institution in Vase Stajića 5 Street (left) and Kindergarten administration building in Pavla Simića 9 Street (right), source: authors.

3.3. Period after 1991: the end of socialism and a period of transition

The period from 1991 to the present times has been marked by socio-political situation different from the previous one and numerous changes occurred in the development of Novi Sad. After the collapse of the SFR Yugoslavia and the formation of the State Union of Serbia and Montenegro, and afterwards the Republic of Serbia, Novi Sad became the second largest city in the newly formed state. The socialist system has been replaced with new capitalist system. With the introduction of a so-called transition, towards private ownership and a radical market economy, the image of the city significantly changed. This period was marked by economic collapse. In terms of demographics, there have been many changes due to unplanned migration. Cultural and ethical norms were changed, which had a direct impact on architecture. Illegal construction increased, which caused the changes of physical structures in the city. After a period of very popular construction of houses on the principle of catalogue sale of projects, a new period emerged due to the inflow of capital, the newly formed investors opt for the "new–old" type of family housing – villas. The period at the end of the 20th century was very similar to the period between the two world wars. The city territory expanded again in the direction towards the western part becoming an area of intensive construction activity, as well as areas of southern Telep and Adice, the Tatar hill in Kamenica and along the banks of the Danube, on Kamenjar and Ribnjak. In addition to the construction within the new areas, it is important to mention that in the parts of the city where the villa dominated as a housing type in the period between the two world wars, numerous interventions on existing buildings took place. The level of interventions ranges from the simple changes on the facades, through upgrades, to the total reconstructions. There are several examples of existing buildings completely replaced with a new one, identical in the form of the previous one. Also, some new villas replaced an old building, bringing contemporary elements of architecture.

In addition to the socio-political and economic situation, this period is also characterized by the newly formed elite who has built spacious and luxurious houses of the villa type, with new alterations in the program and spatial organisation. Serving space was designed as a separate functional whole. In some examples, the servants' room was also designed. However, the main difference from the previous period is reflected in the larger area of today's villas, as well as in the more complex program. The difference is reflected also in the way public space is organized. Villas built in the period between the two wars were planned on the principle of chambers, while today the principle of unique space is more often applied. Usually, on the ground floor is a representative hall, living room, lounge, and dining room, and upstairs is a zone of private character. The quality of the solution determines the number of bedrooms and associated bathrooms.

Types of program transformations during this period are listed:

1. Transformation of the one-family housing program – re-establishment of the villa as a type of single-family housing (construction of new villas under the influence of original examples in the same or new locations).
2. Transformation of the multifamily housing program - the emergence of the type of urban villa (multi-family housing with individual features of single-family housing).
3. Transformation of space due to the expansion of existing programs of public character in the field of culture, health, education, research... (renovation or devastation of space due to the need for better functioning of existing programs).
4. Transformation of the program in the future (transformation of single-family housing into something else – letting the facility collapse to use the location for new programs, i.e., achieving individual profit).

4.

Figure 3. Villas that were left to devastation in Futoška 66 Street (left) and in Futoška 96 Street (right), source: authors.

COMPARATIVE OVERVIEW OF CHARACTERISTIC VILLAS IN NOVI SAD

Following the abovementioned periods and events that influenced the construction and transformation of villas in Novi Sad, the examples of 8 selected villas and their changes under social and economic aspects are presented in the table 1. By analysing these representative examples and their transformations, we can follow not only changes in the program, but also differences in the social context and physical changes experienced by both the buildings themselves and the urban parts of the city where villas were built.

Table 1. Comparative overview of characteristic villas in Novi Sad

Address	*Period from 1918 to 1945*	*Period from 1945 to 1990*	*Period from 1991 to nowadays*
Vase Stajića 1	*housing program / villa no access to the original plan*	*different public programs, Art gallery since 1974*	public program – Art gallery; the only one under cultural heritage protection
Vase Stajića 5	*housing / villa program no access to the original plan*	*public program – health care centre*	*public program – health care centre (reconstructed)*
Vase Stajića 7	*housing*	*housing with commercial program (private health care practice)*	*No program, closed to fail*
Vojvođanskih brigada 14	housing program - towards multifamily housing (two apartments, each on one floor)	*public program – kindergarten*	*public program – kindergarten (reconstructed)*
Pavla Simića 9	*housing program / villa*	*public program – kindergarten administration*	public program – kindergarten administration (reconstructed)
Pavla Simića 10	*housing and commercial program*	*housing with commercial program*	Waiting for the reconstruction, closed (not under protection, although one of the worthy examples of villas)
Futoška 66	housing and commercial program	commercial (division of one unit into two)	unresolved ownership relations (closed and released to fail)
Futoška 96	housing program / villa	*public program – centre for medical research (reconstructed)*	closed with uncertain status

According to the above comparative analysis, we can note that in all selected examples the basic program during construction was a residential one, and that all buildings had characteristics of luxury housing. Social and economic conditions in the period 1945 to 1990, brought significant changes and left lasting consequences, which were reflected in the transformations of the program from housing into public facilities (business, health institutions, social protection, culture...). These changes also brought physical changes to the buildings themselves, which later contributed that some of the buildings faced with permanent devastation or even total demolition. The lack of legal regulations and its compliance led these facilities to the final decline in the period after 1991, when the market economy affected the change of programs, but also the aspiration of new owners and investors for a larger number of square meters and better earnings. Some of the buildings were destroyed due to unresolved ownership relations or lack of funds for their maintenance, while others were left to deterioration with an aim to erect new buildings in their place, mostly of the residential type again.

CONCLUSION

Monitoring the program transformations of villas in the periods from 1918 to nowadays, it gave us an overview how and in what ways social contexts have been
5. changing, and what were the economic and cultural parameters of an environment.
On the example of Novi Sad, it can be clearly seen that this type of buildings underwent changes, which mostly occurred on representative ones, thus disrupting the character of the city and the spirit of a place. The valuable elements of the architecture in these buildings were at first destroyed through programmatic transformations and transformation into common ownership. By the change of socialism into capitalism, insufficient legal frameworks and material funds for maintenance and preservation of those villas still in public ownership, as well as by insufficient awareness for the preservation of architectural heritage and nurturing of the values of architecture that had its own specifics through program parameters, functional organization, urban contexts, aesthetic values, but also through cultural significance for the society of those owners of villas that have been returned to private ownership, lot of them faced with devastation and demolition. By neglecting the care for these buildings, individual spaces were obtained with some new programs, realized through new architectural and urban frameworks and through new aesthetic parameters. Analysing all the above mentioned, we can conclude that the program's transformation in some examples, although changing the original character of the buildings, managed to preserve it from devastation and demolition, opening it as public content to the public and thus continuously giving it importance. The world examples of villas from the period between the two wars (Villa Savoy, Villa Tugenhat, Villa Muller...) indicates the numerous and different possibilities by which such valuable buildings could be preserved, and at the same time presented to the public, which in our professional framework, could be the parameters by which this type of objects as representatives of cultural heritage could be preserved.

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ENSURING OF THE FINANCIAL RISKS IN BUILDING OF A CONSTRUCTION PROJECT

Tatjana Ackovska[1]

Abstract

The construction of the projects, when the construction companies enter a business relationship on the market, is always connected with uncertainty and risks. During the realization of the construction projects there are various circumstances that affect the course of the construction of the project itself, and the expected results of the construction and financial realization of the project.

Depending on the type of project and the FIDIC book that is appropriate to be used in the performance, the clauses listed in FIDIC contract provide a variety of performance risks. Specific for FIDIC contracts, is that each of the books has a different dispersion of potential performance risks between the investor and the contractor of the project.

Also, FIDIC contracts always included clauses for financial instruments (bank guarantees; price adjustment; retention money and insurance) to cover uncertainty and diverse types of risks during the period of execution of the project. All these instruments have their own special characteristics, strengths, and weaknesses over the others. Joint implementation provides protection against a variety of risks that affect the financial flows of the project realization. Which of these instruments will be used in the construction of a project depends on the terms and conditions agreed between the investor and the contractor.

The paper provides specific characteristics of those financial instruments and their implementation according to FIDIC contracts. The findings in this paper are answers to the questions of how and why those financial instruments should be used during the performance of the construction project.

Key words**:** *Construction, risk, FIDIC, bank guarantees, insurance, retention money, price adjustment*

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RISKS FOLLOW THE CONSTRUCTION ACTIVITIES – CONSIDERATIONS AND CONCEPTUAL DETERMINATION

For construction companies entering business relationship in the global economy and building of projects is always associated with uncertainty and risk. During the realization of the construction projects there are various circumstances that affect the course of the construction itself, the expected results of the construction and financial realization of the construction of the specific project.

1.

The uncertainty in performance of the construction project, is related to the different degree of economic development of the countries, the cultural differences between the participants in the construction, the exchange rate movement, the business environment of the companies, the distance between business parties and the like.

Risk is a measure of the probability that a particular event will occur in the future, or a measure that that event will cause the situation to change, and as a result, certain consequences will occur [1].

Risk incorporates three components:

- An event or phenomenon that affects someone or something important to us.
- The probability of the event. It indicates the instability of situation that is changing under the influence of the event,
- The significance of the consequences, which is measured in the awareness of the event to which the risk relates and in terms of experiencing the change occurring [1].

Risk is associated with uncertainty and is often considered as a synonym. Uncertainty arises when an event has one or more outcomes, and our knowledge of alternatives is incomplete or inaccurate, so the probability of the outcome cannot be accurately determined [1]. Risk and uncertainty are inherent and exist in every construction project, regardless of the type, size and value of the project which is being executed. They are also connected whit the conditions in the country in which the project is being constructed.

Very often companies face unforeseen events during the performance. In such a situation, the outcome of the event should be perceived and recognized, and it is especially important to predict and calculate the potential risks. In such a situation, it is also necessary to have well-trained staff who will decide how to act and manage in a particular case with the intention of reducing the consequences of a possible event. It is therefore especially important to create a risk-based security system in advance to prevent or reduce the consequences of probable future events.

There are various divisions and groupings of risks. Risks in construction, when construction companies perform a project on the foreign market, can be divided into the following groups [2]:

Performance risks - this group includes the risks associated with execution of the construction project or its design as well as risk connected whit construction techniques and technology. Those type of risks are also connected whit organization problems and running the construction sites, country standards related to environmental pollution, legal provisions around the protection of the workers themselves, the possible risks of site fire and other risks associated with the construction of the project.

- ***Natural disasters and weather conditions*** - unexpected events connected with mother nature and weather conditions. Those can affect the deadline of the project. Unexpected floods, snowfall, wind, earthquake, temperature variations, all of them can disable execution of project on construction site.
- ***Financial risks*** - this group includes the risks associated with the financial flows during the construction of the project. Here is the most significant risk of payment for the work performed, the risk of foreign exchange rates, the possibility of recognition and payment of unplanned costs of performance, adequacy of insurance, the risk that the contractor may not justify the advance paid and the like.
- ***Political and legal risks*** - related to foreign market regulations and rules of law. The most often used here is the need for various licenses for the operation of construction companies on the foreign market, approval, incompatibilities and unfamiliarity whit local laws, differences whit company rules, specific conditions in the contracts, political contingencies in the foreign country, strikes, rebellion, wars, unexpected changes in rule of law.
- **Other risks** - a variety of events that could affect the result of construction such as: loss of qualified staff at a critical moment, a problem with unproductive workers, landowners unwilling to sell a part of land and other similar events.

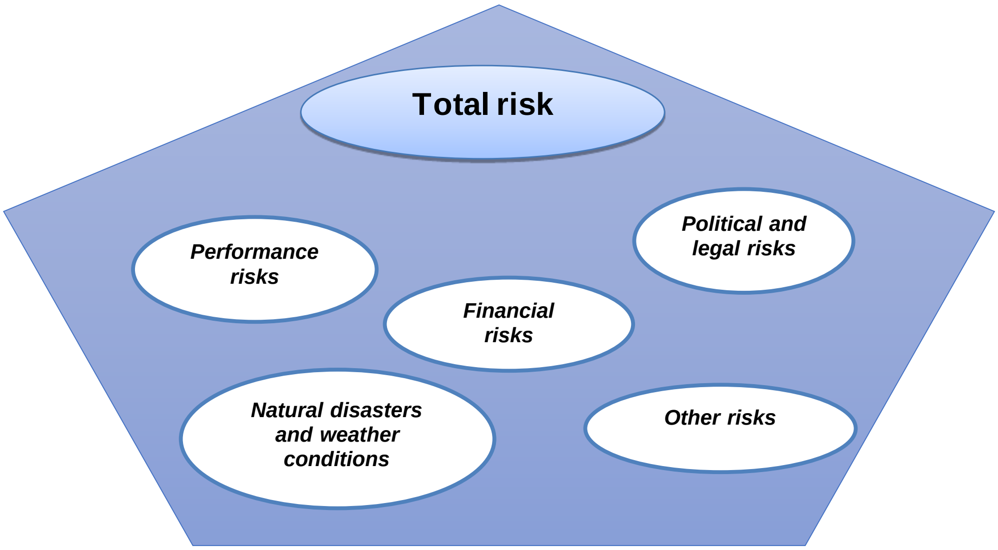

Figure 1. Total risk in construction of the project

source customized by author based on Dr. Nadeem Ehsan, Risk Management in construction industry, Center for Advanced Studies in Engineering, Pakistan 2010, p.3

Each separate risk is calculated in the total risk in execution of the project in construction [2]. Occurrences, during the construction of the project can be of a variety of nature. The consequences of these occurrences can reflect in financial losses, inability to meet performance deadlines, performance failures and reduced quality of work performed, loss of client and investor confidence, loss of company rating and even loss of human lives.

Total foreign market risk is greater than risk in domestic market and contains more components than domestic market risk [2]. It is necessary to consider in advance the possible risks and to ensure that they are provided in the most viable way when agreeing on the performance of construction work. For construction companies, contractors, and for investors, this is a specific and challenging task. It is extremely hard to look at the difficulties ahead of gathering relevant data and information in purpose to get a clear picture of the entire construction period. Therefore, it is especially important to conclude a well-conceived contract, which will include an adequate dispersion of the risks that may occur during construction, but also contract which include clauses for the procedures and instruments for providing risk security. The contract is the base of the relationship between the parties, and it has significant effects on the strategy that the construction company will adopt to achieve the project objectives (quality, costs, duration of execution, and profit).

2. THE SIGNIFICANCE OF THE FIDIC CONTRACTS AND THE TYPES OF FINANCIAL INSTRUMENTS USED TO COVER UNCERTAINTY AND RISKS

Forms of construction contract that are globally accepted as an international standard are the FIDIC contracts. As a result of the idea of establishing a global federation of independent engineers in Ghent, Belgium in 1913, representatives from Belgium, France and Switzerland formed the International Federation of Engineering Consultants FIDIC [3]. This organization defines the terms of contracts for the construction industry around the world and their standardization. Today, after more than one hundred years of its formation, the federation has over two million members, professionals from more than one hundred countries around the world [3].

The FIDIC contracts are widely used worldwide and represent an international standard in the construction of projects. Those are written in simple English language and are easily understood. Publications of FIDIC contracts have been translated into more than thirty languages around the world. There is a practice for international financiers and investors, leading commercial banks, and investment funds, that they are demanding their investment projects to be implemented under FIDIC's systems and contracts. Thus, any project financed by the World Bank, regardless of the region where the construction works are conducted, is agreed, and performed in accordance with the requirements of FIDIC.

Depending on the type, size of the construction project, model of sharing of the risks during construction of the project between contractors and investors, also the duration of the contract there are specific FIDIC contracts which are included in the FIDIC rainbow. This rainbow consists of following books [3]:

- ***The red Book*** - used for construction projects worth upwards of US $600,000 and this book is used when the contractor runs the design of the project. In this book, there is a risk-sharing and a price variation option.
- **The yellow book** - design of the project is the responsibility of the contractor and is also used in the construction of projects worth more than $ 600,000.00. There is also the sharing of risks and the possibility of price variations.
- **The silver book** - Used for conducting the Turn-key projects. The contractors are responsible for the risks of construction. The contract price is fixed.
- **The blue book** - used for projects that are built over a water surface.

- **The green book** - short form on contract. It was formed at the request of the World Bank to implement projects with a value of up to $ 600,000.00 and a deadline of up to 6 months. This form of contract is suitable for subcontracting.
- **The white book** - A model of contract between client and consultant.
- **The golden book** - A model for a long-term contract, that is, arrangements for the design, construction and long-term co-operation and management of the project by the contractor (firm, consortium, or joint venture). This book is best suited for negotiating a Public Private Partnership.
- **The pink book** - The World Bank had demanded FIDIC in the Red Book to specifically address the topic of corruption. This is the origin of the Pink Book, which has been dubbed a “harmonized edition” and is a standard document not only by the World Bank, but also by other investment banks all over the world, such as the European Bank for Reconstruction and Development, the Asian Development Bank, and others.
- **The blue-red book** - A guide to choosing the best deal during the tendering process and concluding the contract.

Figure 2. FIDIC contract books, which contract should be used?

Source: http://fidic.org - International Federation of Engineering Consultants FIDIC (01.06.2023)

Each of these books provides the *basic (general) conditions* of contracts. Whit the so-called *special conditions*, which are also part of the FIDIC contract, depending on the needs of the specific project, parties in a contract can define the specific rules and modify the general conditions of the contract.

FIDIC contracts, as a world-class standard, always offer quality performance of agreed work and fair compensation (payment) for what has been done. The clauses in the arrangement are written to protect the interests and objectives of both parties in the contract as to the contractors and the investors of the construction project. The purpose of contracting for the contracting authority (investor) is timely, quality and at the lowest price to receive the desired construction project, while the contractor expects fair compensation for the quality and timely work performed. A characteristic of these standard arrangements is that they are clear and precise and incorporate all aspects of performance.

In addition, through special conditions, FIDIC contracts are flexible and adaptable to the specific bargains of the participants in construction, both to investors and contractors, and there is a possibility for adaptation to local legal regulations and to implement different requests and specifics which each project that is being performed usually has [4] [5].

Depending on the type of object and the book that is appropriate to be used in the performance, the clauses listed in the contract provide a variety of performance risks. Specifically, FIDIC, agree that each of the books has a different dispersion of potential risks between the investor and the contractor of the project [4] [5]. Thus, the red and yellow books face a fair sharing of performance risks between the investor and the contractor in the silver book, which is used for turnkey projects, the whole risk of performance is hold by the contractor, so these projects are usually most expensive [3]. Sharing risks helps each of the parties to the contract to be able to calculate it temporarily, and thus to control the risk it is exposed.

A characteristic of FIDIC contracts is also that those contracts include causes for financial instruments which are used to cover specific types of risks [6]. Those instruments are:

1. ***Bank guarantees***
2. ***Price adjustment***
3. ***Retention money***
4. ***Insurance policies.***

All these instruments have their own special characteristics, strengths, and weaknesses over the others. Joint implementation provides protection against risks that affect the financial flows of the project realization. Which of these instruments will be used in the construction of a project depends on the terms and conditions agreed between the investor and the contractor. The FIDIC terms and conditions contain all the above financial instruments. The combination of these financial instruments provides acceptable protection against potential risks that may accrue during the construction of a project and to have a direct impact on the financial flows of the project.

2.1. Bank guarantees

The use of bank guarantees began in the second half of the 1960s and the beginning of the 1970s, which were the most appropriate instrument for fulfilling the conditions for the construction of expensive infrastructure projects in the Middle East countries - oil complexes, railways, defense facilities.

In recent years, there has been an increased use of bank guarantees in all areas of the economy and in the construction sector. The widespread application of guarantees has led the International Chamber of Commerce (ICC) to develop implementing rules and so-called Uniform Rules for First Call 458 (Uniform Rules for Demand Guarantees, ICC Publication 458 - UNCR 458), published in 1992 and Uniform Rules for First Call 758 (Uniform Rules for Demand Guarantees, ICC Publication 758 - UNCR 758), published in 2010 [7].

In accordance with the FIDIC contracts, during the period of execution of the construction projects, few forms of bank guarantees are used:

1. Tender guarantee
2. Performance guarantee
3. Bank Guarantee for advance payment
4. Bank guarantee for defect liability period

Each of these guarantees has its own characteristics and specific features that make it different from another.

2.1.1. The tender guarantee

This type of guarantees protects the Investor, from the risks of failure of the tender procedure and from not signing the construction contract in accordance with the submitted tender. The tender guarantee issued by a reputable bank gives the investor a positive signal for the construction company which offers its construction services.

Whit this type of guarantee the bank guarantee that the Bidder will not withdraws or cancel his Bid during the period of its validity, also the bank will pay total amount of the guarantee if the Bidder who during the validity period of his Bid, was notified by the Contracting Authority that his Bid was accepted:

- fails or refuses to sign the Agreement, if requested, or
- fails or refuses to provide a Guarantee for the satisfactory performance of the works, in accordance with the tender documentation.
- fails or refuses to accept corrections of arithmetical errors of the amount in accordance with the tender documentation.

The amount of this guarantee usually ranges from 1% to 5% of the total bid price. The guarantee must be valid until completion of the tender procedure and signing of the contract.

2.1.2. Performance guarantee

Whit issuing this type of guarantee, the bank is obliged to pay the guaranteed amount to the beneficiary, if the contractor fails to fulfill his obligation under the contract (does not build the project according to standards, does not deliver the goods etc. ...) Subclause 4.2 in Red FIDIC book, clearly states the conditions under which the Employer is entitled to make a claim under the performance security.

In accordance with this Sub-Clause, the Employer is entitled to call the performance security in the following events:

- Failure by the contractor to extend the validity of the performance security in a situation when the Investor ask for this extension.
- Failure by the contractor to pay the investor an amount due.
- Failure by the contractor to remedy a default within 42 days after receiving the notice requiring the default to be remedied [6].

The form of this type of guarantee varies and the total amount of the guarantee ranging from 5% to 15% of the total value of the contract, The amount of the guarantee and its validity shall be specified in the construction contract itself. In accordance with the FIDIC contracts, this guarantee is valid until the end of the defect liability period of the construction of the project.

2.1.3. Bank guarantee for advance payment

The payment of an advance, when performing construction projects, is always connected whit the bank guarantee for advance payment. This type of guarantee is subject of FIDIC contract in Sub-Clause 14.2 in Red FIDIC book, and according to it the Contractor is obliged to submit a guarantee if in the contract an advance payment has been agreed [6]. It should be presented before the advance payment should be made. With this guarantee, the bank as a guarantor guarantees that the contractor will cover received advance payment with execution of construction work.

This guarantee is usually issued in the total amount of the advance payment, which is run between 10% and 30% of the total contractual amount. The Advance Payment Guarantee shall be valid until full and complete reimbursement of the advance payment during the period of execution of construction project, maximum until receiving of Taking over certificate. According to FIDIC, the repayment of the advance payment will start when the certified interim payments exceed 10% of the Accepted Contract Amount [6].

2.1.4. Bank guarantee for defect liability period

Bank guarantee for defect liability period is useful to ensure faithful performance and defect correction, during the defect notification period. This guarantee is known as a retention money guarantee, because after sublimation of this guarantee to the investor in a required amount, the full amount of the withheld deposit shall be released immediately. This type of guarantee is subject to the Red FIDIC contract, Sub-Clause 14.9 [6]. It is usually issued in amounts from 5% to 15% of the total amount of the contract. This guarantee, according to FIDIC, is valid 70 days after expiration of defect notification period [6].

2.2. Price adjustments

The construction of the project always faces problems whit price fluctuation and variation in both materials and equipment.

Price change coefficient, popularly called Price adjustments, is one of the most used instruments to secure the risk of market price variation in both materials and equipment and to balance the impact of exchange rate changes during the period of performance on the project.

Prices of goods and labor are highly variable due to fluctuations in the currency market. The advantage of this instrument is seen in its easy application and the fact that this instrument provides fair compensation for the work done, compensation at current market prices at the moment of payment of the realization [8].

In accordance with the FIDIC contracts, the Price Adjustment factor “Pn” for the work conducted in the period “n,” is calculated according to the formula [6]:

r = (Pn -1), in which

$$P_n = [A + B \times L_n / L_o + \sum C_i \times M_{n,i} / M_{o,i} + \sum D_i \times E_{n,i} / E_{o,i}] \times Z_n/Z_o,$$

A - percentage of the fixed part in the total contract price.

B - percentage of the cost of living included in the total contract price.

L_n/L_o – basic index of the change of live costs in the current month relative to the live cost in the basic month.

C_i – percentage of the share of individual prices of the calculated materials in the total contract price.

$M_{n,i}/M_{o,i}$ - basic indices of change of prices of individual materials in the current month relative to the prices in the basic month.

D_i – percentage of the share of individual prices of the calculated equipment and plant in the total contract price.

$E_{n,i}/E_{o,i}$ - basic indices of change of prices of individual equipment and plant in the current month relative to the prices in the basic month.

Z_n/Z_o – basic indices of exchange rate in the current month relative to exchange rate in the basic month.

The formula for price adjustment, mentioned above, is in its generalized form. The contract parties shall, at the time of preparation of tender documentation and before concluding the contract, determine the proportions of the specified element (A, b, c, d...) by detailed analysis of the project. The base date and current date prices of the specified elements shall be obtained from the sources specified in the contract.

Price adjustment as a financial instrument, which has the purpose of balancing changes in the costs of goods and services in construction contracts, is used worldwide. Its implementation gives more competitive bids and more equitable and just manner execution of contracts.

2.3. Retention money - guarantee deposit

The quality performance of the works during the construction period and the elimination of defects in the construction of the project that will occur during the guarantee period are ensured by the so-called – Retention money or popular guarantee deposit. If the contractor does not fulfill the obligations for the quality performance of the project, the investor has the right not to pay him the funds from the retained deposit and use this amount to repair poorly performed works. Retention Money is a defined term in the Red FIDIC book, meaning the accumulated retention monies which the Employer retains under Sub-Clause 14.3 and pays under Sub-Clause 14.9 from Red FIDIC book contract [6]. The percentage of deduction and the limit of retention monies must be stated in the particular conditions.

The retention money (guarantee deposit) is calculated as a fixed percentage, often from 5% to 10% of the execution over time, and that throughout the whole period of construction of the project. In accordance with Red FIDIC book, this deposit can be released in following ways:

1. Upon completion of the construction period, half of the guarantee deposit shall be released immediately, and the remainder shall be released (paid) upon expiry of the guarantee period or upon receipt of a bank guarantee for elimination of defects in the construction of the project in the guarantee period, to the amount of 50 % of the deposit retained and valid until the expiry of the guarantee period, usually 2 years after the technical acceptance of the project.
2. The full amount of the withheld deposit shall be released immediately upon receipt of a bank guarantee.
3. The full amount of the withheld deposit shall be released after the technical acceptance and after the omission of construction deficiencies noted at the technical acceptance certificated.

This instrument is easy to use and is therefore accepted in everyday work primarily by investors for the benefit and protection. Unlike them, contractors do not always accept this instrument because the withholding deposit has a direct impact on their monthly performance cash flows.

2.4. Insurance policies

Damages that occur during the construction of projects can be various and adversely affect the property, the profits of the parties, and even the loss of human life. Very often the construction companies, because of the high value and importance of the damage, decide to transfer the possible risks to the insurance companies. Insurance is defined as the equitable financial contribution of other party for the benefit of an individual party which has suffered a loss [4]. This contribution is made through payment of a premium for which an insurance policy is issued. The insurance policy takes the form of a contract of indemnity.

By transferring the risk, if an insured event occurs, the insurer is obliged to pay compensation in accordance with the agreed terms of insurance and the issued policy. Every construction company would like to have all possible harmful events maximally secured, but if all the risks were transferred it would be very costly and would disrupt the financial construction of the project.

Insurance clauses are an integral part of the FIDIC contracts. Under FIDIC contracts the insurance cover shall be for not less than the full replacement value of the insured property [6]. In these contracts, depending on what harmful events and risks are provided, the use of insurance against all risks is encouraged. Most used form of insurance policies are following [9]:

1) ***Insurance of projects under construction*** is the most important type. This type of insurance covers all the basic hazards that can occur during construction and endanger the project and is concluded for a period while the performance of the project, including its warranty period, is completed.
2) **Professional risk insurance** - The errors or mistakes that occur in the execution of architectural or engineering work in the design, execution or supervision of construction are ensured by so-called - professional risk insurance. Such omissions can lead to death, personal injury, and property damage. In the case of a lawsuit, initiated because of the pre-litigation of

damage caused by a professional mistake, the insurance policy against a professional risk provides protection.

3) **Auto - Liability insurance** - covers all material and non-material damage that may be caused by an unintentional error of a third party in the management of motor vehicles, trucks and construction machinery involved in traffic. In addition to the basic auto liability insurance policy, special civil and motor vehicle insurance is also used in the construction industry. This insurance covers all material damage that may occur to vehicles or machines.
4) **Employee insurance** - Construction workers, especially those working on construction sites, are exposed to a considerable number of hazards. The purpose of this type of insurance, which worldwide is the legal obligation of every employer, is to provide compensation if there is an undesired event during or outside of work that would affect employee health.

3. CONCLUSION

Risk in construction projects can be defined as the probability that a particular event will occur in the future, and it will impair the viability of the project and the economic benefits of the project will not exceed its economic costs. This probability of future events is higher than in other industries. In the construction sector, as elsewhere, various risks that affect business can be identified. Financial risks include the risks associated with the financial flows during the construction of the project. It is especially important for parties, who participate in construction project, to conclude a well-conceived contract, which will include an adequate dispersion of the risks that may occur during construction, but also contract which include clauses for the procedures and instruments for providing risk security.

The FIDIC contracts are widely used worldwide and represent an international standard in the construction of projects. A characteristic of FIDIC contracts is that those contracts include causes for financial instruments which are used to cover specific types of risks. Those instruments are:

1. Bank guarantees
2. Price adjustment
3. Retention money
4. Insurance policies

The combination of these financial instruments provides acceptable protection against potential risks that may accrue during the construction of a project and to have a direct impact on the financial flows of the project.

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MECHANICAL PROPERTIES OF 3D PRINTING CONCRETE BASED ON GEOPOLYMER

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Abstract

The construction sector is unproductive compared to other sectors. Therefore, we should strive for greater automation of the production process. In order to reduce CO_2 emissions in the construction sector, it is increasingly necessary to use new materials and new construction methods. Today, with the help of 3D printing, it is possible to construct a building with high level of productivity, using less environmentally harmful materials and with minimal construction waste. This method of manufacturing elements and objects enables a significant reduction in construction time and reduces the number of workers needed. The main advantage of printed concrete and construction technology is the production of elements without formwork, which increases architectural freedom and reduces costs and construction time. The development of various concrete mixes for 3D printing has enabled the production of 3D printed elements and houses around the world. Challenges in 3D printing concrete include controlling the fresh concrete properties as well as the mechanical properties of the cured material, i.e., compressive strength, adhesion between layers, and deformation. There are printed concretes made of cement and geopolymer. In this paper, an analysis of the composition of concrete was carried out and the composition of the mixture for the production of 3D printed concrete based on geopolymer was compared.

Key words: *3D printed concrete, automation, concrete mixture, mechanical properties, geopolymer*

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INTRODUCTION

The construction sector experiences a lack of productivity compared to other sectors. Therefore, we should aspire for greater automation of the construction process. Automated building construction with 3D printing technology has gained increasing attention in recent years. Potentially, it can greatly improve the construction industry. It can also offer astronauts easier construction on the moon
1. [1]. On the other hand, it is necessary to use materials that pollute the environment to a lesser extent. Currently, 2.8 billion tons of carbon dioxide are emitted in the world by traditional construction methods. Construction waste represents another problem of this branch of industry. Recycling and use of ecological materials is a very important factor towards the further improvement of the construction industry [2]. CO_2 emissions due to the production of Portland cement amount to about 1.5 billion tons per year, which is 7–8% of the total CO_2 emissions from various industrial sectors worldwide [3]. Today, it is possible to build a building with a high degree of productivity, using materials that pollute the environment less and with minimal construction waste using the 3D printing method.

3D printed concretes (3DPC) are concretes of special mix designs, mostly reinforced with fibers, which are applied in layers (horizontally layer by layer) through the nozzle of a 3D printer. The main advantage of 3DPC and construction technology is the production of elements without formwork, increasing architectural freedom and reducing costs and construction time [4]. According to [5], about 15% of the construction costs of concrete structures are related to formwork.

The main disadvantage of objects built with extrusion-based three-dimensional concrete printing (3DCP) is the limitation of their dimensions. There are cement and geopolymer printed concretes. Concrete printing is an innovative process for the production of concrete components using a layer-based manufacturing technique. This method can be used to produce complex geometric shapes without formwork and thus has a unique advantage over conventional construction methods. The construction process takes place as follows. Prepared concrete of special mix design is extruded through the nozzle of the printer under high pressure [1]. Depending on the manufacturer of the 3D printer and the characteristics of the concrete itself, special attention should be paid to the speed of layering. Currently, the most common printer for making such objects is the COBOD BOD2. The maximum speed at which this printer can create layers is 1m per second, but the manufacturer recommends that it should be 250mm/s for longer printing periods [6].

The fresh properties of concrete for this purpose are the most important from the aspect of the success of creating contours. 3D printing of complex shapes requires a high workability of the concrete so that it can be squeezed out of the printer nozzle smoothly, as well as a high early strength of the concrete to accept the following layers. There are a large number of proposals by different authors regarding the composition of the mixture for making concrete.

In this work, the compositions of the mixture for making 3DPC based on geopolymers will be discussed and compared. The development of various concrete mixtures for 3D printing has enabled the production of 3D printed elements and houses around the world. Challenges in concrete 3D printing, in addition to controlling the fresh properties of concrete, are the mechanical properties of the hardened material, i.e. compressive strength, adhesion between layers and deformation.

2. GEOPOLYMER CONCRETES

Portland cement is the main binding material in concrete. The production of ordinary Portland cement (OPC) is increasing by 9% annually and around 4 billion tons are produced. This increase in cement production poses a major threat to the environment due to the emission of CO_2 and other greenhouse gases [3]. One of the possibilities for less emissions of greenhouse gases, which occur during the production of OPC, is the production of geopolymer cement and concrete.

Geopolymer cement is produced by treating raw materials (basically industrial and agricultural waste) containing aluminosilicate with alkaline silicate [3]. By producing geopolymer concrete (GPC), CO_2 emissions can be reduced by 80%. Also, construction waste is used as raw material.

According to [7] geopolymer, also known as inorganic polymer, is an alternative material that acts as a binding agent in concrete. Geopolymer is a type of alkaline aluminosilicate cement that can have superior mechanical, chemical and thermal properties compared to OPC and with significantly lower CO_2 emissions. Geopolymers are synthesized by activating an aluminosilicate source (metakaolin, fly ash and blast-furnace slag) with alkaline activators.

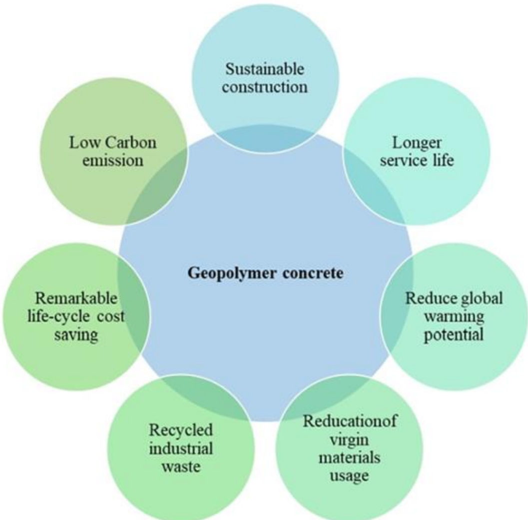

Figure 1. The usefulness of geopolymer concrete in construction, according to [8]

Alkali-activated materials have two main binding components. These are raw materials and alkaline activators. According to [9] it is possible to use raw materials:

- Fly ash (FA),
- Ground granulated blast-furnace slag (GGBS),
- Metakaolin,
- Silica fume (SF) and
- Red mud.

As an alkaline activator is used:

- Sodium silicate (Na_2SiO_3),
- Sodium hydroxide (NaOH) i
- Potassium hydroxide (KOH).

An important factor when using GPC is the temperature during concrete care.

The temperature at which the concrete is cured has a visible effect on its compressive strength (Figure 2).

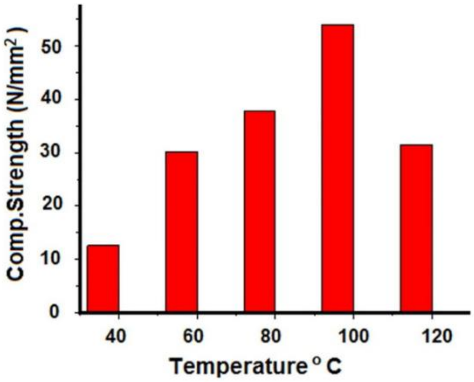

Figure 2. Effect of curing temperature on compressive strength, according to [8]

It can be seen from Figure 2 that an increase in temperature doesn't necessarily mean a higher compressive strength. Care should be performed at a temperature of 60÷90 °C for 6÷24 hours. Initial strength is achieved by heating, which represents 90÷95% of the total strength of the concrete. The fact that in order to achieve higher compressive strength, a high temperature is necessary during concrete curing, which limits the use of such concretes on the construction site. However, these concrete have their share in prefabricated constructions where adequate care can be provided during the production of elements. Also, the strength is significantly affected by the use of sodium silicate (Na_2SiO_3) and the ratio of sodium silicate to sodium hydroxide (NaOH). The ratio of Na_2SiO_3 to NaOH can vary from 1 to 2.5.

3.

3.1. PROPERTIES OF 3D PRINTING GEOPOLYMER CONCRETE

3.1.1. Materials

Raw materials and activators

Class F fly ash (Gladstone Fly ash) with low calcium content was used as a cementitious material in [5]. Class F FA is readily available and is produced as bituminous coal or a by-product of coal combustion. D-class sodium silicate (Na_2SiO_3) and sodium hydroxide (NaOH) with a concentration of 8.0 M were used as activators. The unit ratio of Na_2SiO_3/NaOH was adopted. In the article [10], GGBS was used as a raw material and sodium silicate with the addition of water in a smaller amount as an alkaline activator. Panda B. et al. for research purposes [11] primarily used FA class F, according to the ASTM C618-12a standard, as raw material with the addition of GGBS and SF. The share of each of the raw materials was in the ratio FA (78.46%), GGBS (13.85%) and SF (7.69%). Alkaline solutions, used as an activator, were formulated by mixing a commercial solution of potassium silicate (K_2O_3Si) and sodium hydroxide. The same authors in [12] used FA (85%) and GGBS (15%) without SF. Potassium hydroxide and silicate solutions were used as the activating solution for formulating geopolymeric binders. The mentioned authors in [13] used the same mixture of FA, GGBS and SF, but with a different composition of activators. The activation solution was formulated by mixing a commercial solution of sodium silicate and sodium hydroxide. Li Z. et al. [14] used a mixture of FA and GGBS with a ratio of 1:1 as raw material. For the alkaline activator, they used sodium silicate, according to [15]. The composition of the adopted raw material according to [16] consisted of slag (S) and FA (class F) in different proportions. The first mix was in the ratio (S:FA) 100:0. The second in the ratio 75:25, the third 50:50, the fourth 25:75 and the last 0:100. N-class sodium silicate was used as an activator. Similar proportions (15:85; 30:70; 40:60) of the same raw material components were used for research purposes in [17]. Potassium silicate was used as the activating solution. In the article [18], a mixture of GGBS (90%) and steel slag obtained as a by-product during steel production (10%) was used. The authors defined 6 mixtures, where the amounts of raw material are unchanged, and the ratio of alkaline activators (Na_2SiO_3 and NaOH) varies in the ratios 100:0, 90:10, 80:20, 70:30, 60:40 and 50:50.

3.1.2. Aggregate

According to [5], sand with the largest particle diameter of up to 0.3 mm was used as an aggregate, so that the workability and homogeneity of the mixture was as good as possible. The used aggregate was in saturated-surface-dry conditions, in order to more adequately manipulate the amount of water in the mixture. Industrial sand (TGS Industrial Sands Pty. Ltd., Australia), grade 70 was used for research purposes in [10]. The largest particle diameter was 0.184 mm. Aggregate with a maximum grain size of 2 mm was used to define the mixture in [11]. The same aggregate was used to define the mixture in [12] and [13]. Sand with a maximum particle size of 1 mm was adopted in [14]. Fine river sand with a high particle size of up to 2 mm was used for research purposes in [17].

3.2. Properties of fresh concrete

When 3D printing concrete, it is of great importance that each created layer has identical dimensions. In order to achieve this, the size of the diameter of the printer nozzle itself through which the concrete is extruded, the speed of the printer head, the flow of concrete and the amount of concrete slump are important [5]. Compared to ordinary concrete, the mixture must be designed to be easily extruded through a nozzle, creating continuous layers that set quickly and have a low slump value [19].

3.2.1. Concrete consistency

The authors [5, 11, 12, 13, 14] state that the main challenge when defining the printing mixture is to develop zero-slump or low-slump concrete, which is self-compacting concrete (SCC). Since these are two contradictory goals, they can be partially fulfilled simultaneously. Also, defining a compound that is easily extruded through the printer nozzle and that doesn’t settle is critical to the success of the 3D printing process.

Al-Quatifi et al. in [5] the consistency of concrete was determined using the spread-flow test (three slump tests), in the accordance to ASTM C1437-20 standard [20]. The test procedure according to this standard is described in detail in [5, 20]. This method is very similar to the method according to the standard SRPS EN 12350-5:2019 [21], which is applied in Serbia. Tests have shown that the addition of steel fibers (GM2) does not have a great effect on the concrete slump, while the addition of polypropylene fibers (GM3) visibly affects the reduction of the concrete slump.

The consistency of concrete was determined in [14] using the method of determining consistency by the slump, according to the Chinese standard GB/T 14902–2012 [22]. The concrete slump according to this standard was 4.5 mm, which is equivalent to consistency class S2, according to SRPS EN 12350-2:2019 [23].

3.2.2. Setting time

Concrete setting time is a term used to describe the time allowed for pouring, compacting and transporting concrete. It can be determined using a Vicat apparatus. Also, the setting time is the time in which the acceleration of chemical reactions occurs and on that occasion changes in concrete characteristics occur [5]. The layering of the structure has a negative effect on the strength of the elements. Therefore, it is important to achieve a high bond strength between the layers, which depends on adhesion. This is mostly influenced by the printing time, the time interval between layers and the bonding time.

In the production of GPC, the ratio of alkaline activator and FA, as well as the ratio of Na_2SiO_3 and NaOH, have almost no effect on the setting time [24]. On the other hand, the setting time of GPC depends on the concentration of NaOH. According to [25, 26] decreasing the molarity of NaOH can effectively delay the setting time of GPC. Therefore, with a higher concentration of NaOH, a shorter (initial and final) binding time is achieved. Also, a shorter setting time can be achieved by increasing the amount of GGBS [27], as well as using Na_2SiO_3 and NaOH, instead of only NaOH as an alkaline activator.

3.2.3. Yield stress

An important fact when defining the mixture is the stress at the yield point in fresh concrete. Namely, each created layer suffers the loads of the following ones. In order for the adhesion between the layers to be adequate, the bearing capacity of the fresh concrete should be ensured. Reiter et al. [28] were the first to point out the need to develop yield stress to support vertical construction during 3D concrete printing.

It is convenient for the material to have a high load capacity in the fresh state and a low viscosity. On the other hand, materials that have a high limit stress are more difficult to squeeze out of the nozzle, and interruptions occur during concrete printing. In principle, the effect of interruption during printing can be influenced by choosing an adequate pump for such a mixture [11]. Panda B. et al. [11] replaced the use of accelerators and retarders by adding 5%, 10% and 15% GGBS concerning the amount of FA, which led to an increase in the ultimate stress in fresh concrete. An increase in the content of GGBS leads to an increase in tensile stress and viscosity, which is probably a consequence of the chemical composition, i.e. the presence of calcium in GGBS and its angular particle shape [17, 27]. Also, the addition of clay contributes to the higher yield stress of fresh concrete, while a higher ratio of alkaline activator and raw material contributes to a stress reduction [12]. In [11], 5 mixtures with different amounts of binding material and sand were analyzed. The last two mixtures (G4 and G5), which contained more sand and less binding material, had higher yield stresses, but unfavorable extrusion during printing. The initial yield stresses were respectively 0.38 kPa (G1), 0.56 kPa (G2), 0.79 kPa (G3), 1.02 kPa (G4) and 1.62 kPa (G5). Based on the experimental test, the yield stress of 0.6–1.0 KPa was found to be a favorable range for smooth extrusion of GPC, and mixture G3 was selected as the most suitable mixture in this range. For a typical layer of 15 mm, according to [12] the initial yield stress should be about 180 Pa. The addition of subsequent layers should be accompanied by an increase in the yield stress of the first layer, and for a layered element height of 1m (≈ 67 layers), the stress of about 12 kPa should be ensured.

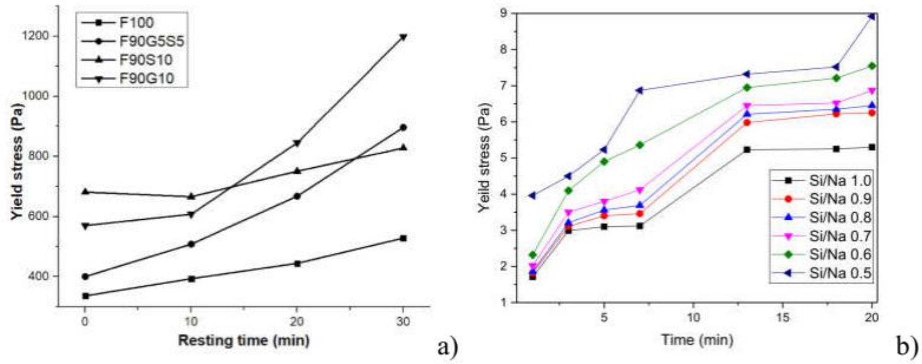

Figure 3. Evolution of the yield stress of GPC with time, a) according to [13], b) [18]

Figure 3a) shows the development of stress at the yield point for the first 30 minutes from the moment of concrete preparation. The results of 4 different mixtures are shown. The control mix was only with FA (F100). The mixture labeled F90G5S5 indicates that 10% FA has been replaced with 5% each of GGBS and SF. The mixture with a 10% addition of SF (F90S10) had the best initial yield stress, and the mixture with 10% of GGBS (F90G10) had the best yield stress after 30 minutes.

Figure 3b) shows the importance of the Si/Na ratio on the yield stress. From the diagram, it can be seen that a smaller Si/Na ratio contributes to a higher stress. The mentioned ratio can be calculated as the quotient of the alkaline activator Na_2SiO_3 and the sum of the alkaline activators Na_2SiO_3 and NaOH. After 1 minute of mixing the concrete mixture, the initial yield stress was a minimum of 1.71 Pa, and a maximum of 4.0 Pa. After 20 minutes of making the yield stress was in the range of 5.30 Pa to 8.95 Pa.

3.2.4. Viscosity

Building materials with high yield stress and low viscosity are most often used in the 3DCP industry, where viscosity is an indicator of the ease of extrusion of concrete [11, 13, 17]. High viscosity concretes are not suitable for 3DCP of objects [1]. One of the main challenges in creating contours is to maintain a uniform viscosity level, thereby obtaining a smooth surface of the layers and improving strength [4]. The problem to be solved in the application of 3DPC is the development of a mixture that can be fluid enough to flow through the hose without clogging while having enough viscosity to retain its shape after the printing process [13].

It is very important for the mixture to have a low viscosity during extrusion so that it can be easily transported through the hose and nozzle of the printer, and that after the mixture is extruded, its viscosity recovers as quickly as possible so that it retains its shape after being extruded from the printer nozzle. The viscosity recovery test was researched by Panda et al. in [13]. The test contained three stages, i.e. viscosity measurements. Stage (I) referred to the state of the material before pumping and extrusion, then (II) to the state during pumping and (III) after extrusion from the nozzle (Figure 4a). It was found that the addition of SF has a significant effect on increasing the initial viscosity. Thus, the addition of 5% SF to the control mixture (F100) leads to a recovery of the initial viscosity of 13%. By adding 10% SF, the initial viscosity recovery was 20%. Also, it was found that the addition of GGBS does not affect the viscosity recovery.

A similar analysis was carried out in [17]. It was found that the designed mixture can recover 70-80% of the initial viscosity within 60 seconds of the end of the extrusion, thus enabling the acceptance of the next layer, without deformation of the previous one, after only one minute (Figure 4b).

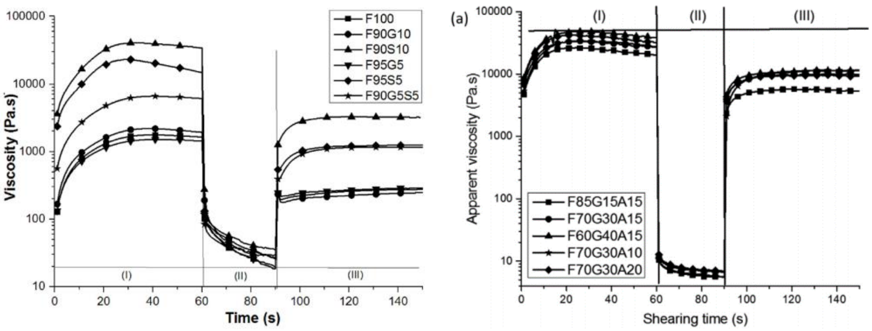

Figure 4. Viscosity recovery of different mixtures, a) according to [13] and b) [17]

3.2.5. Green strength

During 3D printing, the strength of fresh concrete can be used as an indicator of the number of layers that can be applied without significant deformation of the underlying layer, while the compressive strength of hardened concrete (usually after 28 days) indicates the ultimate compressive strength.

According to [17] the strength of fresh concrete for the F70G30A10 mixture was 0.01 MPa, while the compressive strength of hardened concrete, after 28 days, was 28.6 MPa.

In cases where the strength of the fresh concrete is low, accelerators can be added during the mixing of the mixture or directly in the printer nozzle to achieve a higher speed of layering and productivity of the construction process itself. The speed control mechanism was analyzed in [28].

3.2.6. Printability

Parameters such as extrusion, shape retention and buildability are collectively described as "printability", which refers to the deposition of concrete in layers according to a pre-prepared CAD model.

The stress at the yield point is directly related to the characteristics of shape retention and buildability [17]. In 3DCP, construction is a challenging issue and to overcome this, the freshly deposited material (layers after extrusion) must regain its original viscosity and tensile stress before the second layer starts to fall over it.

Extrusion and shape retention is also a key factor for 3DCP. After extrusion, the material must retain its shape according to the dimensions of the nozzle and can be expressed by a dimensionless number called the shape retention factor (SRF) [11]. The determination of the SRF is expressed as the quotient of the cross-sectional area of the printed layer and the cross-sectional area of the nozzle opening of the printer [11, 12]. In order to obtain a high SRF, the material must have low slump characteristics, i.e. a high yield stress, so that it remains stable under its own weight. Of course, a high yield stress can achieve a high SRF, but the stress at the yield point should not exceed certain values, so that the mixture can be extruded.

The shape retention test was researched in [13]. Based on the production of a single layer of three different mixtures, the size of the shape deformation was determined. Mixture F100 showed a very low ability to recover the original viscosity. This was also evident from the large deformation i.e. low SRF of 0.3 was observed after its extrusion (Figure 5). The shape deformation was smaller for the F90G10 mixture (SRF=0.46), and especially for the F90S10 mixture (SRF=0.8).

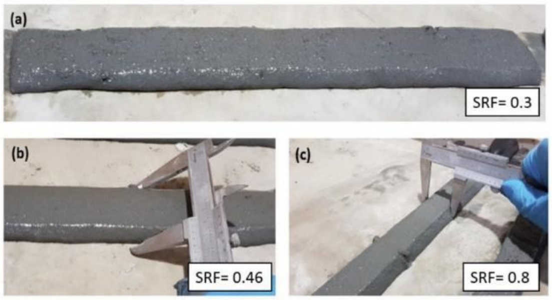

Figure 5. Effect of mix design on the shape retention of the extruded filament width (a) F100 (b) F90G10 i (c) F90S10, according to [13]

As there is no standard for measuring buildability, the layer slump (3.3.1.) was used to evaluate the buildability [12]. For this research, it was determined that during the extrusion of the last (18th) layer, the printer's nozzle is quite far from the position of the layer, which is the result of the increase in the slump value of the lower layers and a small yield stress.

4. CONCLUSION

Based on the analysis of the attached works, it can be concluded that FA and GGBS are the dominant raw material for the preparation of 3D printed geopolymer concretes. Likewise, most authors in their research opted for sodium silicate, when it comes to alkaline activator. The ratio of activator to cement material ranged from 0.100 to 0.260. Sand with particles no larger than 2 mm was used as an aggregate in all the aforementioned studies. The predominant use is river sand. The use of sand in relation to raw material was between 85% and 175.39%.

Based on X-ray analysis, the chemical composition of raw materials and alkaline activators was determined. The range of values of chemical elements of raw material and alkaline activators is shown in Figures 6 and 7.

The share of components in the mixture for making 3D printed geopolymer concrete is shown in Figure 8. From Figure 8, it can be concluded that the amount of raw material in the concrete mixture is between 31.55% and 49.14%. Then, the share of fine sand is from 38.29% to 55.34%. Various alkaline activators are represented in the concrete mix by a minimum of 9.09% and a maximum of 20.64% by weight of the total mixture.

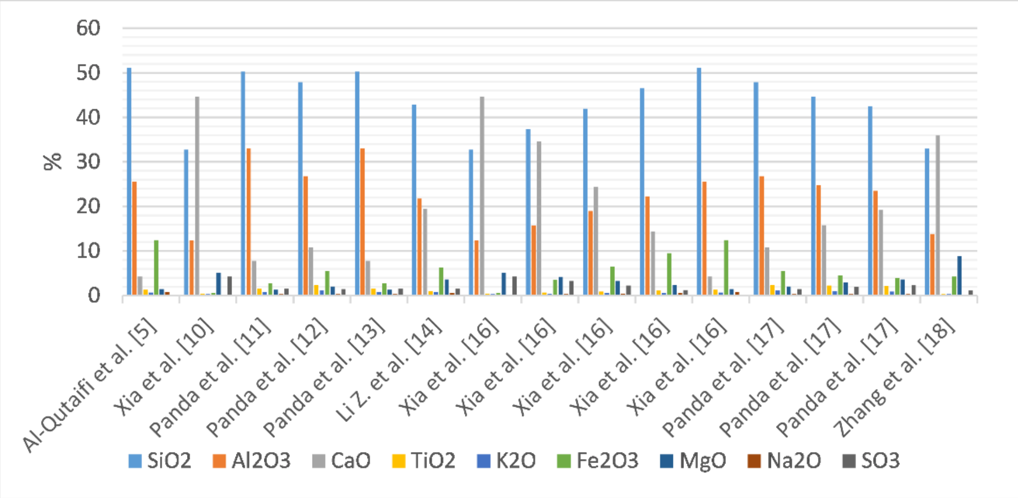

Figure 6. Chemical composition of raw materials

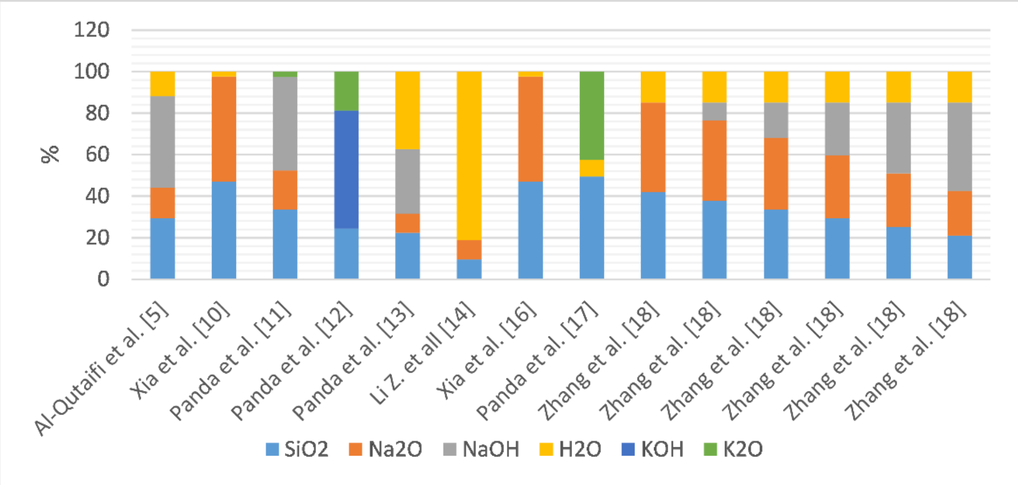

Figure 7. Chemical composition of alkaline activators

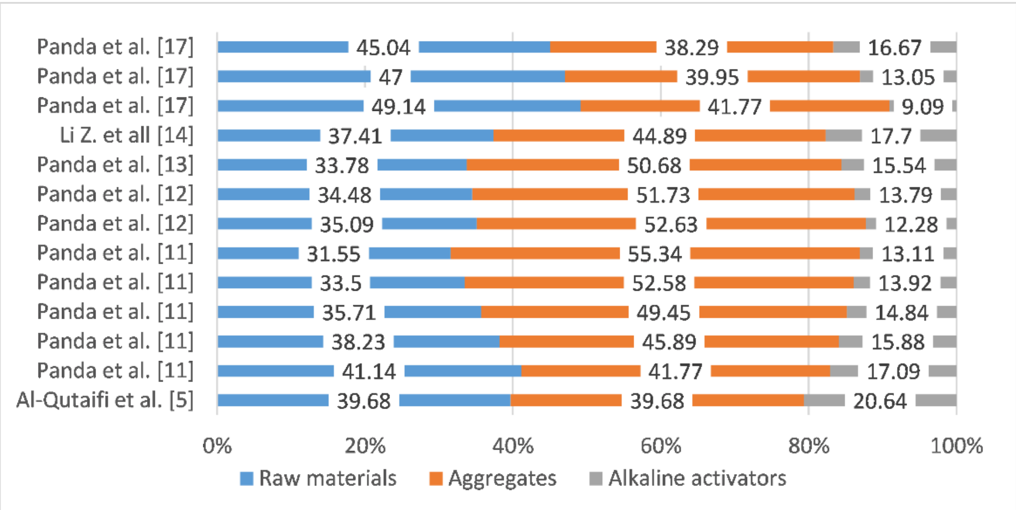

Figure 8. Mix designs of 3D printed geopolymer concrete

Analyzing the literature, it can be concluded that most of the properties of fresh 3DPC are of a cause-and-effect nature, and that they depend on each other.

Using the method of determining the consistency by the slump, the concrete mixture should be of consistency class S2, equivalent to the standard SRPS EN 12350-2:2019 [23].

The ratio of alkaline activator and FA, as well as the ratio of Na_2SiO_3 and NaOH, have almost no effect on the setting time of GPC, but the concentration of NaOH and raw material GGBS does. A lower molarity of NaOH results in a longer setting time, and a higher concentration of NaOH, as well as GGBS, results in a shorter setting time.

Probably the most important property of fresh concrete during 3DCP is the yield stress. Its value ensures the acceptance of subsequent layers and is directly related to the characteristics of shape retention and buildability. However, care should be taken because formulating a mixture that has a very high yield stress can cause problems when the mixture is pushed out and lead to the production of a discontinuous layer. The yield stress is best affected by the concentration of GGBS. Increasing the content of GGBS, as well as the addition of clay, leads to an increase in tensile stress and viscosity. By reviewing the literature, it can be concluded that the initial stress at the yield point should be between 0.18 and 1.0 KPa. This ensures the smooth flow of the mixture through the printer's nozzle and the creation of a continuous layer.

Also, in order to avoid clogging when extruding concrete, it must be of low viscosity of low viscosity so that it can be easily transported through the hose and nozzle of the printer. After squeezing out the concrete, it is important that the viscosity recovers as quickly as possible so that the created layer retains its shape. The addition of SF has a positive effect on the viscosity recovery, while GGBS has practically no effect on the viscosity of concrete.

Shape retention is expressed by a dimensionless number called SRF. SRF is the ratio of the cross-sectional area of the printed layer to the cross-sectional area of the printer nozzle opening. That number is less than 1, and it is preferable to be as close as possible to unity because it means non-deformation of the shape, i.e. low slump characteristics and high yield stress.

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FIRST FOOTPRINTS IN THE SAND – OLD NEW BELGRADE

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Abstract

The history of the development of New Belgrade is most often associated with the period of construction after the Second World War in the era of socialist Yugoslavia. The youth work actions, the biggest construction projects and the successes of the new government lead to the misconception that before that time nothing was done in this area. The reasons for canceling previous works and thinking about moving to the left bank of the Sava are hidden in the relationship of the socialist government towards the previous regime, as an ideological opponent, which is best illustrated by the aphorism of Brana Crnčević - "Before the war, we had nothing, and then the Germans came and destroyed everything for us."

This paper will deal with the construction of New Belgrade between the two world wars, when the city of Belgrade, from the capital located on the border of Serbia, became the center of a significantly larger Yugoslav state. In recent years, this period has attracted more attention from researchers, thus expanding knowledge about urban plans and the construction of New Belgrade. The attention is focused on two locations - the first development of the left bank of the Sava known as the "Danish Embankment", and the Old Fairground, as well as urban plans from the same period.

The paper will also discuss the International Competition for the Urban Design of Belgrade (1921-1922), as an incentive for Belgrade's transition to the other bank of the Sava and its connection with Zemun into a single entity. It was announced at the initiative of the Association of Serbian Engineers and Architects and is an expression of the desire for Belgrade to be included in the trends of modern urbanism. This competition was also a precursor to the new General Plan of Belgrade (1923-1924).

Key words: *New Belgrade, urban plans, Danish Embankment, Old Fairground, interwar period*

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INTRODUCTION

With the creation of the Kingdom of SCS (Kingdom of Serbs, Croats, and Slovenes), the conditions for the development of the area of the future New Belgrade changed. The most significant change was the nullification of the former border on the Sava River, which created opportunities for the construction of Belgrade on the territory of the left bank of the river. This direction of expansion was natural for
1. Belgrade, and in the existing circumstances, it corresponded to its development needs as the seat of a new, territorially enlarged state. From the perspective of the spatial growth of the capital, the advantages of the expansion across the Sava were double-construction at a relatively short distance from the inner city core and the integration of the smaller, neighboring Zemun. The idea of expanding Zemun on the ground of the future New Belgrade originated with the Zemun authorities back when the city was under Austro-Hungarian control. At that time, this terrain was an undeveloped and mostly flooded area, which separated the city of Zemun from the Sava, along which the then state border stretched. The process of industrialization and modernization of Zemun, at the beginning of the 20th century, was marked by industrial zones connected to the Danube coast, as well as measures to protect the city from high water levels by digging drainage channels. The city administration also envisioned such a melioration policy towards the Sava, but the outbreak of the First World War prevented those intentions.

The idea of expanding the capital of the new state to this area appeared shortly after its formation, and shortly thereafter it was shaped through individual urban planning projects, which followed the preparation of the General Urban Plan of Belgrade from 1923.

2.

INTERNATIONAL COMPETITION AND GENERAL URBAN PLAN

After the World War I, Belgrade becomes the capital of the Kingdom of Serbs, Croats and Slovenes (later Yugoslavia), which will be followed by the announcement of an international competition for the preparation of the General Urban Plan of Belgrade in 1921 and consideration of the possibility of merging Belgrade and Zemun, under the auspices of a new state and by settling the empty space between these two cities. Soon after, the first urban planning draft was created, which announced the complete transformation and planned construction of the terrain.

The interwar period is characterized by rapid population growth and the parallel progress of trade - restoration of damaged factories, construction of new ones, emergence of new branches of production. The development of the plan was initiated by a group of engineers and architects as a result of criticism of the improper development of Belgrade and spontaneous problem solving.

Already in the 19th century, it became common to organize competitions for urban plans, which were often international (today this practice is rarely practiced, so cities are reshaped by unilateral decisions), and the Belgrade competition followed the competition for the plans of Vienna, Berlin, Zurich, Copenhagen and Paris. The competition announced by the Belgrade Municipality in 1921, lasted from August 20, 1921 to March 30, 1922. The competition received 23 works from different countries: Austria, Germany, Switzerland, Czechoslovakia, Hungary, Romania and France. The jury, which consisted of individual members of the

Program Development Committee, as well as representatives of associations of French and Swiss architects and engineers, decided that none of the works received deserved the first prize. That is why, in May 1922, within the Municipality of the City of Belgrade, the Commission and the Bureau for the preparation of the General Plan were formed. The Bureau performed all technical tasks for the needs of the Commission, that is, implemented its decisions. The head of the bureau was a Russian architect Djordje Pavlovich Kovalevski, who is often mentioned as one of the most important figures for the creation of the General Plan.

By observing the results of the 1922 competition, one of the three second-prized works stands out - Singidunum novissima of Viennese architects - Rudolf Perco, Erwin Ilz and Erwin Böck. The basic concept of the work Singidunum novissima was based on the deep belief that in the future Belgrade will expand towards the west, i.e. that it will develop on the left bank of the Sava and that Belgrade, Zemun and Bežanija will merge. Therefore, even then there are indications of Belgrade moving to the other side of the river. The addition related to New Belgrade was an example of a radial-composite solution, contrary to today's solution for New Belgrade.

Thanks to the interest of contemporary authors [1] [2] in this issue, in some works published in the last few years, the knowledge regarding the interwar development plans of Belgrade to the area of the left bank of the Sava, as well as the construction that started at that time, has been significantly expanded.

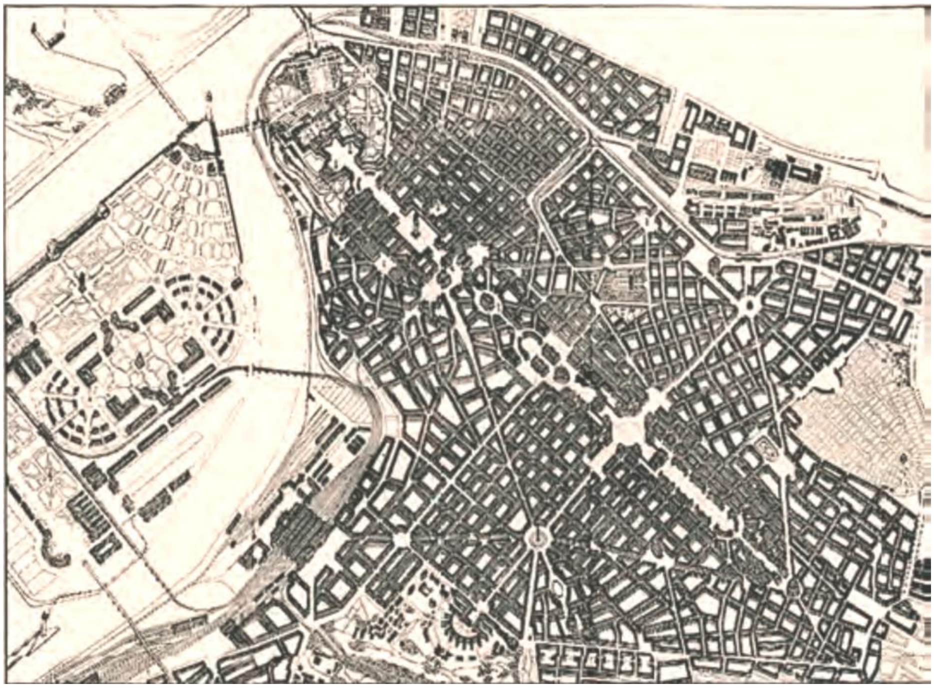

Figure 1. Singidunum novissima - Belgrade crossing to the other side of the river, source: according to [3]

Simultaneously, it also led to a re-examination of the previously existing idea about the origin of New Belgrade, which was built after World War II in this area. The exhibition, authored by Angelina Banković, "General Plan for the City of Belgrade 1923-1924", was installed a few years ago (2021) in the Konak of Princess Ljubica, and contributed to making a wider circle of people aware of this issue.

In 1923, the chief architect of the Technical Directorate, George Pavlovic Kovalevsky, drew up the first urban planning sketch that predicted the complete transformation and planned construction of the entire area within the General Plan for the city of Belgrade.

The General Plan for the City of Belgrade was adopted by the Municipality in August 1923 and forwarded to the Ministry of Construction, which approved it in May 1924. There are two surviving copies of the plan, one in the Museum of the City of Belgrade, and the other in the Urban Planning Institute of Belgrade. The museum specimen was made on blue ozalid paper, which was a common way of multiplicating plans at the time. A legend and a list of 142 objects and spaces of public purpose, which are numbered on the plan itself, are given along its left edge. Along the right edge are the signatures of the members of the Commission and the head of the Bureau, George Pavlovic Kovalevsky. On the plan, it was very precisely marked where each building or unit should be raised. The administrative center was located between Kalemegdan and Slavija, i.e. Dušanova and Nemanja streets. The most important public buildings (state, municipal, cultural, higher education) should have been distributed in the area around the National Assembly and Tašmajdan. Even before the adoption of the plan, Ada Ciganlija was conceived as a leisure area, and it was foreseen that the Great War Island would be connected to Belgrade by a bridge and turned into a sports center. Topčider was intended for a botanical garden and a zoo, and the residential suburbs were positioned in the direction of Avala and Rakovica.

The idea of New Belgrade remained on the competitive works, but the plan counted on a strong coupling of railway and river traffic, so that the banks of both rivers were planned for shipping and railway facilities, which made the city step onto the left bank of the Sava River.

3. DANISH EMBANKMENT

As we mentioned in the previous chapter, the ideas related to the future development of the city, the mass planned construction on the area of the left bank of the Sava required appropriate technical preconditions. First of all, building a bridge over the river and improving the terrain. For the state, devastated with the war with numerous victims, these were very large-scale construction projects that required huge investments, too big for the budget of the Belgrade Municipality, considering the other, more urgent needs that the capital had at the time.

With the construction of the King Alexander Bridge on the Sava in 1934, an important condition for the arrangement and construction of the left bank of the Sava was fulfilled, and in 1937 a fair complex was built. At the end of the same year, the Belgrade Municipality hired the companies from Copenhagen - Højgaard & Schultz and Kampsax, known as the Danish Group, for the filling of floodplains with an area of about 50 hectares on the part of the land between the Sava and Danube rivers and the road to Zemun. The contract was signed on January 31, 1938, and the value of this work was 30 million dinars, which was paid successively upon completion of individual works. The planned completion was in 1940, and the Municipality of the City of Belgrade provided the money by taking a loan from the Mortgage State Bank. The work began in May 1938, when a ceremony was held on the Sydhavn ship, whose epic journey of several months, from Copenhagen through Gibraltar and the Bosphorus to the Black Sea, where it entered the Danube Delta, ended. According to the Belgrade Municipal Newspaper (No. 5-6 May-June 1938), the Prime Minister Milan Stojadinović, as well as the Mayor of Belgrade Vlada Ilić, attended the ceremony on the ship. [4]

Sidhavn, with its steam suction tank, was a navigational and engineering marvel by itself at the time and it had a turbulent post-war life under the name Kolubara. As Belgrade, through its long and dramatic history, was one of the most desirable cities in Europe, some of the biggest battles of the river fleet in history were fought for it, so Sidhavn collected a real archaeological treasure during its work. It was even written about in the Belgrade Municipal Newspaper in 1940, after the Danish group donated the findings to the museum. Among them were: mammoth teeth, cannons, sabers, pistols and grenades. [5]

Figure 2. Danish group in Belgrade, source: according to [6]

The Danes did not only work on the embankment, but in 1938 they also presented the first detailed plan of a planned settlement "over the bridge". The plan of the Danish group included land of about 720,000 square meters, bounded by the road to Zemun, the Sava, the Danube and - a swamp. According to their plan, the envisioned settlement, would be entered via the road from the end of the access ramp to the King Aleksandar Bridge. In the center of the settlement, higher, five-story buildings, separated from each other, and villas along the banks of the rivers were envisioned. A square, a park, a school, a church, a restaurant, a swimming pool, etc.
4. were also foreseen by the plan.

The company Højgaard & Schultz was founded in 1918. Today it still exists as Højgaard Holding A/S and does not mention the work in Belgrade in its history.

BELGRADE FAIRGROUND

The largest planned building built on the ground across the Sava in the period 1934-1941. was "Belgrade fairground", today also known as Old Fairground. The left bank of the Sava was not included in the General Regulation Plan from 1939, however, the construction of the "Belgrade Fairground" and the embankment of the left bank of the Sava and the Belgrade-Zemun road continued unhindered until the beginning of World War II. [7]

With the establishment of the Kingdom of Yugoslavia, Belgrade acquired the status of the capital of a new joint state, with a leading role in the development of international cooperation. That is why in 1923 the Society for Organizing Fairs and Exhibitions (originally called Society for Land Exhibitions) was formed, which was the founder of the fair.

However, due to financial difficulties, the association began the realization of that project only after it was reorganized on September 10, 1933. ased on the contract with the Belgrade administration, in December 1935, the Society received 36.33 hectares of municipal land for the construction of the planned facility, with a 50-year lease of the land and the obligation to start the works within one year at the latest. The area next to the King Alexander Bridge was designated as the construction site. The site was suitable for construction due to the size of the available unbuilt space, as well as the fact that it was located near the city center.

The construction of the Fairground was preceded by a wider survey competition of ideas and proposals in 1936, in just sixteen days. Public pressure prevented the implementation of the first prize-winning solution by eng. Nešić and co-author arch. Ignjat Popović, which was challenged as a conflict of interest, because the author was also the president of the jury at the same time. It should be mentioned that part of the competition works was also an example of a modernist plan, designed by Milorad Pantović, the author of the new Belgrade Fair built years later. Due to the consequences of a conflict of interest, the project was entrusted, by emergency procedure, to the architects of the Technical Directorate of the Municipality, Milivoj Tričković, Đorđe Lukić and Rajko Tatić.

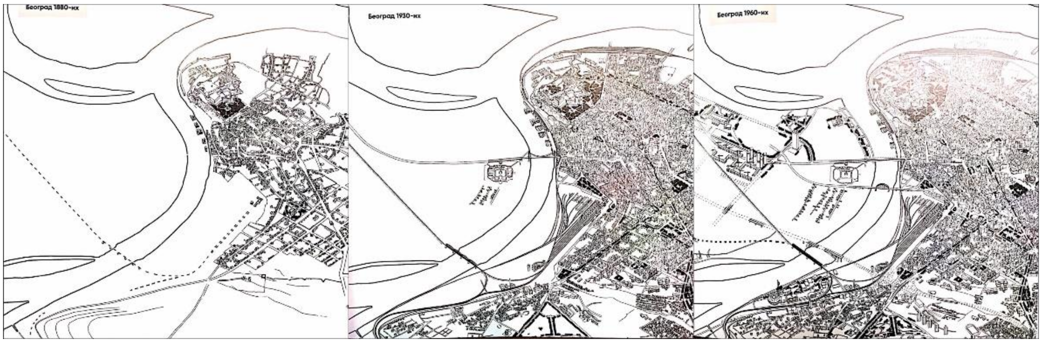

Figure 3. Comparative views of Belgrade in the 1880s, 1930s and 1960s, source: according to [8]

Based on their conceptual solution, the final project was later created, together with the projects of individual fair pavilions. With the initial idea, the entire complex was designed in the spirit of modernism, with which Belgrade obtained one of the first planned architectural-urban units conceived according to the principles of that style. Thus, already in the interwar period, the area of the left bank of the Sava became a training ground for avant-garde architectural ideas that would reach their culmination after the World War II, with the construction of New Belgrade.

The fair functioned for the masses in Belgrade in almost the same way as the world exhibitions in developed Europe in the nineteenth century, and it also had the role of promotion, advertising - newspapers, posters, canvases, radios, leaflets, magazines, lectures, photographs and inscriptions on sidewalks. Ljiljana Blagojević, Ph.D., talks more about the advertising strategy of the fairgrounds in the text *Grad kolektiva koji sanja i „konačno rešenje“* (City of collectives that dreams and the "final solution"). She quotes Stevan Popović, a regular commentator of the fair in the Belgrade Municipal Newspaper: "The illuminated chain bridge, the brightly illuminated pavilions and the central tower with a combined yellow-blue light, attracted all the eyes of the people of Belgrade" and notes that "the mass industry of propaganda comes with an industry exhibition - Le Corbusier's machine civilization was finally exhibited at the Belgrade Fair." [9]

The first fair (in September 1937), which had about 250,000 visitors, was attended by numerous domestic exhibitors and foreigners from twenty countries. Many foreign participants expressed their readiness for the following performances, of which there were several until the beginning of the war, in April 1941.

The construction of the Fairground and its positive effect gave the then municipal administration an incentive to prepare land for the construction of a settlement on the headland of the mouth. The filling of the terrain towards the Little War Island has begun, and the Urban Plan has been prepared at the same time. Due to misunderstandings, the action was suspended, and then completely interrupted by the World War II. The destruction of Belgrade thwarted any further construction on the left bank until the final liberation of the country.

In the center of the fair, a square square was built with the Central Tower in the middle. That building with a circular base and a tower 40 meters high was the "main spatial motif" of the entire complex. Around the square, 5 large "national" (Yugoslav) pavilions were built, and next to the King Alexander Bridge, the representative pavilion of the Nikola Spasić Foundation, elliptical in shape. In addition to the national pavilions, four foreign pavilions were built - Italian, Hungarian, Romanian and Czechoslovak, alongside which the Turkish pavilion was erected in 1938, and the German pavilion in 1939. Various domestic and foreign companies have built a large number of smaller exhibition spaces for their own needs. The total number of "closed" buildings of various sizes was 42, and besides them there were also numerous "open" ones. The infrastructure of the fair consisted of 9,800 square meters of streets, 12,600 square meters of paths and 120,000 square meters of park space. The size of the complex was about 14 hectares, and it is planned that it will be expanded over time. The opening of the first fair in the capital was accompanied by great success, and this institution soon proved to be a significant factor in the development of not only Belgrade, but also the entire country.

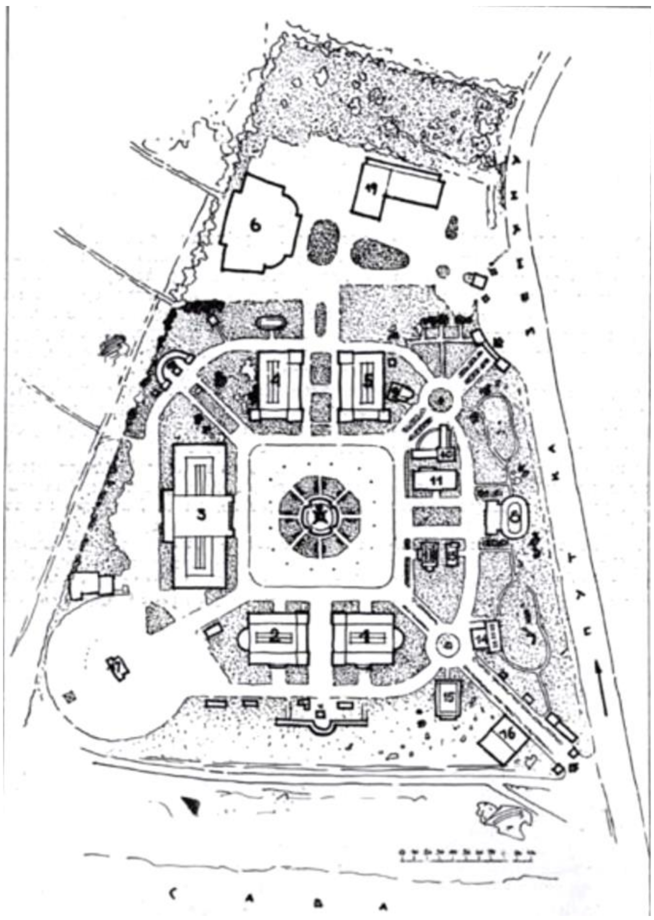

Figure 4. Planimetry of the interwar fair with the Central Tower in the middle surrounded by Yugoslav pavilions, source: according to [10, p. 209]

According to contemporaries, after only six months of work, it became one of the most active focal points of the economic, sports and cultural life of the Kingdom of Yugoslavia. Accordingly, the terrain across the river began to come to life more intensively as a new urban space. At the same time, the presence of the fair, as a
5. capital facility, greatly increased the importance of this area and encouraged its further development.

CONCLUSION

Through the previous research of the first crossings from Belgrade to the left bank of the Sava in the interwar period, when sudden population migrations occurred in Europe as well, it can be concluded that the observed spaces, in addition to indicating the uniqueness of the architecture of the historical period in which they were created, also read the principles that governed them public life and by which individuals and the community were guided.

Aldo Rossi talks about the city as a human creation that "the difference between the past and the future, from the point of view of the theory of knowledge, consists in the fact that even now we partially experience the past about the past" and states that "duration can be observed through monuments, physical signs of the past, but and over the duration of marked directions and planning" [11], so the question can be raised about the importance of the creation of the observed spaces and their further transformations. The tragic period that followed during the Second World War, when it was turned into a concentration camp, represents the most significant stage in its existence, and it is this time that should determine its future appearance and purpose.

The first "footprints in the sand" show, through urban plans in the observed period, the approach to planning the development of the riverside and the construction of complexes for holding fairs such as those where world exhibitions were held. The engagement of the Danish group for this work, as well as transparency in the reporting of public opinion through daily newspapers, attendance and media coverage of events in the fair complex, hint at the idea of the future direction of development and construction of New Belgrade as the capital of a new state and a solution for the necessary expansion of the city.

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DEVELOPMENT OF THE REVITALIZATION MODEL OF DEPOPULATED VILLAGES ON THE EXAMPLE OF THE MUNICIPALITY OF CRNA TRAVA – PART I

Ana Momćilović Petronijević[1], Olivera Nikolić[2], Mirko Stanimirović[3], Marko Joksimović[4], Vladan Nikolić[5]

Abstract

Demographic depopulation of villages on the territory of Serbia has been present for many years. This phenomenon is most dominant in the mountain villages of southern Serbia. Apart from the decrease in the number of inhabitants, these villages are also characterized by their unfavorable age structure. In this paper that is divided into two parts, we performed an analysis of the existing resources of the area and potentials that are not being used to a sufficient extent, for the Municipality of Crna Trava, which is one of the most prominent examples of a place with a drastic and continuous decrease in the number of inhabitants. In the Part I were analyzed the municipality's natural resources, its tourism potential, the existing construction fund and the existing infrastructure with the aim of creating a model of revitalization of depopulated rural settlements, as a basis for strategic development. By synthesizing all the collected data, four models of the revitalization of inhabited places on the territory of the Municipality were created wich presented in Part II.

Keywords: *revitalization, depopulated villages, sustainable development, building heritage*

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INTRODUCTION

We are witnessing a significant and continuous decrease in the number of inhabitants on the territory of Serbia. According to the latest census from 2022, 6690887 [1] inhabitants live on the territory of Serbia, while according to the previous census, in 2011, that number was 7186862 [2].

Although the decrease in the number of inhabitants is present on the territory of
1. the entire country, depopulation is most pronounced in rural areas and mountainous parts of Serbia. This statistics is, as expected, the most unfavorable in the mountain villages of southern Serbia. Apart from the decrease in the number of inhabitants, these villages are characterized by the fact that they are mostly inhabited by old people, while young people, after completing primary or secondary education, move to nearby cities for further education and job search. The biggest percentage of them remain permanently settled in the cities, while they go to their villages only occasionally.

Behind a large number of displaced families there are abandoned households in these villages, primarily residential buildings, but also those of economic nature - barns, mills, granaries. The entire construction fund, due to lack of maintenance, is left to decay, together with the infrastructure and the economy, because with the decrease in the number of inhabitants, the economic growth of the area also decreases.

Municipalities prepare long-term development strategies and various types of programs with action plans, but they only partially act on them in a defined period, most often due to a lack of funds for implementation.

This paper will present the methodology of creating a revitalization model of depopulated settlements as a basis for strategic development. Strategic development is usually made for the area of the entire municipality, and by using the revitalization model, the strategy would be approached by areas to which the same model can be applied, and which are territorially connected.

For the purposes of creating a revitalization model, it is necessary to analyze the existing resources of the area and the potential that is not used or is used insufficiently, along with identifying the shortcomings that need to be overcome in
2. order to successfully apply the model.

RESEARCHED AREA

Crna Trava is a small municipality in southern Serbia. Once it was well-known for its builders, people who built important buildings throughout the country, today it is known as a municipality that is disappearing. It is often referred to as the most underdeveloped municipality in Serbia, the municipality with the smallest number of inhabitants, or the municipality with the largest decrease in the number of inhabitants between two censuses.

Crna Trava is located in the south-east of Serbia. It covers an area of 312 km2, with a population density of 3 inhabitants per km2. It is 66 km from Leskovac, the center of the Jablanica district. It is positioned in the upper and middle basin of the Vlasina River, bordered by the Grdelica Gorge and the South Morava Valley from the west, the branches of Suva Planina mountain from the north, the Serbian-Bulgarian border from the east, and Mount Vardenika and Vlasina Lake from the south [3] [4]. Crna Trava belongs to the Jablanica district and is one of the smallest municipalities in the border area. Neighboring municipalities are Babušnica, Vlasotince, Leskovac, Vladičin Han and Surdulica.

Figure 1. Map of the Municipality of Crna Trava with rural settlements [5]

Demographic trends in the municipality of Crna Trava are indicative of the negative development of that area. The analysis of previous data shows that during the second half of the 20th century, there was a significant decrease in the number of inhabitants both at the level of the entire municipality and in individual settlements. Between 1948 and 2002, the number of inhabitants decreased drastically by 81,2%, and by 2022 even by 92,2%. Only in the last two decades, from 2002 to 2022, the number of inhabitants was halved, a drop of as much as 58,4% was recorded.

Table 1. Decrease in the number of inhabitants in Crna Trava over the years [6]

1948.	*1953.*	*1961.*	*1971.*	*1981.*	*1991.*	*2002.*	*2011.*	*2022.*
13614	*12902*	*12319*	*9672*	*6366*	*3789*	*2563*	*1663*	*1066*

The main factor of this decrease in population is mass migration caused by the one-sided process of industrialization, uneven development policy that neglected hilly and mountainous areas, insufficient infrastructure (especially bad roads and their poor maintenance) or even the complete lack of it, as well as the lack of institutional contents. The negative population growth also contributes to this trend, and since the 1960s it has been in constant decline [7]. Aging, decrease in population and emigration of young people are the factors that have influenced the decrease in number of fertile population, decline in the birth rate and increase in the death rate.

Apart from the unfavorable situation in terms of the number of inhabitants, their age structure is also very unfavorable. According to the 2022 census, the average age of the population was 56,37.

Table 2. Age of residents in the Municipality of Crna Trava according to the 2022 census[8] [4]

Age	*0-9*	*10-19*	*20-29*	*30-39*	*40-49*	*50-59*	*60-69*	*70-79*	*80+*
Number of inhabitans	*40*	*51*	*59*	*87*	*101*	*170*	*249*	*180*	*128*

Most of the inhabitants of Crna Trava live in districts, the largest of which have less than 100 inhabitants. The municipality consists of the town of the same name and 24 rural settlements with associated districts. The town itself has 338 inhabitants, while in the settlements the number of inhabitants is rarely a three- digit number [8].

3. ANALYSIS OF RESOURCES AND POTENTIAL OF THE MUNICIPALITY

In the previous part of the paper, some of the main reasons for depopulation of this area were listed. In order to start the process of improving the demographic picture, it is necessary to determine what resources and potentials the Municipality of Crna Trava has and which models of revitalization of villages and towns can be successfully applied to this Municipality.

3.1. Natural resources of the Municipality

The municipality of Crna Trava is rich in natural resources on which economic development in the researched area can be based.

It has been proven that apple, pear, raspberry and blueberry varieties achieve a high yield and quality in the area of the municipality from **agricultural branches**, in fruit growing. In vegetable growing, the soil, climate and altitude are suitable for growing potatoes. As this place was bypassed by the great pressure on agriculture, which did not become mechanized or industrial, the soil, air and water were not polluted by pesticides or heavy metals, and the area is suitable for **growing organic food**, which is in increasing demand today.

In the field of **cattle breeding**, the conditions are favorable, both because of the unpolluted environment and because of the large areas of meadows and pastures that make up 35% of the territory and are among the best pasture areas in Serbia with a stable vegetation cover [9]. The livestock fund in the municipality is extremely modest. Based on research conducted in 2019, the livestock fund counted 90 goats, 550 sheep, 90 pigs, 1 horse, 133 heads of cattle and about 500 poultry birds [9]. By renewing the livestock fund, opportunities are gained for the production of organic milk, cheese and meat.

According to data from the Faculty of Geography in Belgrade, forest coverage is over 50% and in some areas over 60%. Large areas under forests represent the basis for the development of **forestry and wood industry**. The available wood mass in the territory of the Municipality can ensure normal production in the wood processing industry for the next 100 years [9].

In addition to *wood forest products* as raw materials for the development of the wood-processing industry, the use of **non-wood forest products** (NWFP) represents a special potential in the researched area. The natural wealth of Crna Trava and the existence of significant natural sites of wild plant species and mushrooms (blueberries, cranberries, wild strawberries, wild blackberries, rose hips, medicinal herbs and mushrooms) allows their use based on the principles of sustainable development.

According to previous research, NWFP is a traditional source of household income in rural areas around the world, and more efficient use of forest resources in the future will be of great importance for the economic development of rural areas [9][10]. Thus, the education of collectors, engagement in controlled collection in order to protect biodiversity, purchase stations, processing and drying plants, as well as processing raw materials into semi-raw materials or finished products could be organized in this municipality.

Tourist potential of the Municipality

The tourist potential of the researched area can be divided into several areas:

3.2. - **rural tourism** - the vicinity of Vlasina Lake, only 10 km from the town, located on the territory of the neighboring Municipality of Surdulica, is one of the most significant tourist potentials of this place. The beautiful environment, untouched nature and clean air provide great opportunities for the development of this type of tourism.

- **hunting tourism** - two rivers, Vlasina and Čemerčica, are a good basis for the development of sport fishing for trout. Surrounded by the mountain peaks of Čemernik, Ostrozub, Tumba, Plana (Gramada) and the Vlasin Plateau, it has a good starting point for hunting tourism. There are two hunting reserves here. One is of the open type and is called "Kačar-Zeleničje", while the other is a fenced hunting area called "Valmište" and is located below Mali Čemernik [4]. These areas are rich in hunting game, such as does, deer, wild boars, foxes, wolves and rabbits. Large areas under forests, inhabited by various game, could be the driver of hunting tourism at certain times of the year, depending on the hunting calendar. (that is mostly different from the summer season – Vlasina Lake, rural tourism).

- **sports tourism** - cycling is considered a possible development asset of tourism in the territory of Crna Trava. Crna Trava hosts numerous national and international competitions in mountain biking. The mountain bike association "Orlovac" advocates for the creation of a mountain bike park, for the improvement of hiking in Crna Trava and for the development of ecological awareness among members of the association and the population.

- **tourist potential through tangible and intangible heritage** - Crna Trava is said to be the cradle of building construction. In addition to the construction of residential and public buildings, the builders of Crna Trava were especially known for building industrial chimneys in the territory of former Yugoslavia. The craft of building chimneys is dying out because, today, less than five builders who are originally from this area build them. In order to preserve the craft or at least the memory of it, as well as to point out the contribution to the construction of Yugoslavia, the Technical School in Crna Trava established a Museum of Construction in part of its working space, and the Municipal Library "Sestre Stojanović" is preparing a permanent exhibition entitled "Sedenjka čekajući pečalbara" (Waiting for our men working abroad) with which it wants to honor the men, but also the women of Crna Trava who took care of the households during the part of the year when the men were in the field. Intangible heritage could be protected through organization of workshops of old crafts, old building techniques and the like.

Analysis of the existing building fund

According to the last census, 2959 housing units were recorded in the territory of the observed Municipality. 595 units are permanently inhabited, 136 temporarily uninhabited, 176 abandoned, and as many as 2043 are used only occasionally, during holidays and seasonal works[11]. Therefore, only 20% of the total housing
3.3. fund is actively used. As many as 1,364 residential units are out of use for most of the year.

Abandoned buildings of national construction in the territory of this municipality have been damaged to a certain extent. The damage is mostly physical in nature, caused by the action of external factors, the dominant ones being moisture and frost. The picture is like this partly because of the nature of materials they were built of, and mostly because of poor or complete lack of maintenance. One of the factors contributing to the degradation of these facilities is demographic and economic in nature, family stratification and departure of young people to the cities, while the elderly population, over 60 years of age, predominates in the villages. In poor material condition, the inhabitants of remote villages are not able to adequately take care of their facilities. The distance from larger warehouses of adequate building materials, where there is a supply of suitable materials for rehabilitation, is another reason for the picture we see.

Nevertheless, the largest part of the buildings, almost 70%, can be revitalized and continued to be used with adaptation to their purpose.

Figure 2. Rural settlement Dobro Polje [12]

The oldest types of buildings that can be seen in the researched area are buildings that were constructed before the First World War. Whether it's about post-and-pan buildings or brick buildings, these oldest buildings are mostly in very bad condition. It was established that a large part of the oldest houses had collapsed, or are prone to collapse. A certain number of buildings have lost their primary residential function, and functionally they have been replaced by new buildings within the same yard. Those that are in somewhat better condition are used as storerooms for larger tools, sheds for wood and similar forms of auxiliary rooms.

The houses in which people stay occasionally have most often undergone certain adaptations and reconstructions, whether it is structural repairs and reinforcements, or there was a need to expand the living space, which is the more frequent case.

As expected, the houses built after the Second World War are in the best condition, require the least investment in renovation, but at the same time have the least features of traditional architecture characteristic of these areas.

3.4. Analysis of existing infrastructure

The geographical position of Crna Trava is such that it is relatively isolated from the main traffic roads. The only significant communication is the road connection with Leskovac via Vlasotince and with Vladičin Han via Surdulica, through which it is connected to the highway Belgrade - Skopje.

The regional road network is weak and does not have an asphalt surface in full. These are the regional road Crna Trava - Predejane (r - 240) and the regional road Sastav Reka - Strezimirovci. The area of the municipality is very poorly connected to the surrounding area by traffic. There are 19 local roads with a total length of 100.5 km, of which a very small part is paved with asphalt [4].

The electrical network needs reconstruction. According to the data of the Municipality, it was improved only in the villages of Zlatance, Preslap, Gradska and Krivi Del.

Only the town of Crna Trava has a central water and sewage network. In the villages, water supply is carried out through captured water intakes, from which the water, usually by natural fall, is brought to the reservoir. The sewage system in the villages has not been built, septic tanks are in use.

4. CONCLUSION

The natural resources of a certain region, tourism potential, construction fund and infrastructure are the most important parameters for creating a model of revitalization of depopulated settlements. In order to repopulate a certain region, it is necessary to create conditions for the population to engage in those activities for which there is sufficient potential in the observed area.

The starting point in the creation of a revitalization model for villages in general, including the villages of the Municipality of Crna Trava, should be precisely this analysis of parameters. The analysis of all parameters, starting with the natural potentials of the Municipality, then tourism potentials, existing infrastructure and preserved building stock, will be tabulated in the second part of the paper. The synthesis of all collected data will create four possible revitalization models applicable to this Municipality.

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DEVELOPMENT OF THE REVITALIZATION MODEL OF DEPOPULATED VILLAGES ON THE EXAMPLE OF THE MUNICIPALITY OF CRNA TRAVA – PART II

Ana Momćilović Petronijević[1], Olivera Nikolić[2], Mirko Stanimirović[3], Marko Joksimović[4], Vladan Nikolić[5]

Abstract

Crna Trava is a municipality in the south of Serbia where a large decrease in the number of inhabitants was recorded between the two censuses. In the first part of the work, an analysis of the existing resources of the area and the potential that are not being used sufficiently, for the municipality of Crna Trava, was carried out. By synthesizing all the collected data, four models of the revitalization of inhabited places on the territory of the Municipality were created: a model based on animal husbandry and milk and meat processing, a model based on forestry and processing of wood raw materials, a model based on forestry and processing of non-wood forest products and a model based on tourism. In the conclusion of this paper, specific rural settlements were proposed where each of the models would be most applicable.

Keywords: *revitalization, depopulated villages, sustainable development, building heritage*

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INTRODUCTION

Based on what was presented in the Part I of the paper, it can be concluded that Crna Trava is the municipality with the most pronounced and continuous trend of decreasing population in Serbia in recent times. In this regard, an analysis of resources and potential of the Municipality was carried out, in order to obtain a realistic picture of the resources available to the Municipality, as well as the
1. disadvantages that are present and that potentially cause depopulation.

Based on the analysis of the Municipality's natural resources, tourism potential, existing infrastructure and preserved building stock, models of village revitalization that could be successfully applied to this Municipality are proposed in this part of the work.

MODELS OF REVITALIZATION OF DEPOPULATED SETTLEMENTS OF CRNA TRAVA

2. The previous methodological approaches in the treatment of villages and rural areas were fragmentary, sector-oriented, and the importance of the methodological approach of this work is reflected in the interdisciplinary nature of rural research, which results in a realistic assessment of the potential of villages and the ***development of revitalization models*** based on established parameters from various fields. The scientific concept starts from the form to the whole, from the local to the regional and national, the results of the project lay the foundations for further successful interventions on the revival and settlement of abandoned rural regions through a broader social, economic and demographic approach. House - household - village - municipality - region - country. The starting point in the process of revitalization of the village is an abandoned residential building, a modular unit on which systematic research will be carried out, with an extension to the garden and auxiliary buildings in it. The natural resources of a certain region, tourist potential, building fund and infrastructure are the most important parameters for creating a model of revitalization of depopulated settlements. In order to repopulate a certain region, it is necessary to create conditions for the daily life of the population to engage in economic activity.

For the purposes of the work, the characteristic parameters for populated places in the Municipality of Crna Trava are shown tabularly, in two tables. Table 1 contains demographic data, data on building fund, natural resources and infrastructure. Table 2 defines data on economic and tourist potential.

The municipality of Crna Trava is rich in unpolluted natural environment, pastures, forests and water courses. The direction of the economic development of this Municipality must be focused on the use of natural resources and the production of healthy food, with the mandatory preservation of healthy environment, and the construction fund is rich in buildings that are used occasionally.

By synthesizing the data shown in tables 1 and 2, 4 models of the revitalization of populated areas of Crna Trava were created:

MODEL 1 – based on cattle breeding and milk and meat processing
MODEL 2 – based on forestry and wood processing
MODEL 3 - based on forestry and processing of non-wood forest products
MODEL 4 - based on tourism

2.1 MODEL 1 – based on cattle breeding and milk and meat processing

During the creation of Model 1, a synthesis of data related to the current number of inhabitants, the current construction fund of the settlement, the area of pastures and watercourses, road connectivity and quality of roads, presence and quality of water and electricity networks was carried out. Positive ratings for each of the parameters indicate the possibility of developing a model according to which the existing and newly inhabited settlement has fulfilled the conditions of residential comfort, whose economic activity is based on cattle breeding and milk and meat processing. Two territorially close groups of settlements stood out.

The first group consists of the villages of Zlatance and Preslap, which are positioned east of Crna Trava, where Zlatance is directly dependent on the territory of the Crna Trava settlement. They are connected to each other by local unpaved and partially asphalted roads and are in the immediate vicinity of the 231 national road. The second group consists of the settlements of Čuka, Jovanovce, Bajince and Mlačište, which in terms of natural resources, construction fund and infrastructure meet the conditions (improvement of the electrical network is necessary) for the application of the Model 1, but these villages are on the verge of extinction, because a total of 47 inhabitants live in all four of them. These villages are also near Crna Trava, territorially connected in the south-west direction. In the third group there are the villages of Brod, Krstićevo, Dobro Polje, located north of Crna Trava, on the 231 national road, but facing extinction, with 58 inhabitants in all three villages.

2.2. MODEL 2 – based on forestry and wood processing

All villages in Crna Trava are rich in forests and wood raw materials [1, 2]. For the development of Model 2, demographic data, construction fund and the proximity of national and municipal paved roads, which are necessary for the transport of wood raw materials, semi-products and products, were also observed. Thus, the group of villages Ruplje, Rajčetina, Pavličina and the group of villages Kalna, Gradska, Darkovce, Jabukovik, Sastav reka, Krivi Del, Gornje Gare, Brod, Dobro Polje and Vus stand out for the application of this Model. The first group of villages in the west of the municipality is well connected to Crna Trava and Predejane by national road 232, and thus also by the highway. The second group of villages, located in the east and north of the municipality, has an exit to national road 231, which intersects with 232. The first group of villages is at the demographic minimum, without a population of working age, while in the second group, in the villages of Gradska, Kalna, Darkovce and Krivi Del there is a working population to successfully apply Model 2.

With Model 2, it is very important to develop the wood processing industry. It is difficult to find dry lumber of good quality on the Serbian market and it is mostly imported from Bosnia and Herzegovina or Russia. In the town of Crna Trava, there are industrial production halls that can be used for that purpose.

Table 1. Demographic data, data on the construction fund, natural resources and infrastructure [3-5]

name of the settlement	number of inhabitants	households					nature			water		traffic			water supply network		sewage network		electricity network	
		total number	inhabited	uninhabited	abandoned	temporarily in use	pastures and meadows	forests	cultivable soil	watercourse	proximity to lakes	state road IIA order	municipal asphalted road	municipal macadam or earth road	collective urban	collective rural	central city	individual	unapređena	postojeća
Zlatance	49	220	30	0	2	188	●	●		●	●	●	○	●		●		●	●	
Preslap	91	172	55	3	0	114	●	●		●		●		●		●		●	●	
Kalna	58	171	33	7	0	131	○	●		●			○	●		●		●		●
Gradska	170	225	87	18	43	72	○	●		●		●	○	●		●		●	●	
Darkovce	69	274	52	10	85	127	○	●		●			○	●		●		●		●
Jabukovik	25	89	16	11	2	60	○	●		●				●		●		●		●
Sastav Reka	17	22	10	1	0	11		●		●		●		●		●		●		●
Krivi Del	64	118	37	3	3	73	○	●		●				●		●		●	●	
Gornje Gare	30	133	16	9	0	108	○	●		●		●		●		●		●		●
Vus	2	17	1	2	0	14	●	●		●				●		●		●		●
Dobro Polje	9	58	5	4	0	49	●	●		●				●		●		●		●
Krstićevo	15	57	11	3	2	41	○	●		●				●		●		●		●
Brod	34	221	25	18	29	149	●	●		●		●		●		●		●		●
Obradovce	14	67	6	0	0	61	○	●	○	●				●		●		●		●
Crna Trava	338	426	162	28	0	234	●	●		●		●	●	●	●		●			●
Čuka	8	90	5	0	0	85	●	●		●	●	●		●		●		●		●
Jovanovce	22	109	11	4	7	87	●	●	○	●				●		●		●		●
Bajinci	5	60	5	1	0	54	●	●	○	●				●		●		●		●
Mlačište	12	93	6	2	3	82	●	●		●				●		●		●		●
Ruplje	4	18	3	0	0	15		●		●		●		●		●		●		●
Ostrozub	0	18	0	1	0	17	○	●		●				●		●		●		●
Bistrica	2	50	2	3	0	45	○	●		●			●	●		●		●		●
Bankovci	5	98	5	0	0	93	○	●		●				●		●		●		●
Rajčetina	10	55	6	1	0	48	○	●		●		●		●		●		●		●
Pavličina	10	98	6	7	0	85	○	●		●		●		●		●		●		●

Table 2. Data on economic and tourist potential.

name of the settlement	Eeconomic potential				tourist potential						
	agriculture	cattle breeding	forestry	wild plants and mushrooms	rural tourism	hunting tourism	fishing tourism	cycling tourism	hunting ground	nature reserve	memorials
Zlatance	○	●	●	●● blueberry, wild blackberry, cranberry, mushrooms	●	●	●				●
Preslap	○	●	●	● blueberry, mushrooms, ivy, burdock	●	●	●				
Kalna		○	●	● wild strawberry, wild blackberry, ivy, burdock	●	●	●				●
Gradska		○	●	●● blueberry, wild strawberry, wild blackberry, mushrooms, ivy, burdock	●	●	●				●
Darkovce		○	●	●● blueberry, mushrooms, ivy	●	●	●				
Jabukovik		○	●	○ wild strawberry, wild blackberry, ivy, burdock	●	●	●				
Sastav Reka			●	● ivy		●	●				
Krivi Del		○	●	● ivy, burdock	●	●	●				
Gornje Gare		○	●	● blueberry, ivy, burdock	●	●	●				
Vus	○	○	●	● blueberry, mushrooms		●	●				
Dobro Polje	○	●	●	● blueberry, mushrooms	●	●	●				●
Krstičevo		●	●		●	●	●				
Brod	○	●	●	○ blueberry, ivy	●	●	●				●
Obradovce	○	○	●	● blueberry	●	●	●				●
Crna Trava	○	●	●	○ blueberry, mushrooms		●	●	●			●
Čuka	○	●	●	○ blueberry	●	●	●				
Jovanovce	○	●	●	●● blueberry, mushrooms	●	●	●	●	●		●
Bajinci	○	●	●	●● blueberry, mushrooms	●	●	●		●		●
Mlačište	○	●	●	●● blueberry, mushrooms		●	●		●		●
Ruplje			●	● blueberry		●	●	●			
Ostrozub		○	●	●● blueberry		●	●			●	
Bistrica	○	○	●	● blueberry	●	●	●			●	
Bankovci		○	●	○ blueberry	●	●	●	●		●	
Rajčetina		○	●	○ blueberry	●	●	●				
Pavličina		○	●	● blueberry	●	●	●				

MODEL 3 – based on forestry and processing of non-timber forest products

On the territory of Crna Trava Municipality, several types of wild forest plants and mushrooms that are used in the food or pharmaceutical industry can be found in wide areas of the forest territory [6]. Of the forest fruits, the most common are blueberries, wild strawberries, cranberries and blackberries, of medicinal herbs ivy and burdock, and St. John's wort, thyme, chamomile and yarrow are also harvested. The collection of forest non-wood products and their processing can be the driver of the economy in this area.

For the development of Model 3, in addition to diffusion of wild plants and mushrooms, data were synthesized on the housing construction fund needed to house the collectors, economic facilities, road network and other infrastructure resources. The population of different ages can participate in the collection of forest products, not only working age population.

Mushrooms are harvested from May to September. Depending on the variety, the fruit of forest fruits are collected from May to August, at the same time leaves of forest fruits which have medicinal properties are also picked. In the case of ivy, the leaves are harvested from spring to autumn, the flower in October, and the fruit later, when it ripens. The leaf and root of burdock are used in the pharmaceutical industry. The leaves are harvested from May to July, and the root in March and April or in September and October. From the above, it can be concluded that non-wood forest products can be harvested from early spring to late autumn, and their processing and distribution is also possible in the second part of the year. For the development of the industry in this region, it is necessary to organize a network of purchase stations, cold storages, dryers and factories for processing, although these plants can also be processed in households.

By synthesizing the data from Tables 3 and 4, the groups of villages in which Model 3 can be particularly applicable are distinguished. *The first group of villages* consists of Zlatance, Gradska and Darkovce. All three villages touch each other territorially and are rich in different varieties of wild forest plants and mushrooms. In *the second group* are also territorially connected villages, Jovanovce, Bajinci and Mlačište, which are rich in blueberries and mushrooms. Collection is also possible in other villages, but the mentioned settlements are imposed as centers for the development of this branch of economy in the Municipality and as places for positioning economic facilities for storage and processing. Processing centers can also be positioned in Crna Trava, which has abandoned commercial buildings.

2.4. MODEL 4 – based on tourism

For the development of Model 4, based on tourism, data on the population, construction fund, infrastructural resources of all kinds, as well as the tourist potential analyzed through the presence of hunting and fishing areas, cycling routes and existence of memorial monuments, were synthesized.

The villages of Zlatance and Čuka are located on national road 321, from Vlasina Lake, which is in the territory of the Surdulica Municipality, only 7-10 km away, and they have 310 households, of which 273 are use occasionally. The proximity of the lake makes them suitable for the development of rural tourism throughout the year, but also for the accommodation of seasonal workers for the collection of forest products.

The village of Mlačište is rich in waters where mountain trouts live, and on its territory there is a fenced hunting ground "Valmište" with a hunting lodge and an artificial lake. Mlačište is a village with 93 households, only 6 of which have permanent residents. The existing construction fund creates potential for the development of hunting, fishing and rural tourism. In the village, several unpaved roads cross from different directions, asphalting the road to Crna Trava on one side and Vlasina Lake on the other side would create a high-quality road network, which is especially needed in winter hunting months.

In the villages of Ruplje, Ostrozub, Bistrica and Bankovci there is a nature reserve "Kačer-Zeleničje" with protected plant species of Moesian beech and cherry laurel popularly known as "zeleničje". This is the territory of the hunting ground of the same name, and the cycling route passes through Ruplje and Bankovce. The villages are rich in clean mountain streams and fish. Thus, this group of villages stands out as suitable for the development of Model 4, namely hunting, fishing, village and bicycle tourism.

The results of suitable revitalization models for the settlements of Crna Trava Municipality are graphically shown on the map (Figure 1).

CONCLUSION

The municipality of Crna Trava is rich in natural resources and potentials for the development of an economy based on sustainable development and organic
3. production, to the extent that instead of being the poorest, it could be the richest in Serbia. The town itself and twenty-four rural settlements, twelve of which are depopulated, with less than 100 inhabitants, nine with less than 10 inhabitants and one with 0 inhabitants, indicate pronounced demographic depopulation and difficulties in starting the economy due to the lack of labor force.

The previous research, as well as this research, established that Crna Trava has infrastructural problems because it does not have a quality road network, the most kilometers of roads are unpaved roads, an outdated electrical network, individual water supply and waste water disposal. Investing in this sector, without considering the development potential, could lead to new, unsuccessful investments.

This research determined that there are 2,959 households on the territory of Crna Trava Municipality with at least one residential building and one or two auxiliary buildings, of which 2,043 residential buildings are used occasionally, and 312 are uninhabited or abandoned. The assessment of the condition of the buildings in households, which was not carried out in detail in this work on a larger number of buildings, but in seven districts in the town of Crna Trava and the nearest villages Zlatance and Jovanovce, concluded that with minimal construction interventions, two thirds of the residential buildings could be in constant use, both for the life of the inhabitants and for tourism. A more detailed assessment of the situation will be carried out in the next research.

A significant result of the research is the creation of a methodology for determining the resources and potential of each inhabited place in the municipality. With this methodology, it is possible to realistically see the potential, but also the shortcomings of each inhabited place. The data obtained through the application of this methodology lead to the creation of a settlement REVITALIZATION MODEL, of which, in the case of Crna Trava Municipality, there are four: MODEL 1 - based on cattle breeding and milk and meat processing, MODEL 2 - based on forestry and wood processing, MODEL 3 - based on forestry and processing of non-wood forest products, MODEL 4 - based on tourism. Figure 1 shows the scheme of the revitalization model for each village in Crna Trava and the town itself, where two revitalization models can be applied in the villages of Dobro Polje, Darkovce, Gradska, Čuka, Crna Trava, Jovanovce, Bajinci and Ruplje.

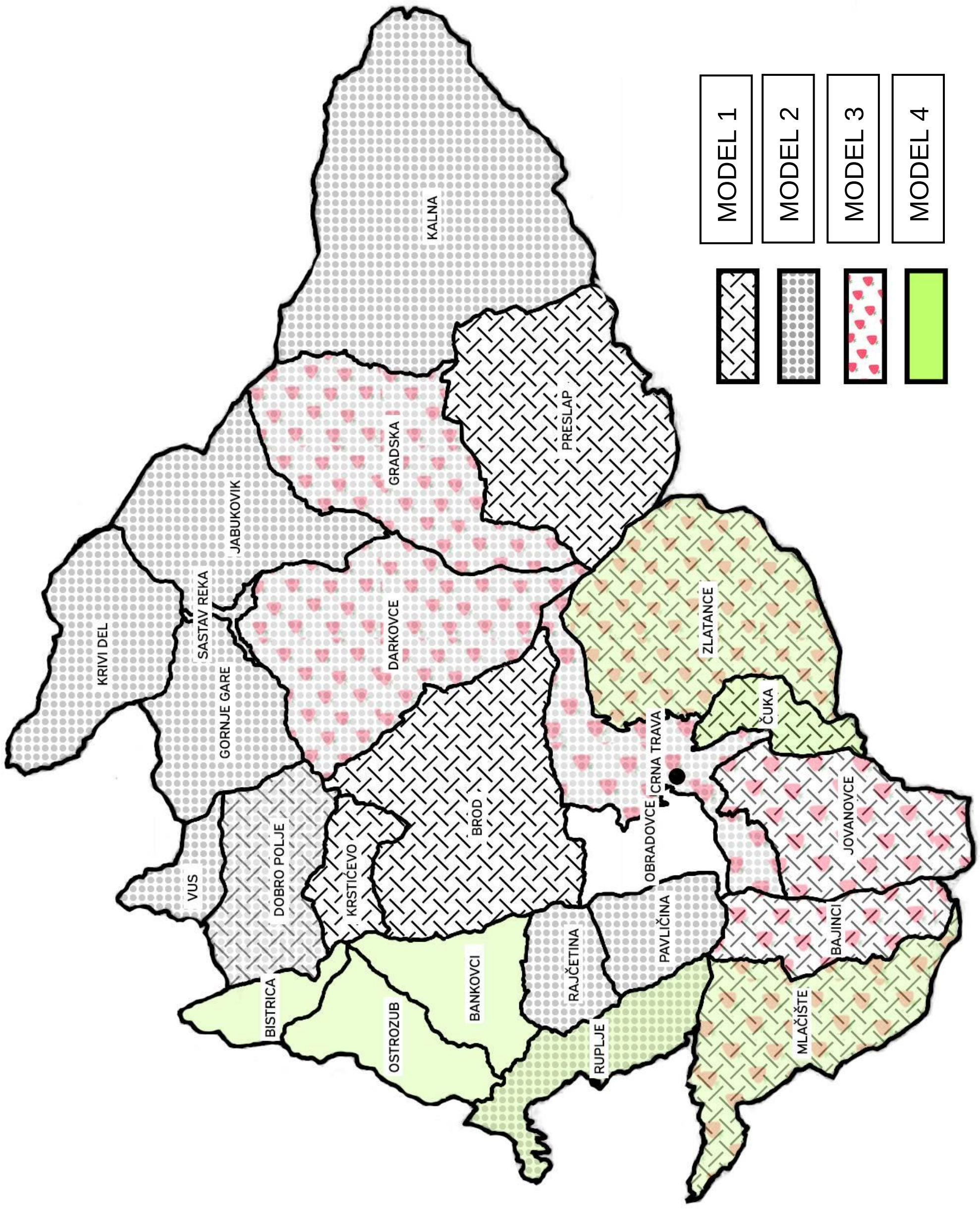

Figure 1. Revitalization model scheme for rural settlements of Crna Trava Municipality, according [7]

The village of Zlatance in the south-east of the Municipality and Mlačište in the south-west of the Municipality stood out as places with a particularly pronounced economic potential because three models of revitalization can be developed equally in them. Zlatance has a better road network and a better connection with the center of the Municipality and larger towns, as well as an improved electricity network, so the development of the economy in this place is not conditioned by infrastructure investments. In order for the village of Mlačište to develop its economic development models, it is necessary to build a 6.6 km asphalt road from Pečurka above Obradovac to Mlačište on one side and from Rupljе to Mlačište, a length of 7.4 km on the other side, thus this village would have a good connection with Crna Trava via national road 232, but also with larger centers via highway A1.

Obradovci is the only village for which no single model stood out, but they are all applicable. This village has cultivable soil and pastures, forest and blueberries, it relies on Crna Trava and with the development of the surrounding places, it will also develop.

The presented methodology and revitalization models that are the results of this research can be applied to every municipality in Serbia and should be the starting point of every development strategy.

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NEW RATING OF THE STEEL BRIDGE IN CENTER OF NIŠ AFTER RECONSTRUCTION

Milan Gligorijević[1]

Abstract

Bridges possess great capital value. They present vital links in road infrastructure networks and it is important to keep them well maintained despite their difficult operating-conditions.
The application of the Bridge Managements Systems enables us to optimally use the available resources for adapting the existing bridges with the traffic and safety requirements.
The author of this paper, in his doctoral dissertation, offered a new proposition based on the optimized criterion of priority evaluation and in the framework of the inspection examination of the steel bridge in center of Niš, noted an extreme increase of damage, with the alarming drop in load carrying capacity and the safety of bridge structures. The paper present the proposed methodology based on the results of bridge monitoring over a period of several decades which was used to provide bridge status assessment and new ratting of this bridge after reconstruction.

Key words: *Bridge Management System, Damages, Deterioration, Maintenance, Priority evaluation, Repair and Reconstruction, Forecast.*

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INTRODUCTION

Man has always felt need for bridges. A utilitarian definition of bridges is that they are structures intended to carry a road across some obstacle. This entails in addition to the satisfaction of certain human needs, it also implies the creation of new forms on the face of the earth and an objective aspiration to functionality, stability, rationality, interior harmony and harmony with the environment. Also, bridge
1. structures must be safe and durable, but often, a bridge can be a work of art. A technically impeccably performed design, which means optimum functionality and reliability with the least possible cost, will not be complete if it has not resulted in a beautiful bridge as well.

It can be said that bridges are not structures, since bridges contain structures.

Success in designing and building of bridges is based on knowing the theory of structures and materials, imagination and courage of designers in developing new ideas, and in the will to learn from other's mistakes and own experiences. Contemporary analysis methods are being increasingly used in studying and designing of bridge structures, which results not only in more lightweight and more cost-effective bridges, but also in adequate formation of structural details which enables bridge structures to perform better, and thus enables achieving larger spans of contemporary bridges, which so reach further. New findings with new technology help human imagination become reality.

Bridges are vital links in road infrastructure networks and it is important to keep them well maintained despite their difficult operating conditions. Harsh environment, increase in both traffic intensity and heavy transport, and the aging of existing bridges are the main reasons for bridge deterioration. The increase in bridge deterioration and in maintenance costs, in view of the limited funds, have motivated the development of Bridge Management System (BMS) that support decision makers in allocating the limited funds to top-priority bridges.

2.

THE BRIDGE MANAGEMENT PROBLEM

Managers of bridge system are confronted by uncertain and often conflicting option usually centred on three basic, though not independent, questions: How do the various possible strategies for maintenance and repair affect the cost and performance of the system over some period of time? What is the potential effect of
2.1 the range of possible values of uncertain and intangible factors? And, above all, what strategy should be implemented under specified constraints, such as a budget short of optimal for maintenance?

Aim is to find a solution for this problem in bridge management's system.

Development of BMS in the world

The term *management*, in this paper, is used to denote the husbandry, administration, that is, preservation and maintenance of the entrusted assets - that is, taking all the measures possible to use the assets well and long.

The Bridge Management System (BMS) deals with the activities related to the bridges, starting from their committing to traffic, until the termination of their service.

The BMS is accordingly, a sum of the organizational elements, laws, standards and procedures used by the road service in order to organize, perform and monitor the activities ensuing the construction of a bridge. The road managements can use the BMS to achieve the set goals more effectively. The most important goal among them is the optimal engagement of available resources for adapting the existing bridges to the traffic and safety needs.

If we are familiar with the organization elements, laws, standards used by the road service to organize, perform and monitor the activities that follow the bridge construction, it is clear that each road service has a sort of a BMS, developed to a certain extent, which is used more or less successfully.

In practice, however, even in the well-developed countries there are weaknesses in this field, so for a certain time there are attempts to improve the existing solutions and achieve the best BMS. The weaknesses have been discovered in all the fields – organization, regulations, standards, and in the activities "which follow the construction of a bridge". An increase of damages is perceived in the bridges, with a decrease in the bearing capacity and safety of the bridges, and even the collapse of some of the very important bridges.

It called for undertaking urgent actions with the aim of defining the problem, establishing the present status through the exchange of information, setting the goals and finding the ways to achieve the optimal result by the appropriate research and techno - economic analyses.

The result of these actions is not complete yet, but the improvements are already felt, so it can be concluded that the developed countries are nearing the successful solution of the improvement of their BMSs. The success is evident in the increased level of the bridge status, causes and effects of damage on them, consequences in the negligence of maintenance, and especially in the awaken interest of the professional public, state and political structures, as well as the public in general.

It resulted in the increased funding of research in this field, for the maintenance needs and finally for the introduction of the modern BMS with an information system relying on the modern technology at its core.

The non-developed countries and developing countries fall behind the developed countries in the measure their overall level of development falls behind the industrial countries. However, many of them, as ex colonies, receive the knowledge transfer from the metropolises, from which they often inherited the organization of organization of state government and in this fashion the maintenance and regulation. The limited density of road network, as well as modest economic potential, coupled with the climatic conditions in many of those countries, complete the image of the present condition in this field in those countries, which is characterized as having a lot of weaknesses in the field of BMS.

The East European countries do not lack the professionals and the density of network and climatic conditions require a modern approach to the bridge management system, but it is not developed to the necessary level, which can be ascribed to various causes.

Bridge management is a process, used to supervise, monitor, maintain and repair detected deterioration of bridge structures, using available resources during design service life. Design service life is a predicted period of usage of bridge structures, with regular maintenance but without any considerably repairs.

The subject of bridge management includes entire service life of bridge structures, starting from the concept and basic preliminary studies, through the designing, construction, service and maintenances processes (adaptation, restoration, reconstruction) to the final replacement or removal of bridge structures. For these reasons, management as a business process requires a multidisciplinary approach and knowledge of all technical and other non-technical disciplines. The ultimate goal is optimum satisfaction of the durability philosophy, i.e., achieving maximum effects with a minimum of invested resources. For this reason, bridge management and adequate maintenance is a perspective business in contemporary civil engineering.

Strategy of development of bridge management system in the world is based on the methodology for development of optimization system and usage of resources in the process of management and maintenance of bridges. This includes status of bridge structures, their bearing capacity, damage degree, that is, deterioration of constitutive elements of bridge structures, traffic effects, as well as repairs, restoration and reconstructions.

The bridge management concept started to develop in the world relatively recently, in order to meet the growing demand. The first bridge management systems in the world started to develop since 1970 [1].

One of the first countries to introduce a systemic, well-planned and organized research in the bridge management domain is the USA.

The fist bridge management programs in the USA date back to the early 1970’s. Collapse of several bridges in the USA, first of the "*Silver*" bridge in 1967 [2], and then of other capital bridges, and the growing gap between the available resources and the needs of the national network of the USA bridges stimulated increased research of this issue and gave rise to the development of bridge management system by the mid 1980’s. Soon after that, in 1991, the intermodal law on efficiency of transport in the USA obliges the states to develop and implement the bridge management systems. Bridge Management Systems in the majority of the USA states were developed in the mid 1990’s [3].

Nowadays, state transport agencies in the USA, established bridge inspection programs, and most of them are implemented into the contemporary Bridge Management System *AASHTOWare Bridge Management* (earlier *Pontis*). In the world, in the recent years, the number of states which developed or are developing bridge management system is increasing considerably.

Contemporary Bridge Management System contains bridge status assessment, modeling of the future deterioration and behavior and modules for decision making about most cost-efficient ways of maintenance, repair and renewal of bridge structures.

Preservation of the important properties of bridge structures during their service life represents a permanent task of Bridge Management Systems. According to the data from the extensive experience of management in the developed countries, planned maintenance during the service life of bridge structures requires investments of approximately 2% to 3% of the investment value annually.

2.2. Development of BMS in Serbia

In Serbia, generally speaking, due to the long lasting lack of investment into maintenance and reconstruction of bridges, the bridge status can be evaluated as unacceptable, especially in terms of their age. Regular maintenance is mostly primitive, which accelerates ageing of structural elements and deteriorates the bridge status, and large repairs and restorations are almost the only form of activities, and they are performed in the situations when they remain the only alternative to closing down the bridge.

The basic contemporary Bridge Management System in Serbia was introduced in 1986 as original, and very modern system for the time [4]. For the needs of quality management of bridges and implementation of this system in the territory of the Republic of Serbia, an electronic database of bridges was formed (BPM), which at any moment provided all necessary information about the researched bridges structures on the basis of performed inspections. Formation of the data base had a goal to collect the available information about bridge structures in order to establish a priority in bridge maintenance and development of bridge management system in Serbia.

Establishing of priorities in the bridge structure maintenance activities should be understood as a response to inadequate finances which were allocated for bridge maintenance in the general political and economic conditions in Serbia in the last several decades. Since 1991, the version SR - 02, was used, which contains inventory data and data on the condition of bridges at the moment of inspections. In order to make the work on data input easier, detailed user instructions were made.

Following the further development of computer technology, the database on bridges passed through several development phases, and since 1999, the version SR – 03 was used, and since 2003, there has been a version working under MS ACCESS.

However, practical application of the Bridge management system in Serbia during a long time exhibited certain illogical issues in the obtained lists of priority activities.

In his doctoral dissertation [1], the author of this paper provided a new proposal based on the optimized criterion of priority evaluation. This removed the detected illogical issues of our current bridge management system and provided a considerable improvement of efficiency in determining the priority list.

The proposed methodology, based on the results of his own bridge monitoring lasting for several decades, is used to provide bridge status assessment and maintenance perspectives of bridges in the city of Nis. The results of this newly proposed methodology, on the example of the steel bridge in the center of Niš, that
3. are presented in this paper.

ASSESSMENT OF BRIDGES STATUS IN THE CITY OF NIŠ

The author of this paper formed a database for bridges structures in the city transport of Niš [5] in 1997, after producing the Analysis of in the bridge status. Since 1998, he has been monitoring deterioration of the status of those bridges on the base of performed periodical control, regular and main inspections of bridge structures in the city of Niš. Importance of these bridges demanded such an approach, which provides an equally timely and cost-effective maintenance and repairs, that is strengthening and/or replacement of these structures.

After every inspection, using methodology proposed in the doctoral dissertation [1], status of all the bridge elements in the data base was assessed, i.e. their rating was made, which was used for making of rank-lists of priority activities and necessary interventions. The analysis of the obtained rank-lists of priorities showed that there were no considerable changes between two regular inspections (2-year interval), if there were no maintenance activities in that period. For these reasons, in this paper shows the rating of the bridges after the main inspections. (6 years interval).

Steel bridge in the center of Niš

The Bridges Management System on the example of the steel bridge in the center of Niš, the author of this paper presented in detail in his paper [6].

After the inspection in 1997, the steel bridge in the center of Niš (Fort bridge), as the fourth on rank-list draws attention to itself by its rating (1176,94), since it is located in the center of the city, immediately in front of the gate of the Fort.

3.1. According to the global status of constitutive bridge structures after inspection in 2003, the Fort Bridge in the city center, with a score of 1531.52, comes to the top of the priority list. However, in the following period, no activities including repair and maintenance of bridges in Niš were undertaken.

Advance of deterioration of the Fort bridge, and especially of prefabricated pre-stressed concrete structures of pedestrian sidewalks, significantly increased the rating (2011,08) of the steel bridge in front of the Fort in Niš, so this bridge remained on the top of the rank-list of priorities of 2009. The first incidental collapse of a part of pedestrian sidewalk occurred in June 2008. [6], which was “repaired” by replacing the adhesion pre-stressed element with a reinforced-concrete one.

The change in the total and component rating of the constructions of this bridge by years is shown in Figure 1.

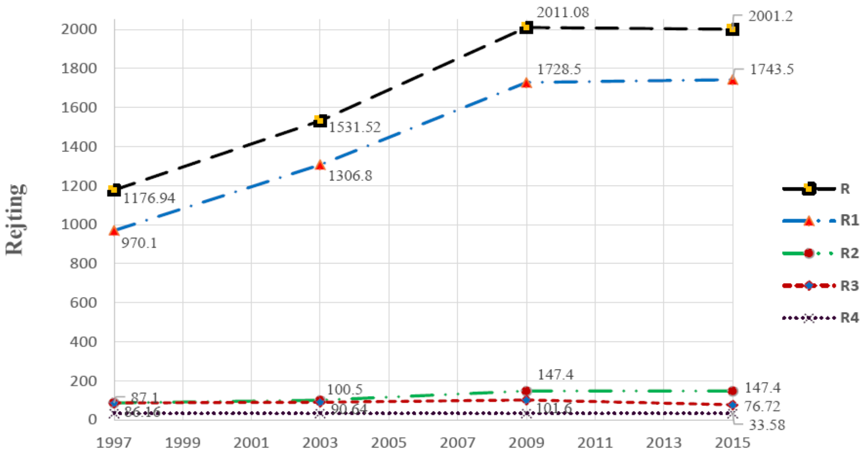

Figure 1. Change rating of the steel bridge in the center of Niš

Notwithstanding this forced intervention, the steel bridge in the center of Niš, with its extremely high rating and the first place on the rank-list of priorities after the main inspection of bridges of 2009 required an urgent and serious repair.

Unfortunately, this did not happen, and in 2014 there was a new, considerably larger destruction of the upstream pedestrian sidewalk. By the end of 2014 and beginning of 2015, prefabricated elements were replaced with steel fiber reinforced cast concrete. As early as in spring 2015, newly built sidewalk exhibited numerous cracks. Even though the damage was detected, the main inspection of 2015 evaluated the new sidewalks with the best mark – “good”, but the deterioration of other bearing elements of this bridge made its rating of 2015 extremely high (2001,2), and the bridge remained at the first place of the rank-list of priorities.

Notwithstanding the performed works on replacement of concrete slabs of pedestrian sidewalks on the bridge opposite the entrance to the Niš fort, it remains on the first place of the rank-list of priorities after the inspection of 2015 because it has an extremely high rating (in the class of bridge status rating 6), which calls for an urgent repair of bearing structural elements, i.e., maintenance type 6.

4. RECONSTRUCTION OF STEEL BRIDGE

The calculated rating of the bridge of R = 2001.2 far exceeds the limit of the status category - **"collapse imminent"** and required a maintenance category **6** where an immediate undeferrable rehabilitation is required. Because of this, the bridge is closed to road traffic.

Although the assessment of the bridge by BMS required urgent rehabilitation and reconstruction, it was only done in the period from February 2020 to mid-2022.

All registered degradations and damages that have been repaired with the corresponding amounts are entered into the bridge database in this bridge management system. According to the proposed BMS methodology, in addition to structural parameters, parameters affecting the structure, traffic profile parameters, bridge equipment and traffic safety parameters, bridge geometry parameters, location parameters, traffic intensity and maintenance parameters are also significant, i.e. with associated importance factors are taken into account. Based on the assessment of the condition, a characteristic number, the rating of the bridge, is calculated. Based on the assessment of the bridge, the general condition of the bridge is determined, as well as the type or type of maintenance.

5. NEW RATING OF THE STEEL BRIDGE

After the reconstruction of this bridge was completed, the author of this paper made a new assessment of the bridge structures in 2022. The new rating obtained is **534.72**, which represents a maintenance category **3** and requires typical **investment maintenance** of the bridge.

Despite the extensive reconstruction, the condition class of the bridge was returned from 6 (urgent rehabilitation) to 3 (investment maintenance). Therefore, by repairing bridge structures, the condition class of the bridge can be returned to one of the previous classes, but not to condition class **1** (new bridge).

This is why bridge structures need to be maintained in a timely and quality manner.

According to the new Rulebook [7], monitoring the state of bridges and determining damage is done according to a unique methodology, with the following types of inspections:

- Regular examinations;
- Control examinations (before and after winter);
- Systematic examinations (once in 5 years);
- Major inspections (once every 10 years);
- Special examinations;
- Extraordinary examinations.

FUTURE STATUS FORECAST

When there is an updated database from the inspections of bridge structures, on can define time bridges spend in a certain status. Using deterministic model, based on the time bridges spend in a certain class of status rating, one can determine the trajectory of bridge structure deterioration and establish the rating class of bridge status in the future. New bridge structures start from the status rating class "1" and
6. they successively pass through every following class of status rating, until the worst status "6" is reached. On the basis of regular inspections of bridges status change in time in Niš, the time bridges spend in certain rating classes was established, and the shortest time required for a new bridge to reach and impermissible status rating "6" was obtained, and it amounts to 42 years, if no interventions are undertaken and no investments are made in maintenance and repairs. It is comprised that bridge structures must not dwell in the status rating class "6".

The key question is: what social community can afford to “replace” the bridges every 40 years?

Number of bridges in the status rating class 6 is only provisional (it is comprised that bridge structures cannot dwell in the status rating class "6"), because “consistent implementation” of such “cheap” strategy – “do nothing” or “wait”, will lead to their certain collapse. Therefore, using such “cheap” maintenance strategy “do nothing” which does not incur any direct costs, will result in the shortest service life of the bridge. For these reasons, it is imperative to plan the bridge structure maintenance activities, which would extend the service life of the existing bridges with the reasonable costs.

Is imperative to plan the bridge structure maintenance activities, which would extend the service life of the existing bridges with the program of preventative maintenances, both at the individual and network level, selection and choice of strategies and programs for maintenance and reconstruction. It is necessary, replacement of structures based on the life-cycle cost analysis method optimization of works and on selection and manipulation of immense number of necessary data for all the bridges in the available resources, instead of the management approach of tackling the “first and worst”, regarding that the level of finances is far below the requirements for reconstruction and revitalization of all inadequate bridge structures
7. for which structural and functional deficiencies are detected.

CONCLUSION

Management of bridges and other structures within a transportation network is very complex system with a high number of extremely diverse but mutually closely connected and dependent activities.

The damage of the bridges on the roads are undesirable, but an expected and inescapable event. The modern BMS helps us to reduce the damage as much as possible, and to guide us as to what and in what order should be repaired. It is often heard that the BMS is the skill in finding the best answer to the questions:

- what ?
- where ?
- when ?
- how much ?

The answer to the first two questions is provided by thedatabase of bridge inventory and the report on the bridge inspection, if it registered damage.

The second two questions get an answer in the management system, through the ***engineering judgment*****,** and the ***economic considerations*** both at an *individual bridge level* or at the *network level*.

For provision of the planned and good quality optimum bridge management, it is very important to have a certified engineer with knowledge and experience in designing and building of bridge structures as a responsible person who manages the database and the bridge inspection results.

The author of this work intensively continues research, in order to monitor all events related to bridges with quality and reliability, predict changes in the future, plan and program works with the most favorable technical and economic effects.

In this way, it develops its own modern, efficient and up to date BMS.

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HOUSING CRISIS: CO-LIVING AS A SOLUTION

Katarina Medar[1], Sonja Petković[2]

Abstract

In search of a better life and greater opportunities, an increasing number of people are moving to urban areas. Current research dealing with the "housing crisis" and population migration to urban areas predicts that the number of people living in urban areas will double in the next 3 decades, and therefore the need for housing will become one of the main issues. Rapid population growth in cities could lead to a number of problems. Among other things, one of the main ones that will be highlighted are precisely the modalities of population settlement.

If we take into account the information about the future urbanization of the planet and the increase in the number of people who will inhabit cities in the coming years, it is inevitable that the need for housing will become one of the main issues. The demand for good real estate and apartments for rent at reasonable prices and in good locations is already a challenge for most, and the projections are also negative. In order for all of the above not to lead to deeper and more dangerous problems, the problem should be approached seriously and specific actions should be offered that would follow the migration of residents to urban areas.

Co-living housing is an alternative, relatively new housing concept that can positively respond to the above-mentioned problems. It represents a modern form of housing and communal life that brings together different people under the same roof. Tenants rent their housing units, which are mostly small in size, and that's why centers of this type allow them to use common rooms and enjoy their amenities. This housing concept is more present in larger, more developed cities where the problem of finding apartments is more pronounced. Some of the main characteristics of this residential typology are economic affordability and a significantly increased accommodation capacity per square meter compared to conventional typologies. Active implementation of such projects can respond positively to the effects of the "housing crisis" and contribute to solving the problem.

Key words: *Housing, Co-living, Alternative housing, Housing crisis, Residential units*

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INTRODUCTION

The situation in the housing market in cities cannot be generalized, but certain common problems can be observed globally. Urbanization, technological progress, and migration, as characteristics of contemporary life, greatly influence the housing market. Challenges such as the lack of housing stock and unaffordable prices persist for the population in urban areas, with young adults being a particularly affected
1. group.

The persistent presence of these issues is commonly referred to as the housing crisis, which has been a global concern, particularly pronounced in the last decade. In response, contemporary society is continuously exploring new housing modalities that aim to address the housing crisis and accommodate the evolving needs of modern lifestyles [1].

This paper investigates Co-living as a relatively new alternative housing typology. This modern concept involves the arrangement of minimal, often standardized, housing units, which are complemented by a range of shared facilities. By analyzing reference examples from various locations worldwide, this study examines the fundamental characteristics of Co-living. This emerging housing typology is predominantly found in urban areas and is distinguished by high population density, fostering social interaction among residents, and economic viability. All the mentioned characteristics make this typology modern, appropriate, and show its capacity to respond positively to current problems in the field of housing in urban areas.

The subject of this paper is the analysis of Co-living housing concepts, along with an overview of their characteristics and advantages. The first part of the paper deals with the housing crisis and presents a theoretical overview of the concept of Co-living housing. In the second part of the paper, an analysis of selected centers of this type is performed, and their main characteristics are presented. The end of the paper contains a discussion and a conclusion in which a comparative analysis will be found and an overview of the obtained results will be made.

The objective of this research is to determine how Co-living housing, with its characteristics, can respond to the problems caused by the housing crisis and be one of the options for housing today. Also, the goal is to get acquainted with the
2. typology of the Co-living concept, as well as to examine basic design principles.

HOUSING CRISIS

The right to housing has always been a fundamental and essential need for individuals. Living space goes beyond physical shelter, it must respond to certain needs and satisfy certain standards. Housing adequacy requires meeting various criteria, including economic affordability, housing security, infrastructure quality, physical accessibility, and suitable location. Frequent and massive deviation from the above-mentioned characteristics leads to social problems—the "Housing crisis".

The term "Housing crisis" has been used for more than a century by planners, theorists, and critics. This problem is present globally and constantly, to a lesser or greater extent, mainly as a result of political and economic circumstances in a territory, state, or even globally. The housing crisis is the result of a widespread capitalist system and can no longer be seen as a fault in the system but as a feature of it. Namely, it can be said that the intensity of the housing crisis and the pressure on the population just vary in different circumstances. In the current global economy, real estate has taken precedence over industrial capital. Urban development and housing have become the main processes governing contemporary global capitalism [2].

Intensive global urbanization and significant population migrations to urban areas have the greatest impact on the current "Housing crisis". These phenomena directly affect the fact that in big cities, the prices of residential real estate are constantly increasing and the adequate available housing stock is decreasing. Urbanization, class changes, the rise of the middle class, and accelerated technological development are actively reshaping the built environment and influencing the demand for housing in both the short and long term.

The latest United Nations research predicts that the world's population will grow by 2.9 billion over the next 33 years and potentially by another three billion by the end of the century. In parallel, migration to cities is expected to continue, so it is predicted that by 2100, 80-90% of the total population will live in cities [3].

If we take into account the predictions related to the further growth of the urbanization of the planet and the increase in the number of people who will inhabit cities in the coming years, it is inevitable that the problems in the housing sector will only deepen. The demand for good real estate and apartments for rent at reasonable prices and in good locations is already a challenge for most, and the projections are also negative.

Due to the unstoppable process of urbanization, growing environmental problems and increasing social differences, there is a need to develop new housing models that will set new ecological and social parameters [4].

Research shows that in the last 12 years the price of residential real estate has increased by 27% (real price growth, 84% nominal price growth) at the global level [5].

The increase in real estate prices and rent affects the middle class the most, and young adults stand out among them. In order for all of the above not to lead to deeper and more dangerous issues, the problem should be approached seriously and specific actions should be offered that would accompany current world trends and positively respond to the housing crisis.

3. CO-LIVING HOUSING – THEORETICAL REVIEW

Co-living represents a new housing typology that is increasingly used and popularized. The main feature is living in a rented space that contains spacious common areas and smaller private residential units, which are fully equipped and managed by an independent administration.

This type of housing represents a modern form of communal living that brings together different people under the same roof. In this way, they are enabled to use more space and enjoy various amenities (Figure 1). This housing concept is more prevalent in larger, more developed cities, where the problem of finding apartments is more pronounced [6].

Figure 1. and 2. Illustration of Co-living (left); Population inhabiting Co-living centers (right) ((http://www.katielukes.com/); (https://flocolive.blogspot.com/2018/12/co-living-rent-lifestyle.html)

The population that inhabits Co-living centers mainly consists of students, digital nomads, and employees who are at the beginning of their careers, as well as individuals who move from city to city and travel the world (Figure 2). Compared to traditional apartments that can be rented, the residential units of the Co-living center are more affordable, offer greater flexibility and different possibilities. Living together is a way to live, work and share everyday life with like-minded people [7].

Co-living housing represents the improvement of life in the city while facilitating life in the community. This concept simplifies the process of finding people to share a living space with, offers cheaper places to live, and designs attractive and modern homes for the younger population [8].

The main motives are described as follows:

- Achieving affordable living by sharing living space and costs;
- The possibility of users socializing;
- Achieving a more spacious living space and better content at a lower price;
- The possibility for users to participate and contribute to the community according to their wishes or financial situation, etc. [9]

Users of Co-living centers can change centers globally. They can search, book and travel from city to city and thus change their place of residence. Each Co-living center offers certain services depending on where it is located. In most cases, the Co-living center concept contains individual bedrooms that tenants rent, and furnished common rooms that they share with each other. Because of this description of the concept, it is often found in the literature that such centers are also called homes for "adults".

Unlike some communes, people who choose to live in a Co-living center are not separated from the world outside their living space. They normally communicate with the world, they just choose to live with like-minded people [10]. In this concept, the emphasis is on the sense of community and the sharing economy. These are one of the main reasons why Co-living housing is increasingly being implemented and built around the world.

The Collective Old Oak Co-living, 2016, London, United Kingdom

A large part of the population in London is faced with the problem of housing, which is either expensive or inadequate. They are constantly pushed out of urban centers, isolated and marginalized. The designers, in cooperation with the start-up The Collective, worked on creating a strategy for new and affordable ways of living for young professionals, based on high density, socialization and togetherness [9].
3.1. This is how The Collective Old Oak Co-living, one of the most recognizable projects of this typology in Europe, was created (Figure 3).

Old Oak Co-living is currently the largest Co-living center in the world. As a project, it was created between the British initiative for Co-living housing, The Collective and the architecture office PLP Architects. The vision of the architects was to create a space where one will live, work, create, exchange, socialize and have fun, all with the aim of achieving the impression of a vertical neighborhood. The regeneration project is estimated to have cost around £10 billion [11].

The facility was built in 2016 in the western part of London at a location that is 20 minutes by subway from the city center. The building consists of two thin tracts that slide over each other. Where the two volumes overlap, a central common space is formed, which aims to improve the possibilities for interaction between the tenants.


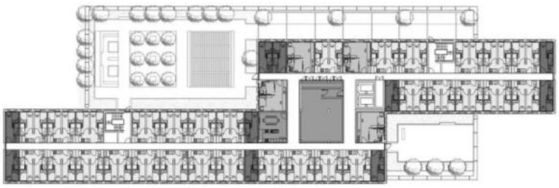

Figure 3. and 4. Co-living Center Old Oak (left); View of a typical floor of the Old Oak Co-living Center (right)
(https://1-content-s3-estateweb.s3.amazonaws.com/assets/8731/files/HS2%202.jpg); (https://architektura.muratorplus.pl/galeria/alternatywna-architektura-mieszkaniowa,7076/4173/38897/?full=1/)

Old Oak Co-living Center contains 545 micro-units for rent, making it currently the largest center in the world. Higher floors are intended for tenants and consist of residential units, shared kitchens, and laundry rooms, while the roof contains a spacious terrace that is used for gatherings and organizing events. The residential units are fully equipped and their minimum lease is four months (Figure 4) [12].

There are two types of housing units that this center offers, type 1 and type 2 (Figure 5). The Type 1 unit is a bit larger. In addition to a bed, a desk, a wardrobe and a bathroom, it also has its own kitchenette. Its square footage is 12m2. Type 2 residential units are smaller in size, and two units share a kitchenette and a table located in their lobby. The square footage of the residential unit type 2 is 10m2.

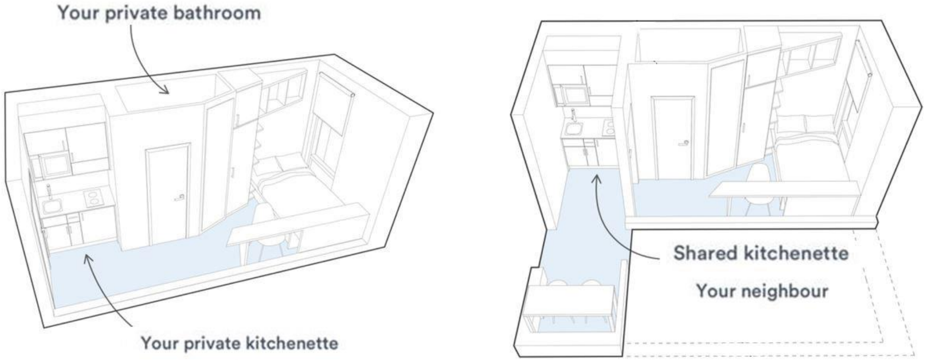

Figure 5. Display of the types of housing units of the Old Oak Co-living Center (https://www.thecollective.com/locations/old-oak)

Since the residential units are of minimal dimensions, the common rooms on the floors aim to be their continuation. Therefore, they contain spacious living rooms, entertainment rooms, kitchens, as well as many utility rooms. Common rooms are modernly designed to attract tenants to spend as much time as possible in them. This is achieved by creating a pleasant environment, choosing adequate furniture, providing interesting content, and using natural materials and colors. In front of the building there is a public area with a bar. In addition, on the ground floor there are catering areas, a large space for work (Co-working), space for public facilities, while the mezzanine has a gym, spa center, cinema and library.

3.2. Treehouse Co-living, 2017, Seoul, South Korea

The Treehouse Co-living Center project began to be realized in 2017, and was finished in 2018 by the architectural office - Bo-DAA. The building consists of six floors inhabited by tenants and the ground floor with common rooms. The center is inhabited by an international population, and currently about one third of foreigners live there [13].

Name of the Co-living center speaks of his idea of form, as well as the concept of the project. The Bo-DAA architectural bureau designed the Treehouse as a Co-living complex that will meet all the needs of the professionals who inhabit it. The building has a form of a concrete triangular lying prism, which in its bases allows light to the inner atrium, the core of this Co-living center (Figure 6).

Figure 6. and 7. View of the form of the Treehouse Co-living center (left); View of the atrium in the interior (right) (https://www.archdaily.com/932735/treehouse-apartment-building-bo-daa?ad_medium=gallery)

Since it is located in a densely built-up city core, the idea was to provide the tenants with a view of the garden and greenery as soon as they enter the building, as well as the moment before they enter their rooms (Figure 7).

m^2The building consists of 72 residential units spread over six floors. The residential units, or micro-apartments, have different layouts on each of the floors, varying in size and content. All units are designed with minimum dimensions in the form of an open plan, and there are three different sizes available: 16.5m2, 23m2, and 33m2. Each residential unit is equipped with its own bathroom, kitchenette, and combined living and sleeping area. (Figure 8).

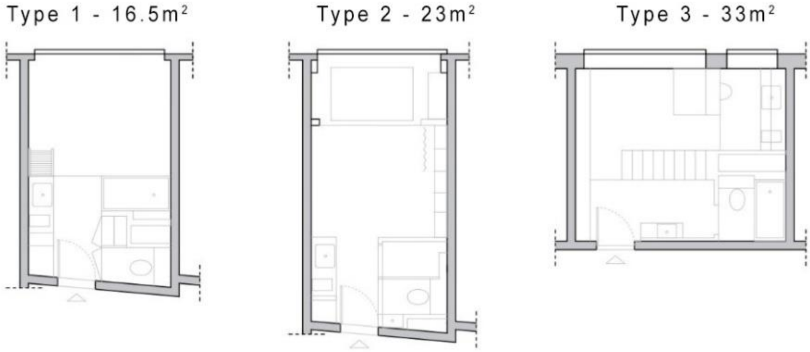

Figure 8. Presentation of the basics of typical housing units in the Treehouse Co-living Center

The majority of housing units are oriented towards the north, while there are three tracts that face the south. This design allows for large slanted windows that provide cool and consistent light into the rooms. The arrangement of furniture varies from room to room. Depending on the floor's theme and the target group of tenants, the interior decoration will also differ.

In this Co-living center, the atrium serves as the central hub for all events, and therefore, the majority of common rooms are located adjacent to it. The primary objective in the interior design of these rooms was to create a pleasant atmosphere that encourages tenants to work and socialize. Next to the atrium, there is a relaxing living room and a co-working space. Additionally, on the ground floor, there is a spacious kitchen where tenants can gather, prepare international meals, and socialize. Apart from the aforementioned facilities, this center also offers a recreation area, a laundry room, a pet bathroom, a library, a small hall for film screenings, and
3.3 a meeting room. On the fourth and fifth floors, a section of rooms was omitted on the south side to make space for a roof terrace. This terrace serves as a gathering spot for residents, offering opportunities for sunbathing, exercise, and it often serves as a designated smoking area.

Lyf One-North Co-Living Development, 2022, WOHA, Singapore

lyf One-North is a Co-living complex located in the eponymous district of Queenstown, a settlement in the western part of Singapore. One-North is a district designed as a research, development and hi-tech cluster as part of the National Technology Plan and consists of important educational and corporate facilities. In keeping with the context, the lyf One-North Co-living complex is designed according to the most modern technological and environmental standards [14]. The concept behind the lyf One-North Co-living Center goes beyond being a mere residential facility. It is designed as a community hub for the entire neighborhood, offering numerous public and semi-public open and closed spaces for socialization, work, and various activities.

This Co-living center, completed in 2022, was designed by the Singapore-based architecture office WOHA. It is conveniently located next to a major metro station, ensuring excellent connectivity to the city. The center consists of two primary seven-story cubes connected by a residential bridge. The building's form is articulated to follow the site's topography and maximize views of the surrounding built environment and Nepal hill. The construction primarily utilizes prefabricated concrete elements, contributing to efficiency. Red steel canopies on the ground floor and roof create covered common spaces, adding a dynamic atmosphere that contrasts with the natural concrete facade. (Figure 9).

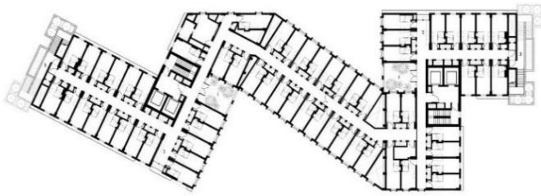

Figure 9. and 10. lyf One-North Co-living complex (left); The basis of a typical residential floor (right)
(https://www.archdaily.com/988293/lyf-one-north-co-living-development-woha)

The lyf One-North Co-living complex comprises 324 residential units distributed across seven above-ground floors. The typical floor layout features a corridor with a series of typical units, while vertical communications, common and auxiliary spaces are located in the intersections of the tracts. Two basic units were designed, a single-story unit of 12m2 and a two-story unit with a gallery of 17m2. Both types have their own bathroom and kitchenette, while the main difference is that the sleeping space is separated from the work space in the second, larger type (Figure 11).

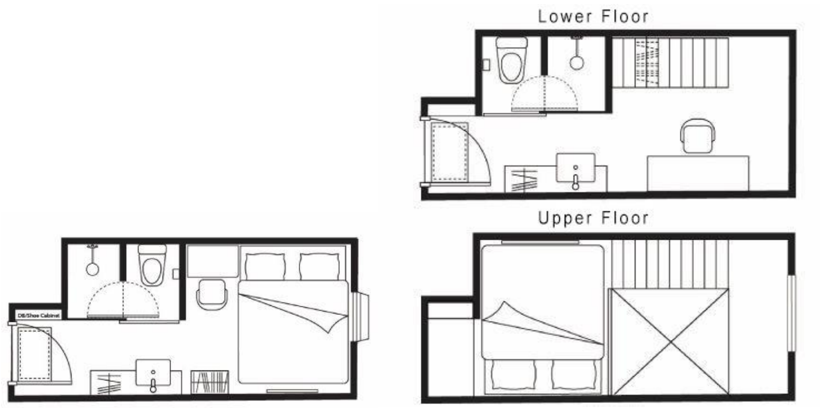

Figure 11. View of the basics of typical housing units in the lyf One-North Co-living Center
(https://www.discoverasr.com/en/lyf/singapore/lyf-one-north-singapore)

The limited size of the residential units is counterbalanced by the presence of substantial common public and semi-public spaces strategically designed across all floors. A covered atrium serves as a central public space and a connection point between tenants and other users, located beneath the bridge that connects the two cubes. On the ground floor, additional public facilities such as a conference hall, gym, laundry, and bicycle parking are available. Taking advantage of the sloping terrain, a more secluded courtyard with a swimming pool is situated on the first floor. Semi-public spaces, serving as extensions of the compact housing units, are designed on the upper floors. Common kitchens and dining rooms for group dining are available to tenants. Multiple levels feature green roof terraces, providing additional open spaces for physical activities and relaxation. The wealth and variety of content in this Co-living center complements the minimal private spaces and encourages the tenant to socialize.

DISCUSSION AND RESULTS

Researching and studying the Co-living concept as one of the representatives of
4. alternative housing, can lead to a large number of results that can serve as the main postulates in further development and influence approaches in the further design of this typology of housing.

In order to obtain the necessary knowledge and to enable a better overview of the different concepts of Co-living housing, in this paper three examples were selected that were processed through a case study (Old Oak Co-living, Treehouse and lyf One-North Co- living). According to their characteristics, all three examples are excellent representatives of Co-living housing. The research highlighted characteristics that can be classified into seven categories:

1. Type and area of the residential unit;
2. Demography and population density;
3. Common contents and common spaces;
4. Degree of interaction;
5. Length of stay and flexibility;
6. Financial aspect;
7. Location.

Co-living accommodation means a micro-apartment or a room with a bed and a private bathroom (some rooms also have a kitchenette). Table 1 shows the number of types of housing units, their areas, as well as the total number of housing units that the center consists of. It can be noted that all three centers provide a large number of housing units.

Table 1. Details of Residential Units

Serial Number	***Co-living Center***	***Number of types of Residental Units***	***Area of Residental Units (m^2)***	***Total Number of Residental Units***
1.	*Old Oak*	*2*	*10, 12*	*545*
2.	*Treehouse*	*3*	*16,5, 23, 33*	*72*
3.	*Izf One-North*	*2*	*12, 17*	*324*

The population that inhabits Co-living centers consists mainly of students, digital nomads, employees who are at the beginning of their careers, as well as individuals who move from city to city and travel the world. High-density facilities, which include Co-living centers, maximize the use of a given plot, and thus enable the construction of a larger number of units. High-density housing units are smaller in size and more economical, making them an attractive option for those looking for affordable housing options. By building vertical instead of horizontal housing (such as Co-living centers), it is possible to reduce urban sprawl and lead to the preservation of green areas.

Table 2 shows the built-up areas of the selected centers, the maximum number of residents who live in that center, and finally, the population density expressed in residents per square meter. According to derived data, Izf One-North Co-living center has the highest population density.

Table 2. Density of population

Serial Number	Co-living Center	Built up area (m^2)	Number of Inhabitants	Density of Population (inhabitant/m^2)
1.	Old Oak	16.000	545	0,034
2.	Treehouse	4.810	72	0,014
3.	Izf One-North	6.823	324	0,047

One of the biggest features of this type of housing is the contents of the common rooms. The purpose of common rooms is to provide necessary facilities to tenants and to contribute to their better quality of life. They contain everything that the tenants do not have in their private housing units, so in a way, they represent a continuation and extension of the living space. The common rooms are designed in such a way as to attract the tenants as much as possible in order to stay in them as much as possible. The interiors of these rooms generally contain bright colors, natural materials, and a large number of plants.

The selected Co-living centers are filled with a number of contents that are shown in table 3.

Table 3. Shared facilities in Co-living centers

Shared facilities	Old Oak, London	Treehouse, Seoul	Izf One-North, Singapore
Shared Kitchen	•	•	•
Shared Living Room	•	•	•
Laundry Service	•	•	•
Co-working	•	•	•
Meeting Room	•	•	•
Library		•	•
Gym	•	•	•
Roof Terrace	•	•	•
Courtyard	•		•
Café/Bar	•	•	
Cinema	•	•	
Space and Entertainment	•		•

The level of interaction among tenants in Co-living centers can vary based on the available common rooms and shared spaces. Centers that offer a greater number of common rooms tend to foster a higher degree of interaction among residents. Common areas such as living rooms, co-working spaces, courtyards, and roof terraces serve as meeting points where tenants can socialize and engage with one another.

Different Co-living centers offer different living conditions, as well as different monthly rents. What is characteristic and common to all three selected Co-living centers is that the minimum length of stay is 3 months, while the monthly rent varies from center to center. The price of a rented residential unit in the Old Oak Co-living Center ranges from $1280-$2080 per month, while the Treehouse Co-living Center charges from $1240-1640. Izf One-North Co-living center is more expensive, and charges about $4,000 per month for renting a residential unit. Prices depend on the type of rented housing unit.

The locations of the selected Co-living centers are shown in Figure 12. It can be noted that all three centers are located in cities with several million inhabitants each (London, Seoul, Singapore). Microlocations are located in densely populated areas of each city, in good locations. In this way, they ensure a good connection with other parts of the city, enable flexibility and easier transportation.

5. *Figure 12. Selected Co-living Centers*

CONSLUSION

The increasing number of non-standard typology residential buildings supports the fact that changes are needed in the way people inhabit the world, especially urban areas. The need to bypass the conventional follows the modern world and technological development. Alternative housing typologies can overcome certain shortcomings that come with standard, established settlement patterns.

Co-living housing typology has a considerable number of characteristics that, through its wider implementation, can influence the negative effects of the housing crisis in the world. Co-living housing is based on relocating as many daily activities as possible to common spaces, which brings with it a large number of characteristics that are not characteristic of conventional ways of living. Co-living facilitates supports daily socialization among users through joint dining, work and other activities. It positively affects the feeling of social equality among tenants through transparent costs, typified units and a clear hierarchy of obligations within Co-living centers. It allows saving space, i.e. it can support a large number of tenants per usable area precisely because of the sharing of space for daily activities. During the design process itself, it is planned as sustainable, and the residential units are rented as furnished, which is financially profitable and without hidden costs. Co-living housing is flexible, moving in and out is easy and fast, it can be short-term and does not involve long-term rental contracts.

All of the above characteristics suit young adults who are becoming independent in big cities and are looking for a supported life and a new functional community.

In addition to the positive features listed above, Co-living can have wider effects on cities and urban structure. Common contents are often projected as public, and the wider community directly benefits from them. The high population density associated with Co-living centers can also have a positive impact on urban sprawl. Smaller residential units and sharing of common rooms affect energy reduction, savings and consequently fewer carbon emissions.

Incorporation of the Co-living typology in housing strategies, carefully planning these types of centers and increasing their number can reduce the negative effects of the housing crisis and bring about positive changes.

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THE EXPERIENCE OF TERRITORIALITY IN THE LIVING SPACE

Đorđe Alfirević[1], Sanja Simonović Alfirević[2]

Abstract

Territoriality is a term that is widely used in science and other areas of human activity. Usually, this term refers to a pattern of behavior of a person or group that is based on the need to control the physical space, object or idea. It can also be seen as the user's level of tolerance and willingness to share the same spaces and content with other people. Although the phenomenon of territoriality has already been researched to a considerable extent in the field of architecture, there are fewer studies in which the presence of territoriality has been analyzed in residential spaces. The subject of this research is the experience of territoriality in the domain of residential spaces, specifically in an apartment or a house.

The research starts from the analysis of the reference literature in which territoriality in residential areas was discussed, and then moves on to the analysis of the presence of territoriality among users in characteristic models of housing units (apartment for singles, for families with one, two and three generations and for coliving communities). After the synthesis of the obtained information, different levels and intensities of the experience of territoriality arising between users, facilities and visitors in the previously mentioned housing models will be compared.

The aim of the research is to examine which aspects influence the emergence and change of the intensity of the experience of territoriality in the residential space, as well as to reconsider the view that the experience of territoriality in the residential space is always present, but of different intensity depending on whether a reaction occurs to the presence of visitors, facilities or other users.

Key words: *Architecture, Territoriality, Living space, Apartment, Coliving*

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1. INTRODUCTION

The polemic about territoriality started at the beginning of the 20th century and initially related exclusively to the description of animal behavior[3]. Prominent researchers who contributed to the clarification of this term[4] are Conrad Lorenz [1] and Robert Ardrey [2], whose research pointed to an analogous aspect of territoriality in human behavior. According to the psychologist Robert Sommer, territoriality is related to an area controlled by an individual, a family or a community, which implies physical possession and even defense [3]. For this topic, the observation of Proshansky, Ittelson and Rivlin is significant, who claim that "the inner determinant of territorial behavior is (the) desire to maintain or achieve privacy [4]." The observation of psychologists Stanford Lyman and Marvin Scott is very significant because they recognized the existence of four territorial zones: public territories, home territories, interaction territories and body territories [5], which in a sense coincides with Hall's spatial levels that exist around of each individual [6]. Michael Efran and James Cheyne state that when two people interact, they share the space between them. The shared space can be considered a jointly owned territory, i.e. as Lyman and Scott would say "territory of interaction" [7]. Based on the analysis of numerous characteristic scientific interpretations, the following basic characteristics of the experience of territoriality in humans can be stated:

a) *Sense of control and ownership* - when a person considers the territory his own, he develops a sense of control and ownership over that space;
b) *Sense of belonging and identity* - people tend to identify with the territory they consider their own, whether it is their home or some other space;
c) *The desire to defend* - when a person feels threatened, he tends to defend his territory;
d) *The desire to maintain or achieve privacy* - occurs as a reaction to the presence of a visitor, object or other user;
e) *Emotional connection* - the territory can be a source of emotional connection and comfort. People often feel more relaxed and secure when they are in an environment they know and consider their own;
f) Occurs at different levels, which indicates the existence of a hierarchy.

2. TERRITORIALITY IN HOUSING AND RESIDENTIAL SPACE

The experience of territoriality has also been extensively explored in architecture, especially in the area of housing.[5] One of the characteristic researches in this area is the study of Suzanne Marie Barclay, where the focus of interest is the appearance of territoriality in the so-called public housing. Discussing the need for human beings to defend the physical space they inhabit, Barclay states that "The concept of territoriality describes the need to control one's environment, to stake out and defend one's turf. [8]" According to her, one of the oldest divisions of space in history began with the appearance of the "threshold", a physical element that separates the private zone from the public space. Architect Oscar Newman, in his work advocates for the

[3] It is believed that the term was first applied in 1903 by the ornithologist Charles Moffat in his work "The Spring Rivalry of Birds", and twenty years later the term began to be applied to the rest of the animal world as well [19], [11].
[4] See: [2], [6], [5], [20], [7], [26], [4], [21], [22], [23], [1], [24], [25], etc.
[5] See: [14], [15], [27], [12], [13], [11], [8], [28], [29], [30], [31], [16], [17], [32], [10, [18], etc.

establishment of a hierarchy of space based on territoriality, i.e. for division into: private, semi-private and public spaces. In his opinion, this division encourages territorial behavior among the inhabitants [9]. In the research entitled "The role of territoriality in the spatial organization of the coliving community", the authors point out that the experience of territoriality is the level of tolerance of users and the willingness to share the same spaces and contents with other people, and at the same time the primary parameter from which different concepts of coexistence in shared space arise [10].

Based on numerous researches on the existence of territoriality among individuals and groups on a wider scale, in nature and external, urban or architectural space, it can be stated that there is an equivalent behavior of users in the interior living space, although the spaces of the apartment and house are usually considered to be individual, i.e. private zone [11], [12], [13], etc. Irwin Altman and William Haythorn note the presence of territorial behavior in living space in terms of "degree of consistent and mutually exclusive use of particular chairs, beds, or sides of the table" [14], which Altman will soon characterize as possessiveness towards forms or spaces [15]. This point of view is significant because it indicates the existence of territorial behavior towards forms (objects) and not only towards spaces (premises). At the apartment level, territoriality can be manifested in several ways:

a) *as a need for space arrangement* - a person who experiences territoriality usually likes to arrange his own space according to his affinities and needs, thus giving the space his own personal character;

b) *as a feeling of protection* - a person who experiences territoriality has the need to protect his space from external influences, by locking doors, installing security systems or simply maintaining hygiene and cleanliness;

c) *as a sense of belonging* - a person who experiences territoriality usually associates his home with a sense of belonging and attachment, considers his apartment his personal space and feels comfortable and relaxed in it;

d) The experience of territoriality in the apartment can also be influenced by the *design and organization of the space*, because some spaces may be more open, more visible and attractive to users, while others may be less open and less visible;

e) *The personal experience of space* is also an important factor in the experience of territoriality. For example, a person who feels insecure may have a stronger sense of territoriality and be less open to others.

Although a living space is usually considered as an intimate space of a user or a group of users, different levels of privacy and intimacy can be observed within an apartment or house, depending on the number of users of the space who share certain contents - such as rooms or furniture / equipment. Daniel Steding believes that there are three groups of spaces within the functional organization of a coliving community: primary, secondary and tertiary, each of which corresponds to a different level of privacy or community. A similar classification is proposed by Rachel Osborne, who mentions primary, secondary and tertiary territories [16]. Primary spaces are rooms such as the living room, kitchen, dining room, etc., which are used in common. Secondary spaces are shared, such as hallways, bathrooms, toilets, etc., they are intended for everyone, but are usually not used at the same time. The tertiary group consists of private spaces with the highest level of intimacy and security [17].

The disadvantage of this classification is that the use of the kitchen and dining room is a specific way of sharing space that certain users are not ready for due to hygiene habits, which can cause certain functional problems. Also, these spaces are often not used in groups, but individually and in different intervals, which raises the question of whether these spaces belong to the first or to the second group (shared spaces). On the other hand, the corridor does not belong to the group of intimate spaces, but to another group that users occasionally and jointly use.

In the research "Influence of boundary materiality on the experience of territoriality in housing", the authors analyze the way in which spatial borders produce different degrees of privacy and allow people to control their own activities and the activities of others [18]. The significance of this research is also that territoriality is considered in the residential area, from the aspect of the residential community, building and unit. The authors state that in a residential unit (house or apartment), as the primary level of use of residential space, different levels of territoriality can also be recognized, which are determined on the one hand by borders, while on the other hand they are conditioned by the relationship between the user and the space. The first level is determined by the physical boundary of the private space of the residential unit towards the surrounding public space and indicates the privacy boundary of the household. The second level occurs in situations with a clear division into social and private spaces in the housing unit and marks the presumed hospitality boundary for visitors. This is the limit to which the guest is usually introduced, if he is not well known. In the case of compound living spaces structures, it is usually the border around the family social spaces, such as the living room, salon or cabinet, less often the dining room and kitchen. The third level is determined by the physical boundaries between intimate and family spaces and determines the intimacy boundary between family or household members. A special type of boundary occurs in coliving spaces, the so-called separation boundary, which separates intimate spaces from other spaces that users occasionally share (e.g. kitchens and bathrooms), to which they can be particularly sensitive due to hygienic conditions and the frequency of maintenance [10]. (Fig. 1)

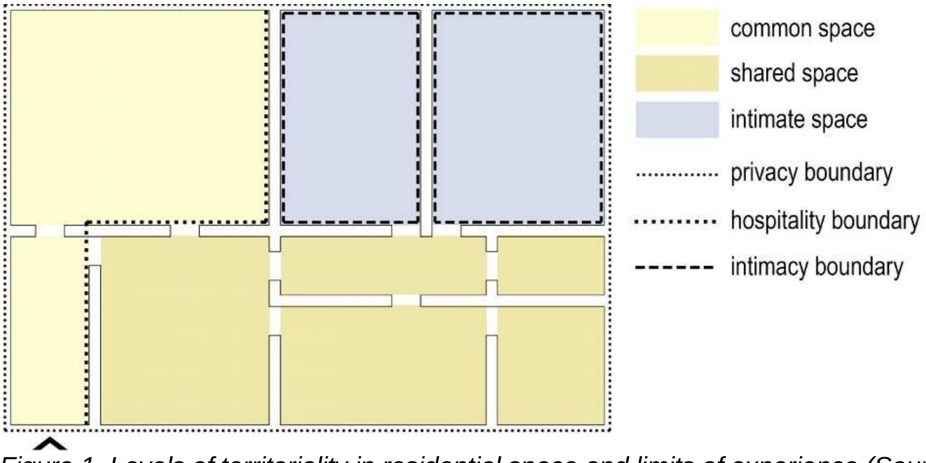

Figure 1. Levels of territoriality in residential space and limits of experience (Source: author's illustration)

3. TERRITORIALITY IN PARTICULAR MODELS OF HOUSING UNITS

3.1. Apartment for one person

Although singles do not share their living space with others, they still feel a certain level of territoriality in their apartment, because they consider it their private space, a place they own and have control over. In addition, even though they spend most of their time in the apartment alone, singles often create different zones within their apartment, which they use for different activities and also perceive as their own. For example, the bedroom can be an intimate zone, while the living room can be a zone for socializing and relaxing. Singles can feel territorially threatened when someone else enters and stays in their space for a while. For example, when they invite guests to their apartment, they may feel uncomfortable if the guests do not respect their privacy or some of their rules. This can be especially evident if the guests do not know the rules that the singles have set for their apartment, which primarily depend on their lifestyle. It is important to emphasize that territoriality is an individual experience and may differ from person to person. While some singles may have a strong sense of belonging and control over their space, others are less attached to their living space and consider it just a place to sleep and stay. For single people, their living space is entirely an intimate zone, because they generally do not share it with anyone, except in situations when they have visitors. In such circumstances, the following categories can be differentiated: a) *social space*, which is intended for visits and which the guest can use freely without disturbing the privacy of the owner, b) *shared space*, which the guest can use conditionally, because the owner can in certain circumstances feel discomfort due to someone else's presence, and c) *intimate space*, which contains the owner's most intimate things in the apartment and is not intended for use or viewing by the guest (Fig. 2). It is important to bear in mind that this is not a universal categorization and that the territorial structure of living space for one person may differ in different cultures and social contexts.

Fig. 2 Experience of territoriality in a living space for one person: 1) Domestic Transformer Apartment, Hong Kong, G.Chang, 2007; 2) Residential neighborhood west of Dr Ivana Ribara street, Belgrade, D.Marušić, M.Marušić, Đ.Alfirević, 2011, competition work; 3) Residential neighborhood in Ovča, Belgrade, D.Marušić, M.Marušić, Đ.Alfirević, 2011. (Source: author's archive).

3.2. Apartment for one generation

Territoriality in an apartment where one generation lives - a married couple, father and mother or grandparents, is expressed in a similar way as in an individual, but it can differ in relation to the dynamics of mutual relations between users, and the layout of the rooms. In such an apartment, the bedroom is usually intended exclusively for the private use of the household members. Precisely because of this, this room usually represents a "sacred place" characterized by intimacy and privacy of the highest degree. The living room is usually a room where the social life of the family takes place, and it is intended for gathering and socializing. However, in the living room, certain parts can be intended for individual use, for example a work space or a space for some activity that one of the household members performs independently. The kitchen and dining room are also common areas, but are often used interchangeably, depending on who is cooking and who is motivated to eat. The bathroom and toilet are used mainly for the private needs of household members. In these rooms, each member has his own equipment, which is why certain segments of the space can be personal. Based on the above, territoriality in this type of apartment is expressed through clearly defined boundaries between common and private spaces, but also through the dynamics of mutual relations between household members. (Fig. 3) In the situation of a visitor's arrival, the territorial structure of the space is similar to that of a residential space for one person, with the difference that the bedroom is completely excluded from the possibility of visiting or use by the guest, because it represents the most intimate part of the apartment. As with the one-person dwelling, this structure of territoriality can vary according to culture, social norms and customs. Also, there can be various situations and circumstances that can affect the dynamics of mutual relations and the arrangement of rooms, for example if there is a need to adapt the space for a new family member or if some unforeseen situation occurs such as an illness or an accident.

Fig. 3 Experience of territoriality in a living space for one generation: 1) Housing for the elderly and CAP in the 22, Barcelona, Gina Barcelona Architects, 2020; 2) MC2 Housing, Vancouver, James KM Cheng Architects, 2018; 3) Residential neighborhood in Ovča, Belgrade, D.Marušić, M.Marušić, Đ.Alfirević, 2011. (Source: author's archive)

3.3. Apartment for two generations

In an apartment where two generations live, territoriality manifests itself in a different way compared to an apartment where only one person or one generation lives. Since a larger number of family members use the space at the same time, privacy and intimacy are more compound topics that are treated differently compared to other housing situations. When designing such an apartment, the rooms are often organized so that there is a clear boundary between the space used by one generation and the space used by the other generation. For example, the parents' and children's bedrooms can be located at opposite sides of the apartment, and common rooms like living room, kitchen and dining room are used by all persons in the house. As a rule, sleeping rooms are intended for individual use, so parents and children usually have their own personal rooms that are adapted to their needs. However, common rooms can be where the family's social life takes place, which can pose a certain challenge in maintaining relationships between family members. In a housing situation where two generations live, there is often a sense of belonging and ownership of the space or parts of the space. Given that family members know each other and have long-term relationships, the sense of territoriality can be stronger and manifest differently in relation to situations in which people who do not know each other. (Fig. 4) The specificity of this model is that the parents' room and the room for two children are perceived simultaneously as personal and as a shared space, which is especially evident in the children's room shared by two brothers, two sisters or a brother and sister (the most complicated situation). It is important to keep in mind that long-term relationships and closeness between family members can lead to a stronger sense of belonging and ownership of space, which can be a source of conflicts if an adequate balance between privacy and shared spaces is not achieved.

Fig. 4 Experience of territoriality in a living space for two generations: 1) Block 21, Belgrade, M.Čanak, L.Lenarčić, M.Mitić, I.Petrović, 1965; 2) Block 61 and 62 the southern part, Belgrade, D.Marušić, M.Marušić, M.Miodragović, 1978; 3) Block 23, Belgrade, 1974, B.Janković, B.Karadžić, A.Stjepanović (Source: author's archive)

3.4. **Apartment for three generations**

In an apartment where three generations live, territoriality can be expressed in different ways depending on the dynamics of the user relationship and the layout of the space. There are usually clearly grouped common rooms, such as the living room, kitchen and dining room, which are used for shared activities and socializing, while there are also rooms intended for intimate activities of each generation, for example bedrooms. Grandparents, as the oldest (third) generation, usually have their own room or part of the apartment where they can retreat and have privacy. Parents and children usually have separate bedrooms, while the living room, kitchen and dining room are used as common areas. In three-generation apartments, the layout and way of using the space is often adapted to the dynamics of life and the needs of each generation. For example, parents often adapt to the schedule of school and extracurricular activities of children, but grandparents may also have their own rituals and habits that affect the way the space is used. Territoriality in such apartments can also be manifested through certain boundaries and rules that are established in order to maintain privacy and harmony between generations. For example, a certain room may be considered "sacred" and each family member must respect the privacy of whoever uses it. Also, certain rules for the use of common rooms can be established, as well as rules of behavior in accordance with that. (Fig. 5) Three-generation apartments, as larger residential structures, usually contain at least two bathrooms or a bathroom and a toilet. In order to prevent potential territorial problems, it is recommended that each generation has a separate bathroom within the zone of their room. The exception is children's rooms, which can have a shared bathroom. This way of organizing the space also enables the existence of different generations in the apartment, because each of them has its own space that it can use according to its needs. Also, it would be useful to note that children's rooms with a shared bathroom are often a practical solution, especially if the children are close in age, so that their activities can be coordinated. However, in the case when the children are not close in age or when there is a significant difference in their habits and needs, separate bathrooms are a preferable option.

Fig. 5 Experience of territoriality in a living space for three generations: 1) Block 11, Belgrade, M.Vujović, 2010; 2) Interior Golić, Belgrade, Đ.Alfirević, S.Simonović Alfirević, 2018 (Source: author's archive)

3.5. **Apartment for coliving community**

In coliving communities, territoriality is expressed in different ways compared to the traditional way of living. Coliving communities are typically designed to enable the sharing of common space and resources, which can influence the way territoriality is experienced and expressed. Members of a coliving community usually have their own private rooms, which are considered intimate space, while shared space is considered common space. Common space may include a kitchen, living room, recreation areas, workspaces, and other similar rooms. In such communities, members are often expected to feel comfortable using the common space and to actively participate in common activities. Furthermore, in coliving communities, the emphasis is on shared values and lifestyle, so members can feel a greater sense of connection with other community members and less evident individual territoriality. However, there may still be some kind of ownership over certain objects in the shared space or over certain parts of it, which can affect the sense of territoriality. (Fig. 6) For example, some members may consider certain parts of the shared space as "theirs" because they have used them more frequently (e.g., a chair in the living room or a seat at the dining table) or because they have been the ones to arrange and maintain them (such as the shared kitchen area or bathrooms). Other members may be less attached to specific parts of the shared space and may perceive them merely as a place for communal use, thus not understanding why another member is so protective of that area. These differing interpretations of ownership over the common space and resources can lead to conflicts. Therefore, it is important to establish clear rules and guidelines in coliving communities regarding the usage and maintenance of shared space and resources, which can help reduce conflicts and feelings of territoriality.

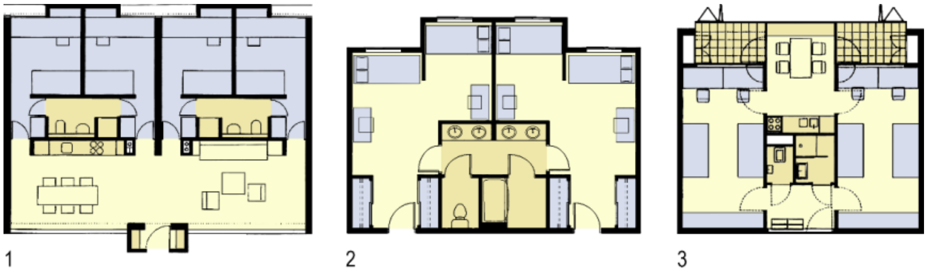

Fig. 6 Experience of territoriality in a living space for coliving community: 1) Casa dell'Accademia, Mendrisio, C.Barchi, J.Könz, L.Molo, 2006; 2) Casas del Rio, Albuquerque, Todd & Associates, 2015; 3) Student Housing Poljane, Ljubljana, M.Bevk, V.Perović, 2006. (Source: author's archive)

4. DISCUSSION

The experience of territoriality in residential spaces depends on several different factors, primarily on: a) the size of the space, b) the structure of the space, c) individual differences among space users, d) environmental characteristics, e) cultural factors, and f) the relationships among household members. This study primarily focused on the first two, the physical factors of residential space.

Space size - the smaller the residential space, the more likely household members will feel cramped, which can lead to increased territoriality and a sense of protectiveness. This is particularly evident when household members have less space than they need for comfortable living. However, if household members are satisfied with the size of the space and do not feel cramped, then a smaller space will not necessarily lead to increased territoriality. On the other hand, a larger residential space can provide individuals with a greater sense of privacy and intimacy, empowering them to create their own personal zone. However, if household members utilize space larger than their basic living needs, then a larger space will not necessarily result in a stronger sense of territoriality.

Space structure - the physical layout of the space and the types of rooms can influence which parts of the apartment are considered private and which are shared. Additionally, room size, ceiling height, the number of windows in a room, the presence of a balcony, and other physical elements can affect the intensity of the experience of territoriality, as individuals are less likely to share or give up favorable conditions in a space where they feel comfort and pleasure.

Individual differences among users - each individual has their unique experience of territoriality and a sense of privacy, which can be related to their personal preferences and past experiences.

Environmental characteristics - if the residential space is located in an unsafe environment, it can intensify the sense of territoriality. Additionally, features of the environment, such as proximity to shops, parks, or other significant locations, can influence the sense of territoriality.

Cultural factors - tradition, customs, and learned values can influence the experience of territoriality. In some cultures, privacy and individuality are highly valued, while in others, communalism and connectivity are emphasized more.

Interpersonal relationships among household members - if the relationships within the user group are positive, it can lead to a less pronounced sense of territoriality, while negative relationships can intensify the sense of territoriality and the need to protect one's private space.

The intensity of territoriality can be stronger in individuals (singles) who feel more connected to the space they inhabit, while it may be less pronounced in others who share the space, as they may be less attached to the shared or rented space. Ownership (or occupancy) relationships can also have a significant impact on the intensity of territoriality, such as in the case of shared living spaces or when an individual lives in a rented apartment they do not consider their own. By analyzing characteristic models of residential spaces, different levels of territoriality among users can be observed, which are summarized in the table

Table 1. Comparative representation of territoriality levels in characteristic models of residential units (Source: author's archive)

		Characteristic models of housing units				
		1 person	*1 generation*	*2 generations*	*3 generations*	*coliving community*
Room type	*Entrance part*					
	Wardrobe					
	Toilet					
	Workspace					
	Salon					
	Living room					
	Dining room					
	Kitchen					
	Storage room					
	Servce					
	Hallway					
	Bathroom					
	Room for 1 person					
	Room for 2 persons					
	Terrace / loggia					
	Legend:	*common / social space,*	*shared space,*	*intimate space*		

5. CONCLUSION

Based on everything previously mentioned, it can be concluded that the experience of territoriality in residential spaces is compound and multidimensional. Its intensity can vary depending on numerous factors, including the size of the space, the structure of the space, the number and relationships among household members, as well as the relationship of individuals with the space and resources. This experience can have positive effects such as a sense of security, intimacy, and belonging to a family or community, but it can also have negative effects, such as excessive protectiveness and, in extreme cases, aggression. Therefore, it is important to consider the factors that influence the experience of territoriality when designing and organizing residential spaces in order to create functional, comfortable, and pleasant living environments. Further directions for research on this topic are numerous and could focus on the influence of culture and social norms on the experience of territoriality in residential spaces or on studying the impact of the physical environment, such as nature, greenery, and lighting, on the experience of territoriality. Additionally, research could explore the development of new methods for measuring the experience of territoriality in residential spaces, including the use of technology and measurements of physiological responses. Considering the initial standpoint that the experience of territoriality is always present in residential spaces but can vary in intensity depending on whether it occurs as a reaction to the presence of visitors, objects, or other users, it can be provisionally confirmed. However, it is important to empirically verify and validate the conclusions from this research.

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ELEMENTS OF SUSTAINABLE ARCHITECTURE IN INFORMAL ROMANI SETTLEMENTS

Milena Grbić[1]

Abstract

The intention of this paper is to denote the fact that informal Roma settlements in their context contain design premises, materialized in spatial forms and building methods, which have the potential to offer design responses in the form of sustainable architecture elements that can be applied in the process of improving the informal Romani housing in Serbia.

Methodologically, the paper starts from a broader interpretation of the interrelation between person and nature in informal Romani settlements, for which the research (that will be presented) has shown that there is an already established relationship. Consequently, it is possible to systematize the characters of physical structures of settlements that have the potential for further design-wise and culturally acceptable improvements of Romani housing, in the domain of sustainable architecture.

The contribution of this paper is to emphasize the fact that the Roma microenvironment already offers the direction of its own chance to participate in the creation of the cities of the future in environmental, economic, and social dimensions of sustainability. Attention to the very specific resources of the Romani settlements has a double effect: it pushes architecture towards a smarter future, and it also has the possibility to operationalize innovative strategies in the process of improving the housing aspects of socially vulnerable Roma.

Key words: *Roma settlements, human – environment relations, adaptation to climate changes, self-build, self-help*

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1. INTRODUCTION

In a world of *happy* countries, a continuity of progress is being noted today in every sense. A quiet balanced evolution of developed cities, arranged regulated societies with developed mechanisms of sustaining the standards for the quality of life, with developed capabilities of predicting and controlling issues is ongoing. The cities that are constantly improved by new cultural contents with new quality housing zones by creating new place and parks (Copenhagen, Paris), are becoming more desirable, and the people within happier.

Social housing represents an important point in realizing individual and social needs of vulnerable social groups, which makes it one of the most complicated social phenomenon's, one of the most basic functions of each urban society and an indicator of the life quality within. According to the research of developing Roma settlements, up until 2002, in Belgrade, 102 Roma settlements and 160 smaller settlements with Romani living there have been registered, but their number, due to the mobility of the inhabitants and the changes in the urban infrastructure is ever-changing. [1] These settlements are characterized by a legally nonregulated status, an insufficient infrastructure, overpopulated, a generally poor environment and a big distance from basic contents and services – all in all a multiple deprivation in the possibility of satisfying needs in the key aspects of life.

Contemporary tendencies of responses to solving such adverse housing situations recommend that all future housing care of these and similar quarters should have a certain sensibility in the regard of sustainable architecture and that including such expertise into the project they have the potential to simultaneously provide a multiple benefit for the concrete inhabitants, but also for the wider population. During the analysis of the phenomenon of unplanned Roma settlements places that already have a strong potential of the sustainable housing concept have been recognized that identifies the multiple functions of housing and that aims to hold its environmental, social, cultural and economic aspects in an incessant and harmonious interaction for the benefit of all inhabitants.

2. METHODOLOGY

When we examine Romani housing, we must have in mind that spatial relations are filled with meanings and that those exact meanings vary between social groups. In Romani settlements a particular causal link was established between taking an acceptable social status and the loss of authentic behavior patterns, and vice – versa therefore the Romani have developed a special social – cultural mentality due to fear of assimilation – the ''ghetto consciousness'', which has in its only positive sense, served to preserve authentic behavioral patterns.

Having all this in mind brings up a thought which calls upon a real practice of housing and usage of space. Pointing our attention for the sake of research of a possible other place was inspired by Henry Lefebvre when he specified that to contemplate the very essence of housing in order to convey it, should be directed towards the experienced, i.e. the unknown and the untold of everyday life. By adding that this space comes from a string and a set of operations and it can't be perceived as one simple object meaning that the produced space of Roma settlements includes, contains and hides social relations, since is does not represent a matter but a set of relations between matters (objects and products) and as such it can function as a tool used for a productive analysis.

In that sense observing the user opens a possibility to make the social space into a transparent media. So, this research was done by observation. By observing the processes that take place in the settlement in certain time intervals (morning, afternoon, evening, night) in the total duration of the research of 21 days. During the research, all processes relevant to the topic were recorded.

The presented research refers to the demonstration of a process in relation to the established methodology and research apparatus in the Laudanov Šanac (slum) and Rupe (unhygienic settlement) both Romani settlements in Zemun, Belgred, Serbia.

3. GENOTYPES OF CREATED PLACES

3.1. Background_1_Unhygienic settlements

Unhygienic settlements were created without control and permission, without a plan, vision, architectural involvement and interference and without any presence of architectural standards, from a first impression – the settlement is defined by a web of streets of unclear profilation, without concrete or partially asphalted surfaces, with no clear beginning or end. The houses are close to one another constructed with permanent construction materials. Massive walls are generally made from brick, block bricks or concrete blocks. The materialization of facades is mostly unfinished, without thermal insulation and additional external processing. The roofs are gable or shed roofs, depending on the position of the construction on the plot and are covered in roof tiles. The builders of permanent houses are construction workers with the help of family members and other residents in the settlements that will later ask for help themselves, Extensions, adaptations and renovation of the existing permanent house, according to the experience obtained from field research, show that they are mostly done as its construction – using handymen and family. Extending a small housing space (in the form of a new room) the family can do by itself.

Although, in the concept of the housing tissue, in relation to unplanned non-Roma settlements (Kaludjerica for instance), there are two important differences: the existence of a usable garden within the plot and the existence of the settlements meeting point.

Namely, instead of threading singular elements into an illegible collection of disconnections, unhygienic Roma settlements, where the social connections are more profoundly built, were constructed with a certain foresight for several future steps of development. Grbic states that the genesis of the neighborhood took place by separating the space within the first plot that in its beginning wasn't maximally occupied by construction for the needs of an individual family. One family house expanded firstly to the edge of the garden, and then – the next generation it was physically separated in order to define a new polygon for new expansions within the new singular family. By comminuting the plot and with the new construction taking place, irregular plots and built structures emerged, and the scheme of the settlement grew more complicated and slowly became less legible. [2]

Consequently, houses in these settlements were developed according to the physical capacities of the enabled space on the plot that is often irregular in form, but most frequently in its surface center of gravity they have a clear and preserved little courtyard. The newly constructed density of construction hasn't changed the consciousness about the preservation of the open space, even in previously built parts of the settlement and wherever possible, the inhabitants transformed infields into small gardens, where they grow certain nutrients – green salad, onion, tomatoes…

In a smaller scale, there are also tendencies where the community show that they have an influence on the appearance, content and quality of their micro-environment, in the modus of unconditional housing circumstances the built social relations within the settlements community are still dominant which enabled that no matter the unplanned beginning and development of the settlement, there is still a space that is not built over and that functions as the settlements square intended for getting together, children playing, celebrating festivities etc.

Figure 1. Infields in Roma settlements.

3.2. **Background_2_Slums**

Simultaneously with the development of unhygienic Roma settlements, slums were also growing – cardboard settlements, where the social, economic and environmental image is far under the already inhumane standards of housing in unhygienic settlements and in which there is also no basic communal infrastructure, adequate hygienic conditions, water, sewer, electricity etc. This housing space is once again very subjective, without a formal institutionally imposed organization, made from needs of a functional organization of a community and everyday life activities taking place. In this setting, ''the hut'' seems as if the organic relation between man and the unbuilt surrounding was created even more by reflex. In slums, living is in dilapidated houses. A dilapidated house comprises of a house that is built from unstandardized housing material, that is most frequently been disposed of as waste material. The inhabitants of slums call their houses *barracks*, while in everyday communication the expression *kartonka – carton house*, which understands housing constructed from cardboard and other non-construction materials (thus the expression – carton city for slums). Even though it is hard to precisely separate, a typical base construction of dilapidated houses is from wooden beams, although there are cases that they can be made of steel or concrete, The materialization of the basic construction is achieved by paneling wooden boards, doors, old nylon, waste tin boards or cardboard. The roofs are gable or single-pitched with a slight slant. On boards positioned towards the slant of the roofs a roof cover is placed. A frequent material used for the roof cover are old nylon, cardboard… The floor is dirt, with cardboard or styrofoam used over it. After setting up the outer frame, the house is furnished on the inside, using cloth and the whole interior looks like patchwork.

Figure 2. Demonstration of a dilapidated house.

A dilapidated house is constructed in a day. It is made by the settlements handyman with the families help. The household members replace elements by themselves on the roof, the walls the floor. Besides renovation, after the house is constructed expansions and adaptations and they are performed by the residents themselves, eventually with the help of cousins or neighbors. The houses in slums, as in unhygienic Roma settlements, are not an agglomerate of individual objects, but are part of a more complicated interoperable system as Grbic calls it – *yard group of objects*. [3] The objects in the courtyard are positioned most frequently in a way that they for the Cyrillic letter 'П', and the 'П' opens towards the improvised street in the settlement with it free part. In the center of the surface there is a yard used for children play, leisure time, drying laundry, forming a summer kitchen as well as a hallway to communicate with other rooms that are not used for living. Very often in the yard there are a few trees. The courtyard of the yard group of objects, just like in unhygienic settlements, represents a previously anticipated polygon that will satisfy the changes made within the modifications made within the family's structure for several generations to come. Because of the materials that the houses were built from, the houses can't go up, so the density of population of this concrete space will never be like in unhygienic settlements. In older and more constructed parts of the slums, all housing expansions are such that the courtyard always stays central in relation to the total surface. [2]

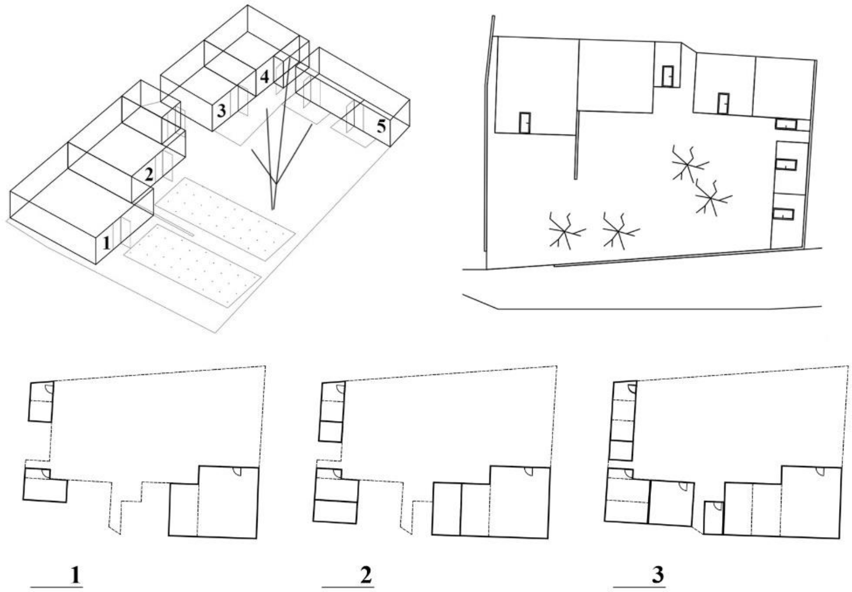

Figure 3. Demonstration of appearance and development of the yard group of objects.

Just like unhygienic settlements, slums also demonstrate a strong identification of the individual and the community, and as such it influenced that there are strong social spaces i.e., meeting point within the settlement, as well as spaces for child play. Also, the fact that the residents of the slums are closely connected by common economic, social and cultural interests, slums also have spaces to guard secondary raw materials. Even if the keeping of raw materials is closely linked to the physical space of each house, slums are dominated by clearly determined and fenced spaces that are used for sorting and disposing of secondary raw materials. Besides the fact that secondary raw materials are a dominant fundus of construction material, their existence points out to another social anomaly – that recycling, that in developed societies takes up an important social and environmentally responsible role, in our society is performed by those whose circumstances of social neglect were forced to do.

4. GENOTYPICAL SELECTION FOR A SUSTAINABLE FUTURE

One of the key points of strategies that tend to expand integral bases of knowledge of the UN habitat of sustainability that, at the same times, provides improvements in quality of life, health and safety, is the recommendation of including local autochthonous know-how and materials into the process of development of a prototypical model of a house. [4] In the aim of improving accessibility and availability of giving adequate housing solutions, the concept that the housing policies further themselves away from the classical approach to uniform solutions and drawing out resources exclusively from the public center, also understands that the methodological framework of designing strategies turns towards the communities resources. In this way, a simple multiplication of the house model would be enabled in which the local residents would greatly participate in. in the case of the Roma settlements we can notice a series of potential.

Autochthonous construction techniques – self-building and self-help. In Roma settlements the neighborhood community represents a sort of a 'third skin' that, in the same way as human skin and clothes has a protective function and a light communication to the outside world. Solidarity as a basic relation within this micro ambient, as well as the connection of the community, horizontal and hierarchal reflects positive relations that enable a collective action and this potential most certainly is one of the resources one should draw material from for future actions to enable or adapt settlements. The visibility of this statement is especially important in the procedure of constructing an individual house. It is important to briefly resume that in the construction or the expansion of dilapidated house, during all of these procedures, the family is participating. In other more complex procedures, the community gets involved as well, while as in permanent houses due to a more complicated process of construction the family's participation is understood in all phases of the architectural development of a house, but also as a helping hand to the handyman. In further training of skillful handymen within the settlement, with a professional demonstration and surveillance in concrete construction acts, a training of a functional group of the community would be achieved, which understands at the same time reinforcing its professional capacities in the processes of construction, repair and extension of the house. Augmenting work capacities of the housing units residents for construction also reinforces working capacities for the future maintenance of developed housing that would very much contribute to lessening the costs for the settlements adaptation.

Using locally adequate materials. In a tight link with autochthonous building techniques in the key of lowering the gas emissions, the use of local materials in construction is advised. Suggestions on the type of the spent construction material can be encouraged by the fact that even the most contemporary achievements in housing design can be combined with traditional locally adequate materials and methods of their construction, Given the fact that in Serbia, as in most developing countries, there aren't sufficient information about the energy that has been incorporated into concrete construction materials, that is an important tool for precise quantification, basic guidelines can be useful. In that sense, acquired skills of Roma residents during the use and reuse of wood and brick products can be considered as one of the key skills that can be used in the process of house and settlement adaptation, since wood is an accessible material and is eagerly used in building houses that are environmentally friendly. [4] Also, UN-habitat experiences apostrophize that a culturally conscious approach in moving the center of gravity about secondary raw materials as a collection of scraps with no function towards a conscious about them as a resource that can be successfully combined with contemporary ways of construction. Since in construction and expansion of dilapidated houses the family is included in all of the processes, within which at least one member is trained and involved in the use and reuse of secondary raw materials in unstandardized ways, through adapting and adjusting certain parts into the totality of the house, it can be considered that these skills are also one of the potentials of the Roma community in taking the role of creating a structural integrity of higher quality, of an energetically efficient and long-term project. Every use of recovered brick, wood for wall and roof construction and the repurposing of doors, cylinders and other types of construction materials can minimize the negative influence on the environment. [4] The cited acquired knowledge, that the Roma community has, also represent a resource that can be utilized in exceptional situations, in sudden consequences of climate change; it is a fact that a dilapidated house, as a source of 'secondary' architecture, can quickly be built and upgraded, and can be deconstructed and moved even quicker.

Significance of open and covered spaces. The porch in Roma housing, whether it be covered or closed space, has potentials in designing premises in the discourse of energy spending. A closed porch is an interspace – a blend in the form of a microclimate and a regulator of temperature between the outside and the inside space. If properly oriented, it can represent a space that enhances the heating of the closed space in the winter months or that disables its overheating during the summer period. A covered porch, on the other hand, provides a protected stay in the open space in all weather conditions.

The capacities of an existing courtyard (open space) in the framework of a prototypical modeling of a house are demonstrated precisely in its accompanying segments. A sufficient spaciousness of the courtyard and the possibility of a tree existing in the courtyard as an on-site potential can very effectively contribute to the amelioration of heating of the house rooms and at the same time, even minimally, reduce the emission of harmful gases by limiting the use of fossil fuels that increases with the augmentation of energy use. This type of principle can particularly be useful in places where the energetic infrastructure is lacking and where fossil fuel energy is unattainably expensive.

At the same time the existence of a courtyard in combination with an already formed solidarity within the family and the community, and correct guidance towards the formation and development of existing small gardens can significantly contribute to the concept of self-sufficient nutrition. This practice often includes growing crops, vegetable gardens, and fruits to get food when an individual or a family can satisfy their own need for food. The concept of self-sustainability can be an integral part of the prototype of the house or the settlement where people rely on their own resources for food and survival.

5. CONCLUSION

In the framework of housing projects there are capacities for a synergy of relations in a form that provides positive effects within multiple inter linked arenas that refer to a sustainable architecture in the sense of reducing energy use, using renewable energy sources, efficient resource use, reducing the emission of harmful gas, improving the inside space quality and the protection of natural eco-systems. The success of making this battle cheaper greatly depends on the designers' ability to generate houses that correspond to the determinants of the local concept. The design parameters are different from place to place, and these differences are subtle and hidden and are often overlooked. The value and the volume of these determinants vary with the variety of cultures and only deep research directed to a concrete community can discover important premises that generate a project that successfully creates an efficient living environment by supporting the local community.

Shedding light on the fact that the Roma micro-environment, deeply in its cultural context offers a direction of its own chance to partake in the creating of a future modern city in the sustainable architecture discourse has a big importance since it realizes the potentials to create equal opportunities in a social cohesion of a modern city. A supportive and a functional micro-community of the settlements is a resource on its own, and by further magnifying other mechanisms are discovered in the sense of knowledge and skills that are embedded in the lifestyle by reflex and necessity, and that open up chances for a participation in decision0making during a concrete creation of the neighborhood. The participatory design and the implementation of local know-how of the users are indeed an important approach of every future strategy.

Honoring the positive characters of the physical structure that integrate principles of sustainable architecture a double effect is achieved: besides the fact that it pushes architecture towards a smarter future, it achieves a satisfaction of special spatial demands that provide adequate conditions for a lifestyle acceptable for the Romani. When planned correctly, cities in each of their typologies, can be places of innovation and efficiency that have a potential to reduce the causes of climate change and to efficiently protect from their influence.

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THERMAL VISION BASED EVALUATION OF TRADITIONAL ARCHITECTURE BUILDING'S ENERGY EFFICIENCY IN THE STARA PLANINA REGION

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Abstract

Providing the necessary conditions for indoor comfort during a building design process positively affects users' well-being and energy consumption. This paper uses thermal vision-based evaluation to examine the thermal behavior of a traditional rural house in the Stara Planina region. Analysis of building envelope elements in terms of building physics was carried out in 2018 during the summer period. The subject building represents a characteristic housing facility from the 19th century, constructed in a connection system and horizontal arrangement of logs, with loam and unpressed straw, as a mixture for filling. The research aims to compare the overall heat transfer coefficient gained by applying the thermography technique with results achieved using an analytical calculation based on the Rulebook on Energy Efficiency of the Republic of Serbia. The difference between values of overall heat transfer coefficient obtained analytically and based on the measurements is mostly below 0.09 W/m^{2}K, which indicate the effectiveness of this approach especially in cases when the exact ratio of materials used for construction is not familiar. The research shows that applying a thermal vision system to determine building envelope characteristics and identify potential areas for thermal improvement of traditional vernacular architecture buildings is a valid and valuable non-contact method.

Keywords: *building envelope, thermal behavior, traditional rural architecture, thermal vision system, Stara Planina region*

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1. INTRODUCTION

In recent years, the construction industry has increasingly promoted a return to traditional building principles and natural materials due to environmental sustainability and good thermal characteristics. Consequently, the energy efficiency of traditional buildings has gained significant interest in both research and practice. Lidelöw et al. classified studies regarding the energy performance of heritage buildings [1]. Authors highlight that cultural heritage values should be more explicitly articulated and analyzed to establish conservation principles or methodologies when considering energy improvements. Ćurčić et al. compared examples of traditional houses in Serbia, Romania, and Bulgaria based on the condition of buildings, their purpose, the degree of preservation, and the applied methods of protection [2]. Based on the analyzed examples, the research proposes the best approaches for preserving vernacular architecture and cultural heritage in rural areas. Lovec et al. examined the thermal behavior of the rammed earth wall of a traditional Vojvodina house, during the summer period [3]. Analysis of thermal performances has shown that this type of wall has low thermal conductivity, high heat capacity, and significant thermal mass effect, which is the crucial element enabling thermal stability. Results from the measurement of the 60 cm tick rammed earth wall have shown small indoor temperature swings (about ±0.5 °C) in conditions of great outdoor temperature swings (up to ±16 °C), and comfortable indoor environment (constant temperatures around 23 °C). Bogdanović and Kostić did a verification of exterior walls thermal characteristics, on the object of Faculty of Civil Engineering and Architecture, using a thermal vision camera [4]. Based on the obtained values of the overall heat transfer coefficients, it can be concluded that they are close to the analytically calculated value, but that there are also significant deviations. The difference between values goes from 0.012 to 0.167 W/m^2K. Kostić et al. examined traditional building envelope thermal behavior based on the on-site monitoring with thermal vision camera during the winter period, based on which the overall heat transfer coefficient was obtained [5]. Comparation of that values with analytically calculated ones show deviations from 0.02 to 0.47 W/m^2K.

Pozas et al. researched the hygrothermal behavior inside the vernacular housings of the Jerte Valley, located in Spain, to promote the preservation of buildings and their energy refurbishment [6]. The results indicate that indoor conditions are comfortable during the warm period, while additional energy will be required to achieve the comfort zone in the cold period. Chandel et al. reviewed energy-efficient features in vernacular architecture in different climatic zones of India, affecting indoor thermal comfort conditions, like built mass design, orientation, construction techniques, and building and roof materials [7]. Earth, with its low compressive strength and durability, is found to be a prominently used vernacular building material due to its thermal insulation property. The paper presents the current status of using earth as a building material, coal provisions, and adaptations of vernacular architecture for improving energy efficiency in a modern context.

Thermography has found wide application as an evaluation and quantitative non-contact method for examining heat losses through the external walls of the building. In addition to enabling the successful detection of thermal bridges, air leakage, and moisture, using infrared thermography, it is possible to determine the actual values of the thermal resistance parameters (R) and the overall heat transfer coefficient (U) that affects insulation level and human indoor comfort [8]. Lucchi investigated the application of infrared thermography for the building energy audit to detect thermally significant defects [9]. Martin et al. review significant contributions in infrared thermography to study the built environment at multiple scales between the 1980s and 2020s [10]. Analysis based on the classification and the chronology of contributions helped to detect the research gaps that could be addressed in the future.

The area of the Balkans, including the territory of Stara Planina region, is recognizable by numerous rural buildings whose architectural expression and method of construction arose from specific climatic conditions, the purpose of the buildings, the availability of materials in the immediate environment, the manner and frequency of use (permanent or temporary), as well as cultural influences conditioned by social and political events throughout history. According to the Koeppern-Geiger climate system classification, Stara Planina's area is a temperate climate zone with dry and hot summers but cold, snowy winters (Csa category). It is spatially and aesthetically determined by the facilities of folk architecture, mainly consisting of single-family residential buildings built by the local population from the period under the Ottoman occupation until the middle of the 20th century [11]. Due to the migration of people from the countryside to the cities, most of these buildings are abandoned today. A part of them is used for temporary stays during weekends and holidays. The heritage of folk architecture in rural areas must be sufficiently explored and recorded. An essential aspect of their restoration and reconstruction is energy retrofitting, which should ensure adequate thermal comfort for future use without damaging traditional houses' original aesthetics and integrity [12].

This paper examines the thermal characteristics of the external walls of the traditional housing facility of folk architecture built in Serbia in the first half of the 19th century and constructed in a connection system and horizontal arrangement of logs, i.e., "čatmara." The current Rulebook on Energy Efficiency for Serbia's territory recognizes only individual materials' thermal conductivity. At the same time, it does not provide data on the characteristics of loam and unpressed straw, the mixture of which was used to fill and coat the traditional house walls [13]. The conducted research uses thermal vision based evaluation to determine the actual values of the overall heat transfer coefficient for the exterior walls of this type of folk architecture facility. The study compares the heat transfer coefficient gained by applying the thermography technique with results achieved using an analytical calculation based on the Rulebook on Energy Efficiency. The paper's primary goal is to compare two methodologically different approaches in calculating the heat transfer coefficient to verify whether thermography is a valid non-contact technique for examining the thermal characteristics of traditional buildings in rural areas.

2. GENERAL CHARACTERISTICS OF RURAL ARCHITECTURE IN THE STARA PLANINA REGION

The Stara Planina region belongs to the Balkan Mountains system, and extends over the territory of Bulgaria and in the southeastern part of Serbia. On the territory of Serbia, the region is bounded by the valleys of the Beli Timok and Trgovišni Timok rivers, and to the east by the border with Bulgaria. The highest peak in Serbian part is Midžor with a height of 2169m. The region is characterized by a sub-mountain zone up to 1250 m high, a mountain climate zone up to 1900 m, and a high-mountain climate zone [14]. The area includes the cities of Knjaževac, Zaječar, Dimitrovgrad and Pirot on a total territory of 1500 km^2.

The ambiance and architecture of the ancient villages of the Stara Planina region have been preserved almost unchanged since their inception in the 19th century. The most important are preserved buildings made of autochthonous material - residential and production buildings, while the most exciting ambiances are in the cores of compacted villages. Characteristics of rural mountain settlements of Stara Planina are minimal demographic potential, advanced depopulation phase, a position that is hard to reach, a dominantly agricultural function of extensive character, and a low level of infrastructure equipment and social services. According to the Spatial plan of the nature park area and the tourist region of Stara Planina [14], the mountain was treated as an area of natural resources and tourist potential in the strategic framework of sustainable development of the Republic of Serbia. Old mountain villages (unchanged or slightly altered) were put under the 3rd level of protection by the Spatial Plan. Old village settlements, buildings of folk architecture, and ambient units complete tourist motives on “cultural trails” and open up the possibility of forming new paths.

The development of rural architecture in the Stara Planina region had a similar course as in other parts of Serbia. At the beginning of the 19th century, an older type of wooden house, built according to the connection system and horizontal arrangement of logs, outside and inside glued with mud (loam and straw), originally called “daščara” or “talpara”, was widespread in these wooden and mountainous systems (Figure 1, left). The log cabin gives way to facilities with visible skeletons of wooden supports and plastered infill made of organic material or brick, called initially “bondručare” (Figure 1, in the middle). They evolved from a one-piece, two-piece, and then upgraded base to get a fourth department at the end of the 19th century [15]. A large number of households, however, remain on the spatial composition of a two-part house for economic reasons. They are primarily ground-level, square bases, with wall infill made of rattan (branches), which was coated with a mixture of loam and straw and soft straw or clay tiles roofs (Figure 1, right) [16].

This type of house (initially called “čatmara”) developed in a horizontal sense, while in vertical, there was no such tendency. A stone basement would be underneath if the house were on steep terrain. Although, even on flat ground, it can have a cellar under the entire building, while the entrance to the house is by stairs. In the spatial sense, the house in these parts is always built with a porch [17]. The original porch is placed along the entire building length and later gets a place in the corner or is pulled out in front of the main façade. In addition to the functional, the porch has an aesthetic moment, which also evolved with the building [18]. In the disposition of the house, the patio is under the same roof as the house and relies on wooden columns from the open sides.

The design is simple yet functional, catering to the needs of the residents. The interior of the original house consists of a central space, a small room, and a pantry. The main room is square, usually 6 x 6 m, with a fireplace in the center [19]. They are also rectangular shaped, with a fireplace against the wall towards the corner. The ceiling is usually absent, and the roof is four-sloped. Access to a small room is from the main room, which always faces south. This room increased over time. The third ward, the pantry, was used for storing dresses and later for sleeping guests.

Groceries are also kept in this room, which is entered from the central space, less often from the small room or porch.

Figure 1. Left-"daščara" church in S. Palanka, in the middle-"bondručara" in village Senokos, right – "čatmara" in village Senokos (Sources: https://sn.rs/nrbso; authors)

The described houses characterized the 19th and the beginning of the 20th century, not only in this region but also in neighboring and even more distant areas. Over time, houses have been transformed, upgraded, and increasingly resemble townhouses, primarily thanks to local population movements. In the villages of this region, a very present type of house is the "L" house, which appeared in the 1930s and 1940s. "L" houses differ from the established construction method [17].

3. METHODOLOGY

The methodological framework of the four research steps is presented in Figure 2.

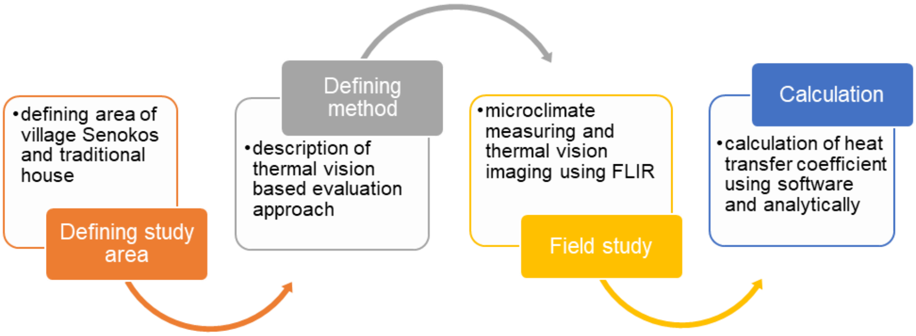


Figure 2. Research methodology framework steps (source: authors)

3.1. Defining study area

The research is conducted in the village of Senokos, located in the southeastern part of Serbia, in Gornji Visok, on the slopes of the Stara Planina, 30km northeast of Dimitrovgrad, in the Pirot district. Senokos is positioned along the border with Bulgaria, surrounded by the Rosomač, Kamenica, and Gornji Krivodol villages. The village is of compact, river-mountain type (Figure 3) [17]. Senokos covers an area of 5025ha in the sub-mountain climate zone, 900m above sea level, characterized by snowy and cold winters, hot and dry summers, and an average annual temperature of 6℃ to 9.5℃ [20]. It is located at the confluence of the Grdeščica and Vodenička Rivers into the Senokoška River. The village belongs to the Stara Planina nature park region with a nature protection regime of II degrees. From the aspect of geological heritage, the profile of the Upper Jurassic sediments on the stretch towards the neighboring village of Kamenica is significant [21].

According to the Spatial Plan of the Nature Park and Tourist Region of Stara Planina, the mountain village of Senokos belongs to an area with the III degree of protection of immovable cultural assets, which implies the restoration and reconstruction of buildings with the possibility of their adaptive conversion into rural tourism functions [14]. The potential for the future development of the village is provided by the planned construction of cable cars, ski slopes, and hotel complexes defined by the Master Plan of Stara Planina [22].

The subject house is located in the southern part of the village, southeast of the access road, on cadastral plot 2986, and its longitudinal side is oriented in the northwest-southeast direction (Figure 4). The family house is minimally distant from the neighboring building on the northwest side, while a green country yard with an auxiliary building opens to the southwest.

The geometry of the building is rectangular, with a prominent central part of the house that has the function of an entrance vestibule. Due to the orientation and position of the neighboring buildings, window openings are mostly placed on the southwest facade, while there is only one smaller opening on the northeast front (Figures 5 and 6). The house belongs to the “čatmara” type, built with four rooms, stone foundations, and wooden construction based on the connection system. The house’s walls are lined with wooden planks on both sides, while the barriers between the beams are filled with a mixture of loam and straw. This mixture was also used for the interior and exterior plastering before the layer of lime plastering. The roof is a gable made of clay tiles.

Figure 3. Map of the Senokos village, source: https://a3.geosrbija.rs/

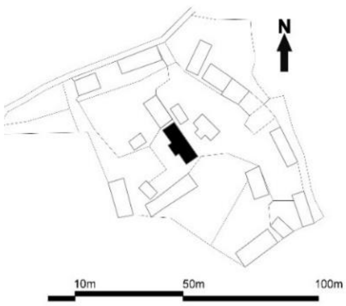


Figure 4. Location of the house, source https://a3.geosrbija.rs/

Figure 5. Southwest façade of the house, source: authors

Figure 6. Northeast façade of the house, source: authors

3.2. Defining thermal vision based evaluation approach

The conducted research uses thermography as a methodological approach in examining the thermal properties of a traditional building from the 19th century in the area of Stara Planina. Thermography is a remote temperature mapping system that allows the visualization of radiation in the infrared part of the spectrum. For thermography, three spectral ranges are defined: the long-wave region from 7 to 14 μm, the mid-wave region from 3 to 5 μm and the short-wave region from 0.9 to 1.7 μm. Thermal radiation is the most important process for thermography. Term thermal radiation refers that every object at a temperature above absolute zero ($T > 0$ K; $T > -273.15$ºC) emits electromagnetic radiation. The amount of radiation emitted by the object and its distribution in the wavelength spectrum depends on the temperature and properties of the material [8].

The emitted infrared radiation of the building's walls was recorded using the thermal imaging camera FLIR ThermalCam B20. This device features thermal sensitivity of 0.08℃, automatic object focusing, detector type FPA with uncooled microbolometer image resolution 320x240 pixels, a detector range of 7.5-13μm, and a temperature range from -40℃ to +70℃ [23]. Thermal vision camera was calibrated to match the emissivity of the wall surfaces on site and adjusted according to field parameters. All deviations that occurred were corrected later in the software FLIR Quick Report 1.2. SP2. Considering that in this research only thermal vision camera was used for temperature measuring, obtained results were compared with similar studies.

3.3. Field study

To examine the thermal characteristics of the external wall of a traditional house in the area of Stara Planina, Serbia, a recording with a thermal imaging camera was carried out in the village of Senokos, in year 2018. Given that most of the preserved buildings are currently used for temporary stay by guests or villagers, most often in the summer months, the thermographic measurement was done during a hot summer day on August 25, at the building currently used as a holiday home. The measurement with a thermal imaging camera was carried out in the afternoon when air temperatures were the highest. During the measurement period, the outside air temperature (t_e) was 30.7℃, while the air humidity was 41%. The internal air temperature (t_i) was 20.3℃. The indoor air humidity was 56%. Only walls not exposed to direct sunlight were recorded from a 3m distance, perpendicular to the wall (Figure 7).

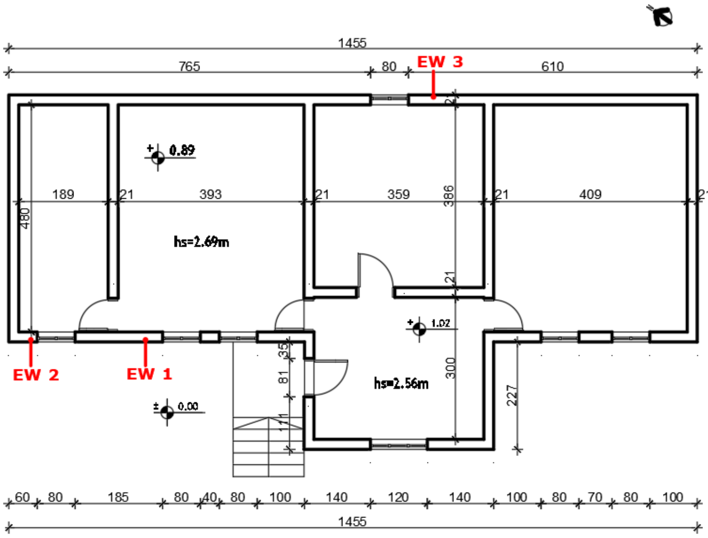


Figure 7. Plan of the house with marked measurement surfaces, source: authors

3.4. Calculation of the overall heat transfer coefficient

The research combines a thermal vision based evaluation approach with an analytical approach in calculating the overall heat transfer coefficient. Apart from the known expressions (1 and 3), the thermal resistance and the overall heat transfer coefficient of the partitions can be calculated based on the known, i.e., measured temperatures of the internal and external air t_i and t_e, as well as the temperatures of the inner and outer surfaces of the partition t_0 and t_n.

The application of these expressions implies a stationary state, the invariability of the heat flux q from the internal air to the inner surface of the partition and through the section itself to the external surface of the wall and the external air:

$$\mathbf{q} = \mathbf{U} \cdot (\mathbf{t}_i - \mathbf{t}_e) = \frac{1}{\mathbf{R}} \cdot (\mathbf{t}_0 - \mathbf{t}_n) \quad (1)$$

$$\mathbf{U} \cdot \Delta\mathbf{t} = \frac{1}{\mathbf{R}} \cdot (\mathbf{t}_0 - \mathbf{t}_n) \quad (2)$$

Where Δt is the temperature difference between indoor and outdoor air, U is the overall heat transfer coefficient, and R is the thermal resistance of the partition.

Based on the given equations and considering that the overall heat transfer coefficient U of the partition is equal to the reciprocal value of the sum of the thermal resistance R of the section and the resistance of internal (R_i) and external (R_e) heat transfer, i.e.:

$$\mathbf{U} = \frac{1}{\mathbf{R}_i + \mathbf{R} + \mathbf{R}_e} \quad (3)$$

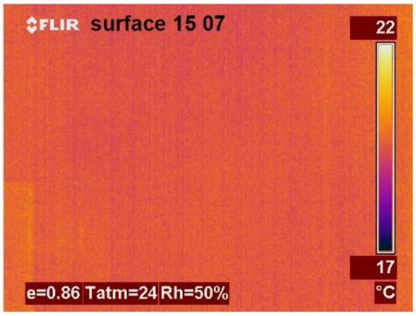
Based on the equations (1), (2), and (3), the thermal resistance R and the overall heat transfer coefficient U of the partition can be represented by the following equations:

$$\mathbf{R} = \frac{(\mathbf{R}_i + \mathbf{R}_e) \cdot (\mathbf{t}_0 - \mathbf{t}_n)}{\Delta\mathbf{t} - \mathbf{t}_0 + \mathbf{t}_n} \quad (4)$$

$$\mathbf{U} = \frac{\Delta\mathbf{t} - \mathbf{t}_0 + \mathbf{t}_n}{\Delta\mathbf{t} \cdot (\mathbf{R}_i + \mathbf{R}_e)} \quad (5)$$

4. RESULTS AND DISCUSSION

Figure 8 shows the distribution of internal and external surface temperatures for specific measurement areas of the facade wall of the northeast orientation of the subject house in the village of Senokos. Considering that the lime mortar fell off on some parts of the façade (darker parts on the Figure 8, right), i.e., the façade structure is not homogeneous, when calculating the overall heat transfer coefficient only temperatures from the undamaged part of the construction were considered.



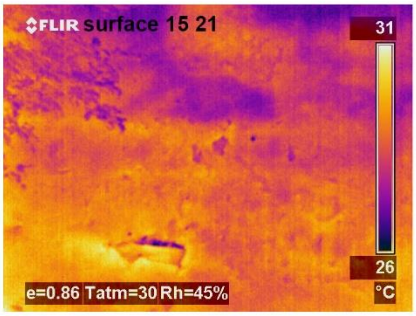


Figure 8. Thermovision images of the surface temperatures of the inside (left) and outside (right) part of the northeast-oriented facade wall, source: authors

Using the obtained data of internal and external surface temperatures by software FLIR Quick Report 1.2. SP2, and measured internal and external air temperatures, the actual values of the heat transfer coefficient (U) for the analyzed building, calculated based on the equation (5), are shown in Table 1.

Table 1. Measured wall and air temperatures and calculated heat transfer coefficients.

Exterior wall	*Internal air temperature t_i, °C*	*External air temperature te, °C*	*Temperature of the internal surface t_0, °C*	*Temperature of the external surface t_n, °C*	*Overall heat transfer coefficient U, W/m²K*
EW1	*20.3*	*30.7*	*19.5*	*25.6*	*2.43*
EW2	*20.3*	*30.7*	*19.5*	*25.5*	*2.49*
EW3	*20.3*	*30.7*	*19.5*	*26.2*	*2.31*

Using the Rulebook on Energy Efficiency of Buildings and Rules governing building with earth [13, 24], an analytical procedure was carried out to calculate the thermal conductivity of the external walls of a traditional house in the village of Senokos. The outer walls of the building are made of lime mortar 1 cm thick, a layer of loam and straw 2 cm wide, wooden planks 3.5 cm thick, and an infill made of loam and straw 8 cm thick. Wooden planks, soil layers, straws, and lime plaster are found on both sides of the wall (Figure 9).

Thermal conductivity (λ) for a mixture of loam and straw is obtained from Rules governing building with earth [24]. For this mixture particle density is estimated between 1400-1700 kg/m^3. Based on the particle density, calculated values for the thermal conductivity of earthen building materials are given. Considering that it is impossible to determine the exact ratio of loam and straw with non-contact method, i.e., partial density, for this research two values of partial density were considered –

1400 and 1600 kg/m^3, which means that thermal conductivity values considered for calculation are 0.59 W/mK and 0.73 W/mK, respectively. Taking this into account, the analytically determined values of the overall heat transfer coefficient for the analyzed exterior wall, based on equation (3), are 2.33 W/m^{2}K and 2.40 W/m^{2}K.

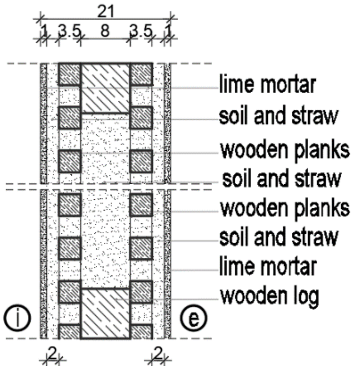


Figure 9. Vertical section through the exterior wall, source: authors

Based on the obtained values of the overall heat transfer coefficients using thermal vision technique (Table 1), it can be concluded that the results are all very close to both analytically calculated values. Since it is only possible to determine the exact ratio of materials used for wall construction with additional testing of samples, using thermal vision is a very efficient non-contact method. This approach is especially significant for traditional buildings, considering that there are no records of the exact building material ratio in most cases. Also, using thermography is significant when quick and non-contact evaluation of building envelope thermal characteristics is necessary. However, in order to define optimal measures for refurbishment, especially for protected areas, combination of different approaches must be applied, like sample examining, energy simulations, etc.).

5. CONCLUSION

As an essential part of a country's historical identity, traditional architecture should have special treatment in the reconstruction and renovation process. Primarily, traditional architecture in the territory of Stara Planina represents a unique combination of specific climatic conditions, local materials, and architectural organization, impacted by different historical, social, and economic events. Undeniably, traditional buildings' capacities gradually deteriorate due to the abandonment of villages and the influence of varying weather conditions and natural disasters. According to this, there is an urgent need for proper measures and actions to preserve traditional buildings, consequently enhancing rural areas' development and tourism.

This paper evaluates traditional house walls' thermal behavior using a thermal vision based evaluation approach. Determination of the overall heat transfer coefficient of exterior walls was conducted analytically and based on the obtained results of wall surface temperatures. A comparison of the results indicates that for analyzed object the difference between values obtained by different approaches is majorly below 0.09 W/m^{2}K. Obtained results are in accordance with the ones conducted in other regions of the country with the similar wall material [3], and with the one conducted on the object with identical wall construction [5]. Directions of further research will include investigation of traditional buildings' earth walls thermal behavior during the other seasons. The focus will be on potential measures for improving building energy efficiency by preserving authentic architecture.

Reviewing traditional architecture from a sustainable and energy-efficient perspective needs further research. A combination of sustainable architecture and traditional building principals, except for renovation of existing object, can also serve as a model for designing new objects, representing a great practice in the future.

ACKNOWLEDGMENTS

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ANALYSIS OF THE CONCEPTUAL DESIGN OF THE MEMORIAL TEMPLE IN THE PORT OF THE ASCENSION TEMPLE IN BELGRADE

Dušan Stajić[1], Ana Momčilović Petronijević[2], Marko Nikolić[3]

Abstract

The subject of the paper is the analysis of the process of architectural and urban planning on the example of the conceptual design of the Orthodox memorial church in Belgrade. The conceptual solution is part of the competition, which includes the design of a memorial temple and ground floor in the port of the Ascension Temple in Belgrade, at the site where innocent citizens died in the bombing on April 6, 1941.

The aim of the work is to point out the complexity of the design through the consideration of a number of influential factors, whose detailed analysis should find the optimal solution that will represent the synthesis of the existing and newly created environment.

Key words: *sacral architecture, temple design, competition*

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1. INTRODUCTION

Architectural design is a complex process consisting of a series of procedures and phases. It can be divided into the analysis and valorization of influential factors, the formation of strategic project determinations, conceptualization and development of the concept [1]. Each of the above-mentioned phases is shown in the paper through the process of creating a conceptual solution for the memorial temple in the port of the Ascension Temple in Belgrade. The conceptual design was created for a public conceptual non-anonymous architectural-urban planning competition that was announced in 2019 by the Serbian Orthodox Church, the Archibishopric of Belgrade and Karlovci and the Temple of the Ascension in Belgrade. The topic of the competition was the creation of a design for a memorial temple and ground floor in the port of the Ascension Temple in Belgrade, at the site where innocent citizens died in the bombing on April 6, 1941 [2] Due to certain circumstances, the judging was not completed.

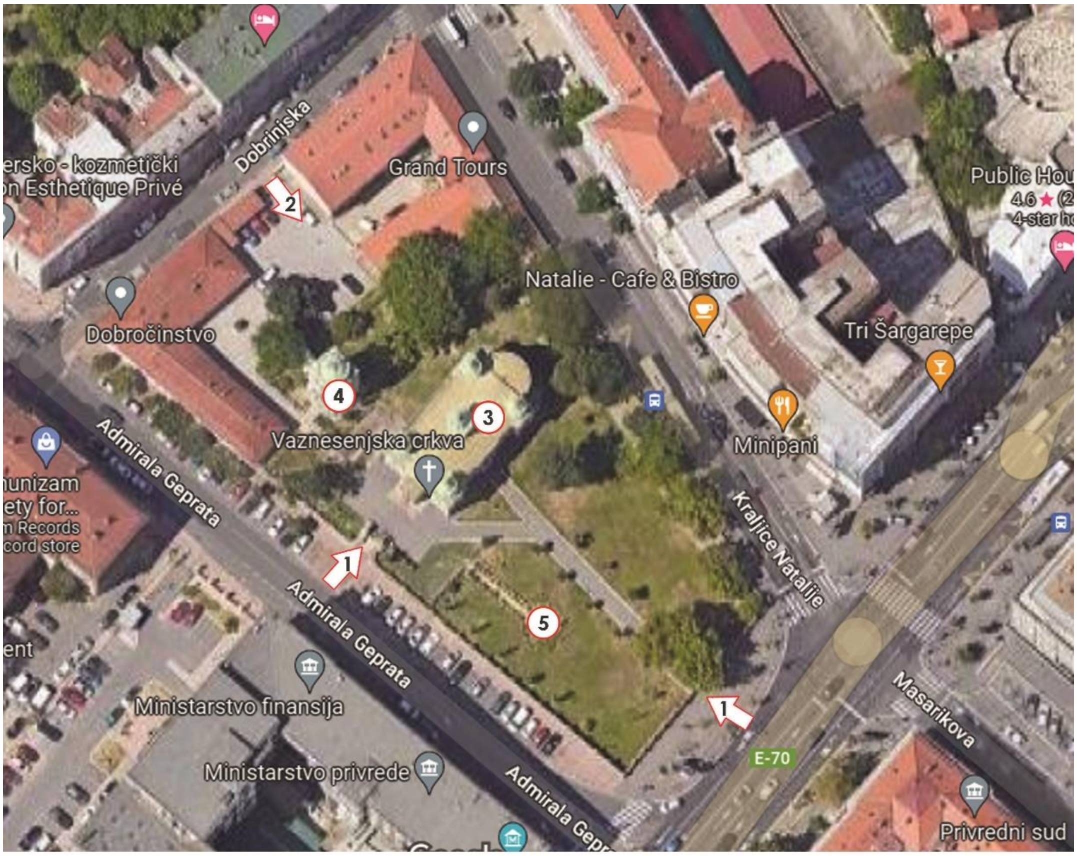
2. ANALYSIS OF INFLUENTIAL FACTORS

The starting point in the process of architectural design is the analysis of all influential factors that represent the basic factors that condition the types and levels of organizations in design as well as the forms of their concretization in space. [3]

According to a certain degree of dependence on the architect himself, they can be divided into objective and subjective. The objective influencing factors are the competition program, the defined rules for the design and construction of the object in question, the location conditions of the plot on which the construction of the object is planned (dimensions and position of the plot, slope of the terrain, existing facilities on the plot, road and pedestrian access, heights of neighboring buildings, existing vegetation on plots, etc.). Subjective influential factors are the attitude of the architect himself, his experience of the object he studies, the object he projects, on the basis of which he gives his personal stamp to the project.

The competition program defined certain conditions, of which the following should be distinguished:

- The newly designed memorial church must not endanger the views of the existing church from the surrounding streets;
- It is necessary to provide space for at least 200 people in the extra-altar area of the church;
- At least 5 priests can serve undisturbed in the altar area of the temple;
- During the design of the church, it is necessary to respect the tradition of building Orthodox churches;
- As part of the project, foresee a crypt under the temple;
- Inside the temple, it is necessary to provide a northern and a southern choir with space for at least 4 singers, a church shop as well as an area for lighting candles;
- In front of the church, provide a porch under which at least 300 people can fit;
- It is necessary to provide access to the gate for people in wheelchairs. [4]



SITE PLAN LEGEND:

1. Pedestrian entrance to the church port
2. Vehicle entrance to the church port
3. Ascension temple
4. Bell tower
5. Site of the cross flag

Figure 1: Situational plan of the current condition of the gate of the Ascension Temple in Belgrade [5]

The analysis of the encountered location conditions, natural and created, determined the following:

- The port of the Ascension Temple is located in Belgrade, municipality of Savski Venac;
- It has the shape of an irregular rectangle oriented with its longer side in the northwest-southeast direction;
- It is bordered by streets: Kneza Miloša Street on the south side, Admirala Geprat Street on the west side, Dobrinjska Street on the north side and Kraljica Natalija Street on the south side;
- In its immediate vicinity, there are: the building of the Ministry of Finance and the Ministry of Justice of the Republic of Serbia, the Beogradanka building, the old General Staff building, Pionirski Park, Manjež Park, Tašmajdan, etc.;
- A retaining wall was formed along the southern and eastern borders of the plot in order to soften the large slope of the terrain, which is in two

directions - from the southeast to the northwest and from the northeast to the southwest;

- The plot is functionally divided into two parts- the northern part consists of auxiliary buildings of the Ascension Church (parish house, guest rooms, parking lot, etc.), while the southern part houses the Ascension Church with a bell tower and a park in which there is space for the construction of a memorial church;
- Vehicle access to the plot is on the north side, from Dobrinjska street, while pedestrian access is from Admirala Geprat street and Kneza Miloša street;
- By analyzing the geodetic plan obtained in the design task of the competition, the absolute elevations of reference points were determined: the elevation of the plateau in front of the Church of the Ascension is 100.24m, the elevation of the Church of the Ascension (the height of the highest dome) is 118.44m, the height of the crown of the church is 111.64m, the height bell tower is 124.04m. [4]

The design of Orthodox temples carries with it certain specificities - in addition to architectural, it is necessary to have a certain theological background - knowledge of church canons and basic principles that define the functional organization of temples, their orientation, content, position of furniture, form, etc.[6] Then, it is necessary to study the values of medieval monuments of Serbian sacred architecture, their development throughout history.[7] However, strict adherence to the rules without a certain creative freedom of the author can lead to an unsuccessful solution or the creation of uniformity in the construction of such objects. Also, copying exemplary forms often produces unconvincing architectural compositions because medieval quotations are interpreted incorrectly, often beyond liturgical needs. [8] The recommendation is to strive towards creating an original design that would follow the spirit of the present time and at the same time respect the church as such - imperishable, timeless. [9]

In order to integrate the newly designed memorial temple into the existing environment, it was necessary to become familiar with the history and architecture of the Church of the Ascension. The Church of the Ascension was built in 1863 during a time of great turmoil and the struggle of the Serbian people for liberation from Ottoman rule. The designers of the church were Colonel Pavle Stanišić, manager of the Main Directorate of Construction and Jovan Ristić, head of the Directorate of Construction. The church was designed under the influence of the architecture of Serbian medieval monasteries, mostly based on the Ravanica monastery. Five high domes with tambours decorated with slender arched windows are characteristic of the Moravska style group of Serbian medieval architecture. The facades are playful with pilasters connected at the very top by blind arches, in the bisectors of which there are narrow portals. In its original state, the church was plastered, and in 1967 the facade was covered with artificial stone. A bell tower was built next to the church itself, which corresponds to the church in terms of architectural values. [2]

Finally, the anthropometric analysis of the spatial organization is also an important factor in the design of Orthodox churches. It is imperative to dimension the temple in such a way as to enable the clergy to perform liturgical services without hindrance and the laos to follow and participate in them.

Given that the site in question is in the immediate vicinity of Zone 1 of cultural and historical protection and the existing Church of the Ascension represents an immovable cultural asset - a cultural monument, the participation of the Institute for the Protection of Cultural Monuments of the City of Belgrade in the creation of the project documentation is mandatory in order not to jeopardize the identity of the entire protected area by building a new memorial temple and its accompanying contents.

3. CONCEPTUAL DESIGN OF THE MEMORIAL TEMPLE

According to the project assignment, the position of the newly designed memorial temple is planned at the place of the sign of the cross to the innocent victims of the April bombing in 1941. However, after analyzing all the influencing factors, the conceptual design of the newly designed temple is positioned 12.5m south of the existing Church of the Ascension, along the eastern border of the gate. The explanation of this position of the memorial temple is as follows:

- The temple was designed in the back of the Church of the Ascension at an elevation of 100.92 m so that it would be lower than the existing church with its height of 10.2 m and so that it would not endanger the view of it;
- Symbolically, the newly designed temple was positioned opposite the sign of the cross to the innocent victims so that the sign of the cross would not be removed;
- The greater part of the existing greenery was preserved and a park was created. [4]

The newly designed memorial temple is oriented like the existing one - southwest-northeast, bounded by a circular sidewalk. In front of the southwest main entrance of the temple, a paved plateau was formed to facilitate the movement of a large number of people.

In the project assignment, the creation of an amphitheater towards Kraljice Natalija street was proposed, which was accepted as a conceptual design. The newly designed amphitheater is positioned on the eastern edge of the plot. It is accessed from the corner of Kneza Miloša and Kraljica Natalija streets. It was conceived as a kind of green auditorium space with views of the existing Church of the Ascension and the newly designed memorial temple. At the foot of the amphitheater there is a plateau suitable for holding suitable cultural and spiritual manifestations.

In order to enable people in wheelchairs to enter the port, a new entrance with a ramp from Admirala Geprata Street was designed, while the existing entrance from Kneza Miloša Street was abolished.

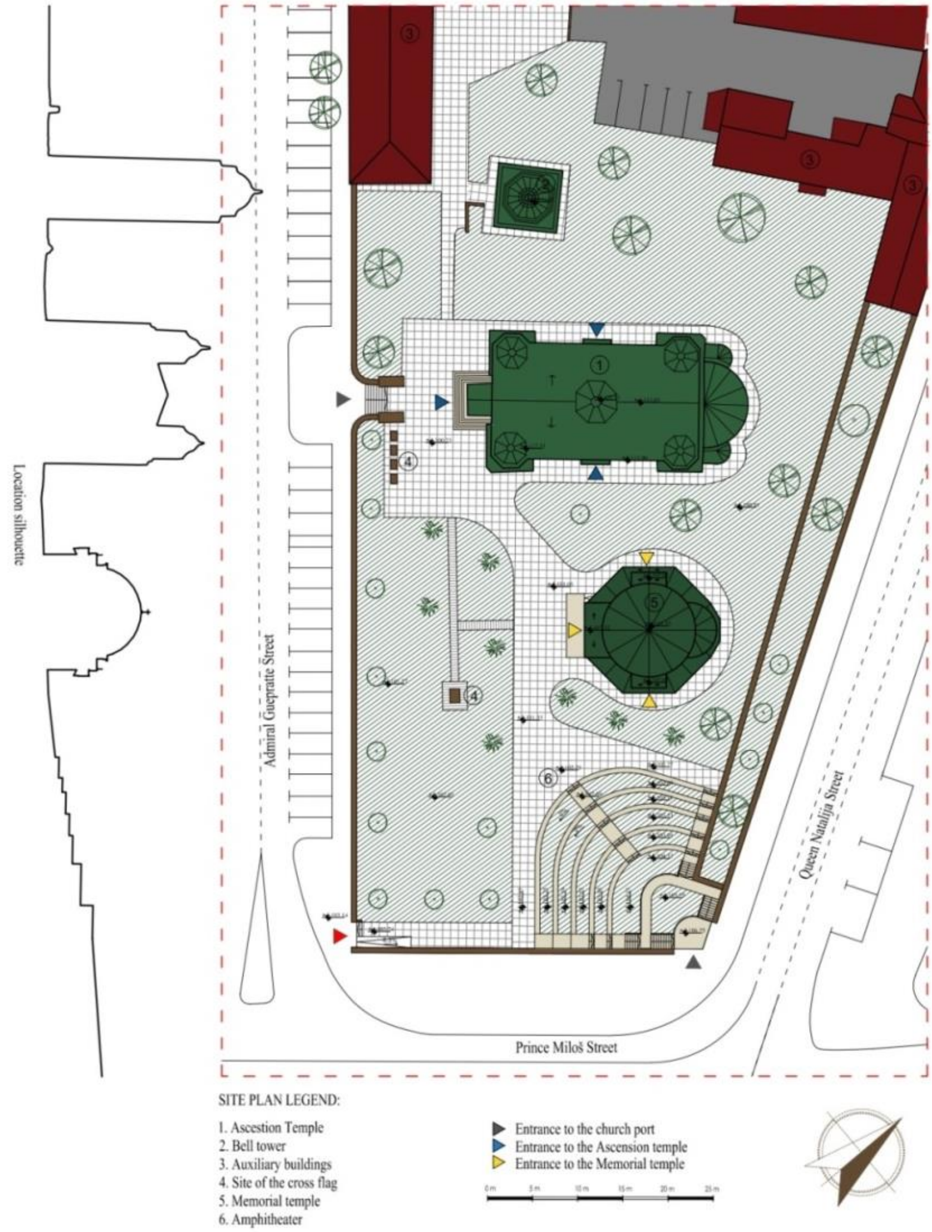


Figure 2: Site plan of the newly designed state of the port of the Ascension Temple in Belgrade [4]

The creation and development of the concept of the memorial temple started with freehand sketching on paper. The drawing represented a kind of tool for generating architectural forms. [10] Initial ideas were expressed through the creation of drawings, shapes and masses were explored and combined, the position of the object in space was considered in order to arrive at the final conceptual solution.

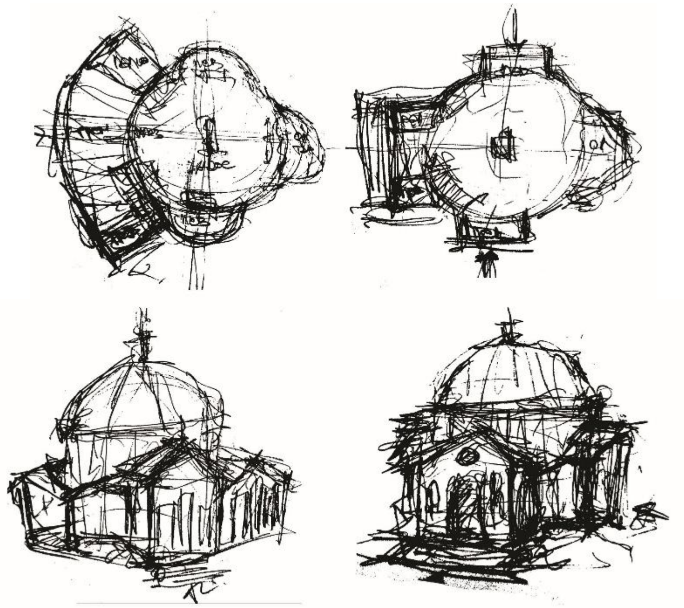


Figure 3: Sketches as a tool in the elaboration of the conceptual design of the memorial temple in the port of the Ascension Temple in Belgrade [4]

The base plan of the newly designed memorial temple is the rotunda, together with the auxiliary parts it forms the shape of an inscribed cross. The inspiration for the not so common form of the Orthodox church was Peter's Church in Ras as one of the oldest churches of the Serbian Orthodox Church.

The spatial organization of the temple follows the needs of religious activities and is formed by an established series of rooms. The main entrance to the temple is on the southwest side. The covered open narthex contains a candle burner and opposite it a small church shop. The nave is connected to the narthex, it is circular in shape, vaulted with a dome. On the south-east and north-west sides of the nave, there are choir space vaulted with semi-shaped vaults. The northeast, the most sacred part of the temple, is the altar apse. The area of the nave with choirs space is 70.0m^2. A maximum of 200 people can stay in the nave at the same time (according to "Neufert", the area of standing room in the temple is 0.25-0.35 m^2 [11]). At the very entrance to the nave, on the south side, there is a circular staircase leading down to the crypt of the temple. In addition to the main entrance to the temple, auxiliary entrances are provided on the northwest and southeast sides to enable the unhindered movement of a larger number of believers.

In the newly designed temple, all the necessary liturgical furniture is provided: the central position in the nave is occupied by the tetrapodos (Icon stand), on the sides are the Bishops throne and the Virgin's Mary throne, the choirs are equipped with counters, stasidia are arranged radially along the perimeter walls. The altar is separated from the nave by an templon, together with the soleum, it is raised by 2 steps. In the altar, in the central part, there is a altar table, on the north and south sides are the prothesis and the diaconicon in the form of niches in the wall. Along the eastern wall of the apse of the altar are placed the high kathedra and syntronos intended for priests.

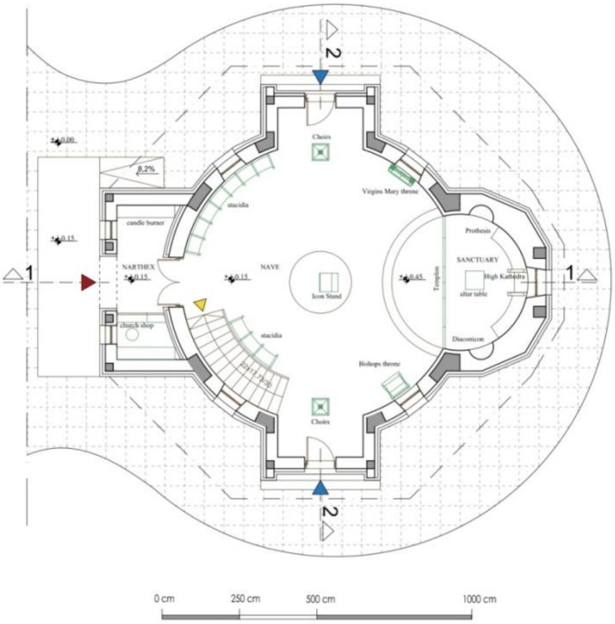


Figure 4: The ground floor plan of the conceptual design of the Memorial Temple in the gate of the Ascension Temple in Belgrade [4]

The crypt of the newly designed temple is positioned under the nave, in identical dimensionsas the nave. Its purpose is not defined by the project assignment. However, the conceptual solution envisages the use of the crypt for exhibition purposes with a permanent display of the innocent victims of the Second World War. Along the perimeter walls of the crypt, there are glazed shelves intended for exhibits. Natural lighting of the crypt is provided by the centrally positioned lantern-glazed ceiling, which further refines its ambience.

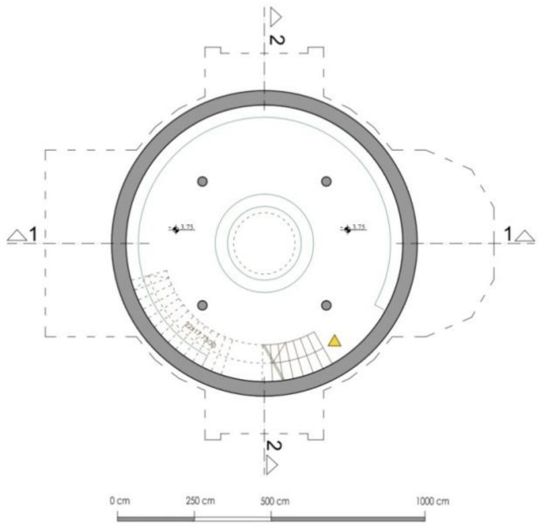


Figure 5: The crypt floor plan of the conceptual design of the Memorial Temple in the gate of the Ascension Temple in Belgrade [4]

The memorial temple is naturally illuminated by symmetrically placed monophores and oculus on the north, south, east and west sides. Due to the lack of natural light in the temple, a mystical atmosphere suitable for its purpose was symbolically created and also an emphasized symbol of "the only true light" that "the Light of Christ enlightens everything and everyone". [12]

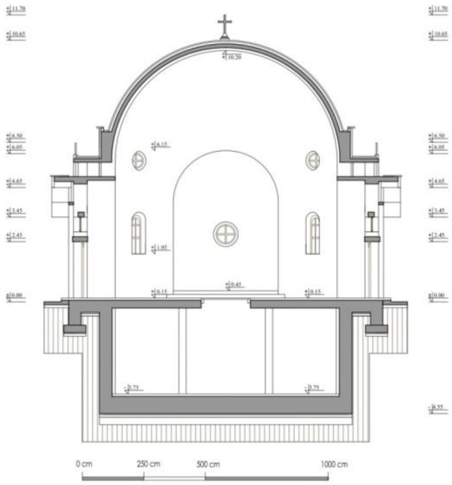
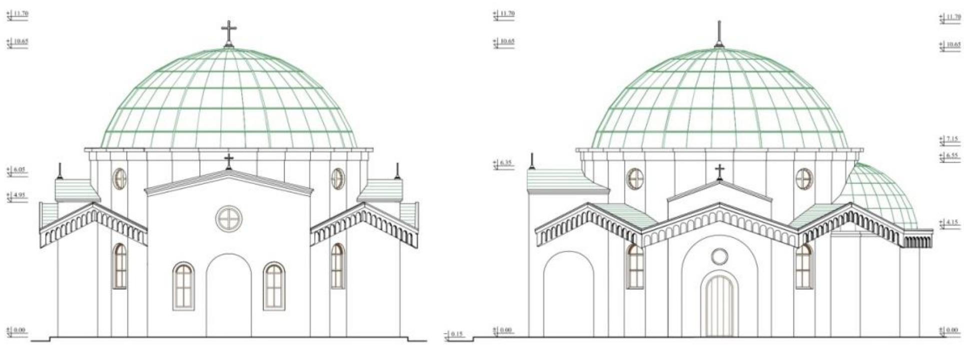


Figure 6: Cross-section of the conceptual design of the Memorial Temple in the gate of the Ascension Temple in Belgrade [4]

The existing Church of the Ascension, with its luxurious appearance, represents the dominant benchmark of the location in question. The goal of designing the form and materialization of the newly designed temple was to create a harmonious whole with the existing church without disturbing (or as little as possible) the existing ambience. The decorative elements that adorn the Church of the Ascension - oculus, monophores, pilasters that end in an arch, are woven into the form of the newly designed memorial church. The selection of a ventilated stone facade in two shades of gray that alternate dynamically also integrates the memorial temple with the existing one. The memorial temple is further refined by the polygonal canopy decorated with rows of blind arcades that extends over its entire circumference.



a) *b)*

***Figure 7:** Conceptual design of the Memorial Temple in the gate of the Ascension Temple in Belgrade: a) view of the west facade, b) view of the south facade [4]*

a)

b)

Figure 8: 3d view of the conceptual design of the Memorial Temple in the port of the Ascension Temple in Belgrade: a) view from Admirala Geprat Street, b) view from Kneza Miloša Street [4]

4. CONCLUSION

The paper shows the detailed procedure for creating the conceptual design of the memorial temple in the gate of the Ascension Temple in Belgrade. The Church of the Ascension is a Patron Saints day church of the city of Belgrade and one of its symbols. Given its importance, any intervention in its port requires extensive analysis by both the designer and the Institute for the Protection of Monuments in order not to jeopardize its status as a cultural monument and also the ambience of the area it covers. Therefore, during the design process, it was necessary to get acquainted with the history of the Church of the Ascension, the architectural style in which it was built, the analysis of influential factors - the project task, the subject location, anthropometric analysis, as well as the analysis of certain theological norms due to the specificity of the type of building itself. As a result, a conceptual solution for a memorial temple was created that respects the tradition of building Orthodox temples, meets the requirements stipulated in the project assignment, forms a unique whole with the existing church based on the applied details and materials, and with its form represents a unique sacred object.

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ENVIRONMENTAL AND ENERGY CONVERSION OF BUILDINGS- POTENTIAL, CHALLENGES, SUSTAINABILITY – CASE STUDY

Dušan Stajić[1], Miomir Vasov[2], Dušan Ranđelović[3]

Abstract

Conversion, regeneration/recycling, and urban renewal by the new reality and contemporary social circumstances become an architectural counterpoint. Using architectural reminiscence, the principles of creative city and creative industry, and the use of new technologies, architecture tries to find feasible, realistic "low-cost" solutions to achieve the most significant benefit in the broadest sense. The ecological and energy component, as inseparable steps, seen through today's eyes, represents a priority. Given that the buildings of the conventional construction method are the most widespread, the work focuses on analyzing their characteristics and the potential of their conversion into ecologically and energetically sustainable buildings by applying modern measures, systems, and management technologies.

Case studies of converted buildings in Western Europe were analyzed by applying the description and comparison methods. These were singled out as examples of good practice based on the obtained positive effects of conversion.

Key words: *Conversion in architecture, Energy efficiency, Retrofitting, Ecological architecture*

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1. INTRODUCTION

Due to the uncontrolled burning of fossil fuels, the use of non-renewable energy sources, and artificial materials in everyday life, humanity is increasingly faced with unwanted extreme natural phenomena and disasters such as the greenhouse effect, volcanic eruptions, earthquakes, and hurricanes. The need for rational energy consumption to preserve the environment first appeared globally in 1973 during the oil crisis, which resulted in the tightening of measures and regulations to increase the energy efficiency of buildings.[1]

Given that the construction industry is one of the most developed branches of industry in the world, its impact on the environment is of great importance for the survival of humanity. The percentage of energy consumption in the construction industry is 40% of the total global energy consumption [2], meaning its share in environmental pollution is proportionately large. To adequately respond to the challenge of reducing environmental pollution, in recent years, the concept of sustainability has been one of the main focuses in developing technologies in the construction industry. In addition to the aesthetic and functional aspects, the ecological and energy components are becoming increasingly important, reflected in the rational use of energy, direction towards renewable and clean energy sources, conservation and recirculation of water and energy, and the use of natural and recycled materials in construction.

Since the most significant number of existing buildings in Serbia was built using the conventional construction method, whose ecological and energy efficiency is low, as much as 39% of the total energy consumption is used to exploit these buildings. [3] Converting them into ecologically and energy-sustainable buildings to meet the requirements and principles of building the future is a challenge that the scientific and professional public will increasingly face.

The paper's topic is the analysis of the characteristics of conventionally built buildings, their advantages and disadvantages, and the study of the potential of implementing adequate measures and modern systems to convert them into ecologically and energetically sustainable buildings. As examples of good practice, the buildings of the developed countries of Western Europe have been selected, which for years have shown a solid commitment to increasing energy and environmental efficiency by investing in renewable energy sources that do not harm the environment.

2. METHODOLOGY

The paper is a manual about the possibilities, challenges, and potentials of converting conventional buildings into ecologically and energetically sustainable ones. Based on the logical order of research, the paper is divided into three parts. Using the method of description with professional literature, scientific magazines, data from the Internet, own observations, and conclusions, in the first part, an analysis of the characteristics of conventionally built buildings, their advantages and disadvantages that initiate their conversion was carried out. The second part deals with the potential for conversion of conventional buildings and the challenges that may arise in the conversion process. Also, by listing in tables, concrete measures and modern systems that can be applied in the conversion of buildings are presented. The third part is a case study of examples of converted buildings in Western Europe. The buildings were selected based on the following criteria:

- They are located in the area of Europe whose climatic characteristics for most of the year correspond to the climatic characteristics of our country;
- They were built using a conventional construction method;
- They are part of urban city units, and their identity woven into the existing area was not damaged by the conversion;
- The results obtained after the conversion of these buildings indicate that the energy savings in their exploitation and the negative impact on the environment have been reduced several times, which makes them stand out as examples of good practice.

The selected buildings that will be the subject of the case study are Zero Carbon House in Birmingham (UK), Galway Home in Galway (Ireland), and Holland Park Home in London (UK).

3. BUILDINGS OF THE CONVENTIONAL METHOD OF BUILDING - DEFINITION, ADVANTAGES AND DISADVANTAGES

The conventional construction method implies constructing masonry buildings using standard, most commonly available materials on the market, with a studied construction technique. Contemporary tendencies in architecture, which promote ecological and energy-efficient construction, indicate certain areas for improvement in the construction of buildings using the conventional construction method. The deficiencies that occur in the construction of such buildings are emitted through three phases of their life cycle: the phase of production of materials for the construction of these buildings, the phase of construction and exploitation of the buildings, the phase after the end of the life cycle of the buildings.

Table 1. Deficiency in the stages of the life cycle of buildings of the conventional construction method [4]

	Description of the deficiency	*Example*
The phase of production of materials for the construction of the buildings	*The amount and type of energy required for the production of materials and the amount of carbon dioxide (CO_2) emitted from the production processes of building materials harm the environment.*	*Cement production requires much energy, primarily obtained by burning coal, emitting large amounts of polluting particles into the atmosphere. About 5% of the total C02 emission comes from cement production. [5]*
The phase of construction and exploitation of the buildings	*During installation and exploitation, certain building materials can hurt the health of users and the environment. The amount of energy spent on the transportation of building materials during production processes, then to the warehouse and to the*	*The vapors of specific colors used to treat walls and floors often contain heavy metals and petroleum derivatives, which can cause long-term respiratory diseases, etc. [4]*

	construction site itself, is an essential factor in the analysis of the justification of its use.	
The phase after the end of the life cycle of the buildings	*Pollution caused by construction materials after the end of their life cycle in the building affects the environment and human health.*	*The most significant part of construction waste - internal waste (about 95%) is not subject to significant physical and chemical changes and minimally harms the environment. This includes waste from concrete, ceramics, brick blocks, and steel. The problem is represented by materials that emit harmful particles into the atmosphere after their life in the decomposition process (asbestos, asphalt binders). [4]*

4. CONVERSION OF CONVENTIONAL BUILDINGS USING MODERN MANAGEMENT SYSTEMS AND TECHNOLOGIES

Buildings of the conventional construction method represent energy-dependent buildings. In Serbia, as much as 39% of the total energy consumption is used for the functioning of these facilities, [2] of which the most significant share is the energy used for heating, cooling, operation of household appliances, and water consumption. By comparison, the average energy consumption in buildings in Serbia is over 150 kWh/m² per year, and in the developed countries of Western Europe, it is below 50 kWh/m².[6] Given that the necessary energy is obtained directly or indirectly by burning fossil fuels, coal, and wood, which emit a large amount of CO_2 and other harmful substances into the atmosphere, which impairs the quality of the environment, the focus of the conversion of buildings is precisely on reducing that consumption.

Table 2: Presentation of management measures, systems, and technologies aimed at improving the environmental and energy efficiency of conventionally constructed buildings

Type of measures, systems, and management technology	*Description*
Improvement of wall, floor, and roof insulation	*Adequate thermal insulation thickness regulated by energy efficiency standards helps maintain a comfortable temperature inside the building and reduces the need to use energy for heating and cooling. [3]*
Prevention of thermal bridges	*Thermal bridges are areas in building construction that transfer heat between the interior and exterior of the building and are characterized by higher thermal conductivity compared to the surrounding materials. These are places where thermal insulation is weaker or interrupted, which can lead to loss of heat or cold. [7]*
Replacing old windows and doors with energy-efficient models	*In this way, the insulation can be improved, and the loss of heat or cold can be reduced. Efficient triple-glazed windows feature a thermal break strip and low-emission (Low-E) glass that reduces heat transfer. [3]*

Use of renewable energy sources	*Installation of solar panels for electricity production or solar collectors for water heating can reduce dependence on conventional energy sources and reduce the emission of harmful gases. [3]*
Installing energy-efficient home appliances	*These devices use less energy to perform the same tasks than conventional devices. They use advanced technologies such as inverter motors, thermal insulation materials, efficient air circulation systems, and sensors to manage energy consumption. [8]*
Efficient lighting	*Replacing traditional light bulbs with energy-efficient LED bulbs can significantly reduce electricity consumption for lighting. LED bulbs use less energy and have a longer lifespan than traditional bulbs.*
Efficient heating and cooling systems	*Replacing outdated heating and cooling systems with more energy-efficient systems, such as heat pumps or high-efficiency air conditioners, can significantly reduce energy consumption. These systems use less energy and can better adapt to the facility's needs. [3]*
Energy management	*An energy management system can help monitor and control energy consumption in a facility. These systems enable automatically switching off unused appliances, adjusting temperature and lighting according to needs, and other energy-efficient measures. However, it is also necessary to have a good knowledge of the characteristics, capabilities, and proper sizing of each system, so that some aspects of the system do not conflict. [9]*
Passive natural ventilation system	*The system involves ensuring the flow of fresh air and the removal of heat from the space without the use of mechanical devices such as fans or air conditioners. It uses temperature difference and wind to allow airflow through the room. Adding vents to the walls or roof can facilitate airflow. These vents are placed in strategic places to allow fresh air in and warm air out. [3]*
Installation of movable facade elements	*Installation of canopies, window shutters can be influenced to prevent heat loss or overheating due to the influence of direct sunlight. [10]*
Rainwater collection	*This practice has many benefits, including reducing water consumption from public water supplies, reducing the burden on sewage systems, reducing water costs for households and commercial facilities, and reducing negative environmental impact. [5]*

In planning the implementation of these systems, it is necessary to consider the specificities of specific buildings and local legal regulations to achieve an optimal balance between environmental and energy efficiency and economic factors. Given that some buildings of conventional construction were built decades ago, their age can be a challenge during conversion. Therefore, it is necessary to conduct a detailed review and assessment of static characteristics to determine the stability of the buildings and the eventual need for specific interventions in a constructive sense. The old buildings were built according to the previously valid building regulations that have been changed to this day, so during the conversion, it is necessary to harmonize them with the currently valid regulations, [11] which may require additional work and costs.

As conventional buildings are, in most cases, integrated into the urban fabric of inhabited places, some buildings of exceptional architectural, cultural, and historical value can be located among them. By converting into energy and ecologically efficient buildings, with strict observance of specific regulations and restrictions to preserve their authenticity, these buildings would be adapted to the requirements and principles of future construction. Also, the identity and spirit of inhabited places created over decades would be preserved.

The conversion of conventional buildings into environmentally and energy-efficient buildings requires significant investments in the short term. Most of these investments include implementing various systems and technologies that have yet to experience mass production and competitiveness to conventional construction systems. However, it is essential to consider the long-term benefits that can be realized through the reduction of energy and ongoing maintenance costs, the increase in the value of buildings, the reduction of emissions of harmful particles into the atmosphere, and long-term sustainability.

5. ANALYSIS OF EXAMPLES OF GOOD PRACTICE

In this chapter, the analysis of three converted conventional buildings is included: Zero Carbon House (UK), Galway Home (Ireland), and Holland Park Home (UK).

Table 3: Basic information about the case study buildings

	Location	*Building function*	*Construction year*	*Conversion year*	*Surface area*
Zero Carbon House	*Birmingham Uk*	*Single-family house*	*1840.*	*2009.*	*190m^2*
Galway Home	*Salthill, Co Galway, Ireland*	*semi-detached house*	*1970.*	*2014.*	*142m^2*
Holland Park Home	*London UK*	*Apartment building*	*1850.*	*2008.*	*345m^2*

5.1. Zero Carbon House, Birmingham, UK

The "Zero carbon house" is located in Birmingham, England. It was built in 1840 in the Victorian style - in a massive brick and stone construction system covered with stone slate. In 2009, the reconstruction and extension of the house was carried out. [12]

a)

b)

Figure 1: "Zero Carbon House" a) before conversation b) after conversation [12]

The author of the project was architect John Christophers. After the inversions on the house, it became an energy-efficient house with zero carbon dioxide emissions into the atmosphere. [12] The table shows the measures, systems, and management technologies applied in the conversion of this building.

Table 4: Presentation of applied measures and systems at the "Zero Carbon House" [12]

Type of measures, systems, and management technology
The addition of the house on its south side was completed.
The roof surfaces of the extended part of the house are covered with solar panels. Also, thermal insulation of 40 cm of cellulose and 10 cm of wooden fiber boards were added to the roof structure of the existing and extended part of the house.
A house ventilation system has been installed, which uses the warm and stale air from the kitchen and bathroom after filtering to heat all the house rooms.
The existing windows were replaced with new ones with triple glazing and frames coated with thermal insulation.
The existing technology in the house was replaced with a new one that saves energy to the maximum (A++ energy class).
In order to reduce water consumption, a rainwater collection system with an underground tank was installed, which is used to irrigate green areas and for sanitary purposes.
For the construction of the extended part of the house, instead of bricks and concrete, which contribute to CO_2 emissions into the atmosphere, hydraulically compressed blocks made of clay were used. They affect the regulation of air humidity in the house.
The external walls are lined with insulating material made of graphite with a thickness of 28 cm. The connecting links of the steel parts of the house structure are covered with basalt fibers. The floors in the house are made of a mixture of rammed earth and red clay. In order to preserve the authentic appearance of the front facade of the house, instead of the exterior, internal thermal insulation of a 35 cm layer of cellulose and wooden slats was done.
Digitized control of energy consumption in every part of the house and management of devices intended to achieve favorable comfort in the house is possible through the display in the living room.

Studying the house using modern instruments, Professor Ljubomir Janković from the Birmingham School of Architecture analyzed the production and consumption of energy in the house, the concentration of carbon dioxide, the movement of humidity, and the air temperature in the house. Based on the research results, it was determined that the total annual CO_2 emission from the 21,000 kg that the house produced before the conversion was reduced to 660 kg after the conversion. Given that the production of electricity from solar panels meets the need for electricity in the house, the excess energy is sold to the electricity distributor. In this way, the house is self-sustaining. According to the calculation, the repayment period of the invested funds for its reconstruction and extension was nine years. By adding wall and roof thermal insulation, the thermal insulation power of the house was improved 16 times. Also, the new windows emit 14 times less heat from the house than the old ones. [13]

Table 5. Display of energy consumption "Zero Carbon House" [13]

standard	*passivehause*	*Zero carbon house*
Specific heat demand	*< 15kWh/sqm.yr*	*7.3 kWh/sqm.yr*
Primary energy demand	*<120kWh/sqm.yr*	*41kWh/sqm.yr*
Infiltration airtightness	*< 0.6ac/hr@N50*	*0.57ac/hr@N50*
U- values, wall, roof, floor	*< 0.15W/sqm.K*	*0.08 – 0.11W/sqm.K*
Glazing Ug	*< 0.80W/sqm.K*	*0.5W/sqm.K*
Window Uw	*<0.85W/sqm.K*	*0.65W/sqm.K*

5.2. Galway Home, Forster Park, Salthill, Co Galway, Ireland

The house is in Forster Park, Salthill, Co Galway, Ireland. It was built in 1970. It is a semi-detached house with a ground floor and an upper floor, with walls built in a combination of concrete and brick blocks with 100mm of unventilated space and wooden roof construction with concrete slab cladding. After buying the house, the new owners decided on extensive reconstruction. One of the main goals was to reduce the total cost of energy consumption in the house. [14]

a) *b)*

Figure 2: "Galway home" a) before conversation, b) after conversation [14]

Architect Simon McGuinness designed the reconstruction and conversion project. The works were carried out in 2014. The table shows the measures, systems, and management technologies applied in the conversion of this building.

Table 6. Presentation of applied measures and systems at the " Galway Home" [14]

Type of measures, systems, and management technology
The house is covered with a thermal envelope. 200mm XPS insulation is placed on the floor. The exterior walls are lined with 180mm mineral wool insulation and a mineral render finish. Blown platinum bead insulation was added to the existing unventilated interspace of 100 mm. In the roof structure, 300 mm of mineral wool was added between the roof supporting elements and another 100 mm between the ceiling beams.
The old windows and doors were replaced with triple-glazed Future Proof PassiV uPVC windows and doors.
In order to reduce the release of heat from the house and prevent the appearance of cold bridges, the interior walls were removed, and the ceiling and exterior walls were finished from the inside with a hermetic membrane made of wet plaster. After that, new walls were built from recycled used materials.
An air-water heat pump system replaced the old oil-fired boiler.
A home ventilation system with heat recovery is installed.
A system was installed to monitor heat loss from the house, based on which the heating and ventilation system is activated.

Apart from the functional and aesthetic benefits brought by the conversion and reconstruction of the house, it also significantly saved energy and reduced negative emissions of harmful substances into the atmosphere. By analyzing the effects of the reconstruction and conversion of the house, it was determined that the energy consumption dropped from 387.5 kWh/m2/y to 42.9 kWh/m2/yr, and the heat release rate decreased even 25 times. [15]

5.3. **Holland Park Home, London, UK**

A residential building in London was built in 1850 in a massive construction system - brick walls and a wooden floor. Its primary purpose was social housing. The architectural bureau "Paul Davis+ Partners" proposed the reconstruction and adaptation project in 2008. [15]

Figure 3: „Holland Park Home“, after conversation [15]

Table 7. Presentation of applied measures and systems at the " Holland Park Home" [15]

Type of measures, systems, and management technology
The internal walls and floor structure were removed so that the entire building would be enveloped with 20 cm thick polyurethane thermal insulation. In this way, a protective membrane was created, and the appearance of cold bridges in the building was avoided. The insulation is covered with OSB boards. After installing the thermal insulation, the floor construction and partition walls were made.
The existing facade openings were replaced with new triple-glazed windows.
The MVHR system (mechanical ventilation with heat recovery) is installed in the building. Fresh air is mechanically filtered and drawn into the building. If necessary, the heated air is spread through the building via the floor heating in the basement. Stale warm air from the kitchens and sanitary rooms is extracted from the building by the ventilation system while keeping the heat. If the temperature in the building is lower than the outside temperature, the system works the same way to cool the building. In this way, energy is saved for heating and cooling the building.
Hot water production is achieved through solar thermal panels. In the absence of sunlight, heating is provided by heat pumps connected to the MVHR system. [15]

After the reconstruction and adaptation of the building, CO_2 emissions were reduced by 83%. The building uses less than 15kw/h per m2 of energy per year for heating, which is significantly less than the production of 130kw/h per m2 before the reconstruction. By saving energy, the calculated payback period for the reconstruction of the building is predicted to be 15-20 years. [15]

6. COMPARATIVE ANALYSIS OF APPLIED MEASURES

The selected buildings are representative examples of converted conventional buildings into ecologically and energy-sustainable ones. The table shows a comparative analysis of the applied measures and technological systems during their conversion.

Table 8. Analysis of applied measures of selected buildings [12,13,14,15]

Conversion measures applied	*Zero Carbon House, Birmingham, UK*	*Galway Home, Forster Park, Salthill, Co Galway, Ireland*	*Holland Park Home, London,UK*
Surface area of the building	*190m2*	*142m2*	*345m2*
Roof solar panels	+	-	+
Thermal insulation	+	+	+
Ventilation system	+	+	-
Windows with triple glazing	+	+	+
energy-efficient appliances	+	+	+
Water collection	+	+	+
Digitalized control technology	-	+	-
Functional redesign	+	+	+
Reduction of energy consumption	*65%*	*89%*	*83%*
Payment period	*9 years*	*6 years*	*15 years*

A comparative analysis of the selected buildings was performed using a tabular representation: the individual building, "Zero Carbon House," the semi-detached house, "Galway Home" and the building intended for collective housing, "Holland Park Home." The table compares the surfaces, applied measures, management systems, and technologies in converting these buildings. At the bottom of the table are summarized the results obtained based on research and analysis of energy consumption in exploiting these facilities before and after conversion.

Based on the attached data in the table, it can be seen that the "Galway Home" object, which has the smallest area after the conversion, has the highest energy savings and, therefore, the shortest repayment period of the invested funds. The "Holland Park Home" facility is in second place regarding energy savings. However, the repayment period of the invested funds ranks it in third place, behind the Zero Carbon House facility. The reason for this is that the "Holland Park" facility's surface area is significantly more extensive than other facilities, so it was necessary to invest more considerable funds in its conversion. The Zero Carbon House facility has the most significant number of implemented systems. However, in terms of energy savings, it is in third place. The percentage of reduction in energy consumption and the expected repayment time of the invested funds do not always depend on the implemented measures and systems in the conversion of buildings. Each building has unique characteristics and should be approached as such to achieve maximum conversion benefits.

7. CONCLUSION

The construction industry is one of the biggest polluters of the environment. One of the primary goals of technological achievements in construction is to reduce pollution and energy consumption. The most significant number of existing buildings were built with ecologically and economically inefficient conventional construction methods. The most significant number of existing buildings were built with ecologically and economically inefficient conventional construction methods.

The paper's topic was the analysis of the characteristics of conventional buildings and the potential of their conversion into ecologically and energetically sustainable buildings using modern measures, systems, and management technologies. In the first part of the paper, based on the analysis of the characteristics of conventional buildings, the reasons why these buildings' economic and ecological components do not meet sustainability standards are presented. Concrete measures and modern systems that can be applied in converting buildings into energy and ecologically efficient buildings are presented. Analyzing examples of good practices of converted buildings in Western Europe, the results of the impact of applied measures and systems on energy saving and long-term repayment of invested funds are summarized. Based on the comparative analysis presented in the discussion, it is concluded that the percentage of energy consumption reduction and the expected payback time of the invested funds do not depend only on the type and amount of applied measures, systems, and management technologies. The factors that influence it are the condition in which the object was before the conversion, the dimensions of the object, the type, number, and quality of the implemented measures, systems, and management technologies in the conversion, the market price of the works, as well as the legal regulation of the conversion defined by the local administration. Therefore, proper planning, professional project management, and prior analysis of costs and potential are necessary to select adequate systems for building conversion. From a long-term point of view, the benefits realized by the conversion of buildings are reflected in the reduction of costs for energy and ongoing maintenance of buildings, the increase of the value of buildings, the improvement of the quality of the living environment, and globally, the reduction of emissions of harmful particles into the atmosphere.

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IMPORTANCE OF INNOVATION COMPETENCE-BASED CURRICULA IN CLIMATE-SMART URBAN DEVELOPMENT BASED ON GREEN AND ENERGY EFFICIENCY FOR THE WESTERN BALKAN REGION

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Abstract

The relevance of introducing competence-based curricula in climate-smart urban development (CSUD) based on green and energy efficiency with the relevant non-academic sector is presented in this study. Western Balkan countries should consider improving energy efficiency and reducing carbon emissions by using renewable energy sources, investing in energy-efficient buildings, encouraging the use of sustainable transportation, developing sustainable waste management systems, implementing smart grid technology, and developing green urban spaces. This can be done only in cooperation with the academic sector through innovative teaching methods based on up-to-date equipment exploitation.

Key words: *competence-based curricula, climate-smart urban development, green and blue technologies*

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1. INTRODUCTION

Nowadays, cities worldwide are major contributors to global emissions, accounting for more than 70% of all global carbon dioxide emissions [1]. The European Bank for Reconstruction and Development (EBRD) concluded that 92% of the population worldwide does not breathe clean air, and air pollution hits countries in the Balkans region especially hard [2]. On the other hand, 55% of the global population lives in urban areas, and the share is still increasing [3]. In the context of the 2030 Agenda for Sustainable Development, the Paris Agreement, the UN Framework Convention on Climate Change, and other global development agreements and frameworks, cities should be well-planned and well-managed.

According to the New Urban Agenda, every urban renewal policy and strategy should include “the linkages between good urbanization and job creation, livelihood opportunities, and improved quality of life” [4]. Western Balkan (WB) region should adopt a new recognition of the correlation between good urbanisation and development which aligns with the 2030 Agenda for Sustainable Development, especially Goal 11 on sustainable cities and communities. Moreover, there is a need for WB countries to adapt “to the impacts of climate change, which also requires significant policy intervention in spatial organisation, resource use, and infrastructure” and “to promote business climate reforms” [5]. Therefore, climate-smart urbanization can be a powerful tool for sustainable development for developing countries since climate change represents a challenge and business opportunity for the creation of new green jobs, boosting new and innovative technological solutions and business models [6].

The EU has set goals that will also affect any WB country that joins the EU:

- reduction of its greenhouse gas emissions by 40% below 1990 levels [7],
- increasing the use of renewable energy [8],
- switching to a low-carbon and climate-resilient economy by 2050 [9].

Western Balkan countries included in this research, Montenegro, Bosnia and Hercegovina, and Albania (in further text: WB countries) already have adopted the national strategic documents that can be a starting point for climate-smart urban development (CSUD) and solutions:

- In Montenegro, the Law on Spatial Planning and Construction of Structures is based on the principles of an integrated approach to the planning process, spatial sustainability of development and quality of planning and construction, prevention or mitigation of climate change impact, etc., all aiming at harmonised economic, social, environmental, energy-efficient and cultural development.
- In Albania, National Strategies on Housing and Urban Development promotes spatial integration, sustainable economic development, spatial interconnection of functional areas, and improved regional infrastructure, transport and mobility.
- Law on Spatial Planning and Land Use, adopted at the level of the Federation of Bosnia and Herzegovina, aims to solve the problems the planning system is facing: the lack of documentation, areas insufficiently covered with urban plans, and some shortcomings of the plan implementation system (no respect for plans).

However, these WB countries on their path to EU accession should further harmonise their procedures with the EU. Therefore, promoting green jobs in urban development and making business-academia connections can be seen as a step toward achieving these goals. Also, climate change has a special long-term effect on urban development, therefore, introducing "smart" approaches in this area should be a strategic decision for any country.

The first step towards creating an environment for climate-smart urban development is introducing education that will raise awareness, provide adequate knowledge and skills and profile new professionals who will incorporate a climate-smart urban development approach in all aspects of their professional activity. In other words, education should align with the initiatives on Modernising Europe's Higher Education Systems and Rethinking Education and, in general, with the objectives of the Europe 2020 strategy, to tackle global challenges such as climate change effectively. Innovative and problem-based approaches, as well as courses based on business-academia cooperation designed to be continuously upgradeable by the practical work of students and contributions from companies, should be introduced in educational programmes.

Western Balkan higher education institutions (WB HEIs) should improve the existing education in CSUD, build professional and technical capacities, apply innovative teaching methods and ICT, and create permanent links with the non-academic sector. Thus, motivated by this idea, the University of Montenegro and the University of Nis together made a consortium consisting of six HEIs from EU Member States and third countries associated to the Programme, seven WB HEIs, and three non-academic partners from the WB region, supported by two non-academic associated partners in the field of urban development. They got the grant for the realisation of the Erasmus+ capacity building project titled "Curricula innovation in climate-smart urban development based on green and energy efficiency with the non-academic sector (SmartWB)", www.smartwb.ucg.ac.me.

The broader objective of the SmartWB project is to improve the quality of higher education in the CSUD field by exchanging knowledge, experience, and good practices, modernising university courses in line with EU trends, and improving the level of competencies and skills of teaching staff. This wider objective fully complies with the priorities of the capacity building projects within the Erasmus+ program, i.e., Green Deal priority.

To achieve this objective, it is necessary to transfer innovative and newly developed technologies and know-how best practices from the EU Member States and third countries associated to the Programme to third countries not associated to the Programme HEIs in the field of CSUD. EU Member States and third countries associated to the Programme HEIs have a large experience in the successful education of students in CSUD - advanced knowledge, qualified experts, modern laboratories for simulating CSUD solutions, and rich experience in developing relations between business and academy.

The research presented in this paper is based on the reports created during the first year of the SmartWB project co-funded by the Erasmus+ programme of the European Union.

2. CURRENT STATUS IN CLIMATE-SMART URBAN DEVELOPMENT IN WB REGION

To check the relevance of the curricula innovation in CSUD based on green and energy efficiency for the WB region, the analysis of the WB regional issues related to urban development was needed. The analysis aimed to indicate the level of readiness for business-academia cooperation and the user needs for green jobs and climate-smart solutions; accordingly, the questionnaire was prepared, and a survey was carried out. The feedback was used to direct the modernisation of courses but also to efficiently develop and implement the interactive web-based platform for sharing best practices and knowledge between academia and business.

From the analysis of the WB regional issues related to urban development, the following conclusions were derived.

Sustainable urban planning is an important priority for WB countries, as the region seeks to balance economic growth with social and environmental sustainability. The region has made significant strides in this area but continues to face challenges related to rapid urbanization, infrastructure development, and environmental degradation. Some of the main challenges in this region include limited financial resources, lack of political will, limited technical expertise, and cultural barriers. WB region faces problems providing adequate infrastructure and services to support urban development, such as water supply, waste management, and transportation. This can make it difficult to attract investment and encourage sustainable development. A high priority for more sustainable forms of transport will drive more efficient use of road space, enhance the attractiveness of non-motorised modes, and improve the accessibility of specific locations. It will also reduce environmental damage, make street space more attractive and improve road safety for non-motorists.

Western Balkan countries should consider improving energy efficiency and reducing carbon emissions by using renewable energy sources, investing in energy-efficient buildings, encouraging sustainable transportation, developing sustainable waste management systems, implementing smart grid technology, and developing green urban spaces. This can be done only in cooperation with the academic sector through innovative teaching methods based on up-to-date equipment exploitation.

The results of a survey on WB countries' industry needs for climate-smart urban solutions have confirmed the necessity of sustainable urban planning, aiming to direct economic development and preserve the environment.

The biggest problems that need to be overcome are a lack of coordination between the public and private sectors; a lack of capacity, both human and financial, for the implementation of smart city initiatives; non-transparency of data; lack of political will; lack of incentives from the state; insufficient information of the population about CSUD, etc.

The fact that over 70% of respondents from each country of the Western Balkans are not fully familiar with the standards of the European Union regarding CSUD is worrying. On the other hand, it is encouraging that more than 90% of the respondents are ready to adopt new methodologies and technologies, to be competitive for future green jobs. Therefore, it is necessary to organize informative activities about European standards in CSUD in cooperation with EU bodies, state governments, the academic community, and the business sector. Also, these standards should be included in engineering and other relevant curricula. Over 60% of respondents in all WB countries believe that it is necessary to innovate current education in terms of CSUD.

On the other hand, it is well known that the EU has set ambitious goals through the European Green Deal to combat and mitigate the effects of climate change and promote sustainable development. As a part of this effort, the EU has introduced a range of legislation and policies related to urban development and the urban environment to promote more sustainable, healthy, and competitive urban areas while addressing the challenges of climate change.

In addition, many networks have been created to enable networking among EU member countries and facilitate collaboration. This makes it easier to share important lessons learned and allows experts to exchange technical information. In urban development, it has become clear that there is a shift from building as quickly and cheaply as possible, to sustainable, smart systems. It is important that each sector is no longer dealt with individually but that there is also an internal collaboration between urban planners, water and wastewater experts, and open space planners.

Therefore, one of the tasks of the SmartWB project will be to develop and implement a technological platform for the collaboration and exchange of best practices and solutions among academia and stakeholders to make cities inclusive, safe, resilient, and sustainable. The platform will summarise well-established solutions for climate action and adaptation to climate change, such as intelligent transport solutions for freight and passenger transport, environmental sensors, intelligent waste management, sustainable food supply, safe drinking water supply, and natural disaster risk management. These solutions should also be applied in the WB region to follow a greenhouse gas-neutral way of life. Therefore, the developed platform should be the way to the promotion of low-emission economic practices and resilient infrastructures.

3. CURRICULA INNOVATION IN CLIMATE-SMART URBAN DEVELOPMENT BASED ON GREEN AND ENERGY EFFICIENCY FOR WB REGION

According to the conclusions of Chapter 2, the innovation competence-based curricula in climate-smart urban development based on green and energy efficiency for the Western Balkan region is of crucial importance for various target groups of stakeholders: students in the field of urban development, teaching staff, representatives of the business sector, professionals in the field of urban development, governmental authorities, public municipal administration, and agencies.

All WB countries should implement new technologies and smart solutions to reduce emissions and make cities inclusive, safe, resilient, and sustainable. Because of that, the selected WB HEIs, experienced in urban development, must strengthen their cooperation with the business sector and improve their studies in CSUD.

3.1. Current status of higher education in CSUD

Before the modernisation of university courses, an analysis of the existing curricula related to CSUD in WB HEIs was performed. Several target groups of stakeholders were identified, and their needs can be summarized as follows:

- Students in urban development require modern and up-to-date courses and teaching materials in urban development, which will provide them with the necessary knowledge and skills, resulting in fast employability in the urban development business sector. They need practical placements and internships in companies or public institutions related to CSUD.
- Teaching staff require theme-based training in advanced urban development areas, including climate-smart solutions, advanced laboratory equipment, and software to provide practical exercises to students. They need close cooperation with the non-academic sector resulting in modernised courses oriented to deliver bachelors and masters with knowledge and skills required by the industry sector.
- Representatives of the business sector in urban development need support from HEIs to apply new technologies and solutions. They require graduated students with specific advanced skills and knowledge to develop new products and services directly applied to real-time problems. Because of that, a strong relationship between the industry sector and university staff needs to be achieved to support them in developing their business.
- Professionals in urban development require general information about the relevancy and developments in urban development, emission reduction approaches, low-carbon technologies, and climate-friendly solutions. They need workshops and events to be informed regarding new technologies and solutions to help them improve their business.
- Governmental authorities, public municipal administration, and agencies need to receive well-developed products and services based on up-to-date approaches and professional expertise. They need to have well-developed business and academic sectors in urban development and related disciplines, which will deliver capacities for satisfying all their needs for services and products in a highly professional, efficient, and cost-effective manner.

After identifying the resources in WB HEIs, the need to purchase up-to-date laboratory equipment, software, and library units was detected. All WB HEIs expressed their need to establish a better connection with the business sector and to provide new and innovative solutions in CSUD education. Along with that, training their teaching staff to acquire new teaching methods in the CSUD will be organized by the EU HEIs.

On the other side, existing curricula related to CSUD in the EU were reviewed and compared to those in WB countries. To compare curricula, one can use different methodologies by which the courses based on CSUD have been classified into nine groups: spatial and urban planning, architecture and building design, material science, energy efficiency, road design and mobility, urban water management, geodesy and analysis, planning and participation procedures, governance and planning policies.

From the analysed results, the following conclusions are drawn.

There are some structural differences at the curriculum level between the universities from the EU and WB countries. The bachelor programs in EU universities have higher concentrations of "Spatial and Urban planning", "Energy Efficiency", and "Governance and planning policies" related subjects. Meanwhile, in the bachelor programs in WB HEIs', there is less to no concentration on such subjects. Given the importance of these topics and the fact they are in accordance with the development of the field today and in the future regarding CSUD, a modernisation of the bachelor curricula in WB countries is needed.

The master programs of the EU and WB universities have similarities and differences. A key finding is that the concentration of "Spatial and Urban planning", "Material Science", "Planning and participation procedures", and "Governance and planning policies" subjects is lower in the EU universities than in WB universities. Also, WB universities have a low representation of subjects in the "Architecture and building design" and "Urban water management" categories. Thus, it can be concluded that, while the two groups of universities have higher similarities in the master program, there is still space for improvement and modernisation of curricula due to harmonisation, according to CSUD.

The content of the curricula of HEIs in WB countries is still developing. In some cases, due to economic restrictions, political situations, or lack of experience or capacity, curricula have been developed more slowly. At the same time, universities of the EU offer a range of courses and programs related to CSUD, including sustainable urban planning, renewable energy, and climate change adaptation. These curricula provide valuable resources for urban professionals to develop the skills and knowledge needed to promote sustainable urban development.

It is necessary to harmonize the contents of courses in all WB HEIs according to the more advanced curricula of the EU universities.

The courses that should be modernised based on CSUD include urban planning and design, environmental science, sustainable energy, transportation planning, and building science. These courses must be revised to include the latest innovations and technologies promoting sustainable urban development and reducing carbon footprint. It is essential to modernise these courses to prepare future urban professionals to address the challenges posed by climate change.

3.2. Expected impact of the curricula innovation

Modernised WB HEIs will not only transfer knowledge but also create economic and social value by strengthening their capacities and providing better working conditions for the next generation.

WB teaching staff will improve their personal and professional development skills through theme-based training. At the same time, the newly equipped laboratories with up-to-date laboratory equipment and software will help HEIs to build their capacities and organise better laboratory exercises.

Stronger connections and cooperation with the private sector will be established through promoting innovation and entrepreneurship. Providing agreements for future cooperation between WB HEIs and the non-academic sector is the first step to enabling students to get skills and knowledge improvement.

A technological platform for sharing experiences in CSUD, summarising well-established solutions for climate action and adaptation to climate change (such as intelligent solutions for transport, environment protection, waste management, sustainable food supply, safe drinking water supply, and natural disaster risk management) will be used for networking and collaboration among HEIs and the non-academic sector.

Aligning the academic world with the labor market will enhance students' employability, and stakeholders will be engaged in providing feedback on their needs for green jobs and climate-smart solutions.

4. CONCLUSION

Countries in the Western Balkans are developing and aiming their capacities regarding climate-smart urban development to be equal to those of other countries within the European market. Reforms on WB universities' programs need to follow regional development and European directives and initiatives. Certainly, the professional and academic preparation of experts in this field begins at the appropriate universities. Thus, academic staff has a high scientific and research responsibility for actively providing knowledge, skills, and competences to aspiring experts in the field of climate-smart urban development.

The consortium of the SmartWB project was put together because the WB HEIs identified the need to invest in upgrading their existing capacities in CSUD, improving technical innovations and equipment, infrastructure, information, and technological systems based on EU standards and constantly strengthening the personnel competences through education and training system. As a result, this will reduce inadequate professional qualifications and the lack of specialised personnel in the field of CSUD in WB countries.

The wider objective of this project is to improve the quality of higher education all over Western Balkan countries. Based on the analysis of the curricula of EU Member States, it was identified that they are more stable and more advanced, while WB countries' curricula are shorter in experience and require further development. It is also preferable that higher education in the Western Balkans develops with harmonised curricula.

The courses that will be modernised based on climate-smart urban development include urban planning and design, environmental science, sustainable energy, transportation planning, and building science. These courses need to be revised to include the latest innovations and technologies that promote sustainable urban development and reduce the carbon footprint. It is essential to modernise these courses to prepare future urban professionals for the challenges related to climate change.

Modernised curricula based on a transfer of the best practices from EU to WB HEIs, trained teaching staff through theme-based training for acquiring new teaching and learning methods, educated professionals in the field of CSUD through the organised LLL courses, laboratories with up-to-date laboratory equipment and software, where the students will gain practical knowledge that can be immediately applied will strengthen not only the WB HEIs but also CSUD field in the WB region. Since using digital tools for teaching and learning is challenging, more activities should be done to help HEIs in the WB with their digital capacity building.

Future activities will be oriented to the development of an open online platform (in English and local mother tongues), in collaboration with EU Member States and third countries associated to the Programme HEIs, to provide new possibilities for business-academia collaboration and strengthen the relations between them by offering state-of-the-art solutions in the field of urban development and all necessary documents needed for investments in business climate sector.

Collaboration between the non-academic sector and academic institutions is essential to develop innovative curricula that promote green and energy-efficient solutions for urban development. These curricula provide valuable resources for urban professionals to develop the skills and knowledge needed.

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RAILWAY VIADUCTS – RE-USING TRANSPORT INFRASTRUCTURES IN EUROPEAN CITIES

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Abstract

Infrastructure works have been on the spotlight for the last several decades, in an effort by local governments to revitalize urban areas affected by their frequent disruptive presence. Urban highways, railway viaducts or road embankments have been used so far in urban regeneration projects to alleviate the urban stress that these barriers have caused and in some cases, to add aesthetic values to the site. Air and noise pollution, urban fragmentation or socio-economical degradation have appeared as a consequence to traffic congestion, harmful urban planning or plain neglect.

Projects such as the popular High Line in New York or Promenade Plantée in Paris have shown that previous railway viaducts can help revitalize urban areas and create enjoyable public spaces. Many viaducts have been the subject of architectural competitions or investments. Re-using these infrastructures by considering the full potential of their architectural attribute has slowly started to be utilized in many urban areas.

In European cities, these infrastructures penetrate dense urban areas, where space is an important commodity. Therefore, any type of conversion or re-using can help these viaducts become a catalyst for urban regeneration, from which not only stakeholders can profit, but also locals and tourists. The local community can benefit from new and diverse activities and overall have a better quality of life with a more enjoyable urban scenery.

This article aims to examine the impact of this kind of infrastructure projects and to assess the advantages, risks and opportunities they create. Railway viaducts from several European cities are the study subjects of this paper. It is also an intention to figure out the methods and instruments which best helped an urban area from a social, cultural, economic and an ecological standpoint.

Key words: *infrastructure, railway viaducts, bridges, embankments, urban regeneration, urban re-use, urban revitalization*

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1. INTRODUCTION

The importance of mobility has shifted the dynamic of urban infrastructures in many urban regeneration and renewal projects. Transport infrastructure is no longer treated as independent but has become part of larger and more integrated projects and policies. At first, elevated railway structures or commonly known as railway viaducts had mostly maintained an infrastructural usage with the occasional appropriation of their arches for secondary purposes [1], the last part of the 20th century saw a different approach which sought to include them into urban development schemes.

In many European cities, disused viaducts were places of poverty, land degradation and abandonment. Their imposing appearance made them a physical barrier in the urban fabric, causing them to become places to be avoided, either by the locals or by investors [2]. Importance was given mostly to the top, where the railway passes, but little to the actual structure with arches. Depending on the viaduct, the arches were rented from the beginning, or appropriated in time by the local population and small businesses. It is worth noting that in the majority of academic publications, the term “arch” is used as an alternative word for the vaulted space underneath the viaduct. For this reason, “arch” will be the frequently used word when referring to that typical space.

Typically, these structures have been regarded from a construction standpoint, where only their engineering prowess mattered. Nowadays, their architectural and urban traits are no longer ignored, but rather pushed forward in urban regeneration and revitalization studies and projects. As a dynamic process, urban regeneration involves both the public and the private domain and its intention is to improve neglected urban areas [3].

Starting with the 1970s and 1980s, this sort of approach began to incorporate infrastructures that had previously been ignored. with Paris's iconic Promenade Plantée, which served as a catalyst for an *adaptive reuse strategy* [4]. The Castlefield viaduct in Manchester was first recognized as architecture when it was officially listed as a historical monument [5]. Similar elevated railways have been the subject of studies conducted by municipal governments or private parties, and they have become useful resources for urban development plans.

The focus of this paper is to understand the way that railway viaducts have been included in implemented urban regeneration or urban renewal projects. This includes examining the set of instruments used for the development and analyzing the effects of their implementation.

2. METHODOLOGY

The paper is centered on evaluating the instruments and methods of the re-use strategies and the effects that they had on the site areas. For this, evaluative research was conducted using literature review on case studies and personal observations derived from a brief analysis of the architectural and socio-economic factors of these projects.

2.1. Toolkit

Data collection was focused on five main projects, but other secondary projects were considered during the research, albeit on a more theoretical level. This permitted the research to have a broader scope of understanding when it comes to railway viaducts. The main viaducts are: Bastille–Vincennes line now known as Viaduc des Arts, part of the Coulée Verte René-Dumont (or Promenade Plantée) in Paris, Castlefield Viaduct in Manchester, Hofbogen railway viaduct (including the Hofbogen station) in Rotterdam, IM Viadukt project in Zurich and Gürtel Boulevard in Vienna. These cases were chosen because of their complex nature and involvement in integrated urban regeneration or renewal strategies.

Each of the five viaducts have been included in projects that contain a common set of methods and interventions spent for implementation. The differences lie mostly in the way they were used, their timeline and the effects that they had upon the site area. The classification of the used methods was done to observe the effects, risks, and opportunities provided by these interventions.

Table 1. Methods, actions, and effects of the implemented projects

	Method	***Actions and effects***
1	*Architecture and design interventions*	*Facades – demolition, renovation, infills* *Public spaces – green spaces, promenades, bike*
2	*Economic displacement*	*Changes in the functional character of an area*
3	*Insertion of creative-cultural activities*	*Changes in population (increase/decrease, social class, and other factors)* *Changes in land value* *Gentrification*
4	*Public-private partnerships*	*Issues regarding external factors (economic crises), internal factors (difficulties with the urban actors)*
5	*Community involvement*	*Involvement during the phases of the project* *Feedback based decisions* *Experimental/test projects to gage public reaction*

3. DISCUSSION

In re-use strategies, the infrastructure, whether it is a station (node) or line (railway viaduct) is no longer treated as an isolated object [6], but as a whole movement corridor that has the potential to create an enhanced architectural landscape. This interdisciplinary approach is at the heart of many sustainable solutions in architecture and urban planning and it may aid in better integrating infrastructure with the surrounding urban fabric.

Many of these projects begin with design interventions, by renovating facades, creating bike and pedestrian paths, or by demolishing improvised annexes and structures.

Economic displacement can cause significant changes in the way the viaduct operates, and it is frequently followed by evictions of former tenants and the incorporation of creative-cultural activities. The latter has become the norm in re-use strategies, where cultural amenities are designed to act as a catalyst for the revitalization of a particular area. The effects can range from changes in the local population, crime reduction or higher land use value, some of them being part of gentrification.

Private-public partnerships are fundamental in re-use strategies, but private investments need to be regulated by good public policies. A comprehensive set of guidelines and actions can be well received also by the local populace who is directly impacted by the intervention.

3.1. Architecture and design interventions

3.1.1. Facades

A common feature of almost all the viaducts is the **renovation of their facades**, by refurbishing the arches including the vaulted space beneath. In many British cities, the space beneath the arches was either filled with uses which were beneficial to the nearby train station and to the industrial area or left open for circulation [2]. In most western European cities, in lieu of a strict regulation, people appropriated this space through improvised facades and additions.

The **architectural unity of the arches** was a common feature for viaducts such as the Gürtel, Hofbogen or the Bastille–Vincennes line in Paris. This was lost after the Second World War when their arches were appropriated by locals and small businesses who left their own mark on the structure, by replacing original glass walls with panels and by building annexes and other structures.

Fortunately, because of proper urban interventions, the aesthetic value of the arches was rediscovered. The 19th century Bastille-Vincennes Viaduct, now known as the Viaduc des Arts in Paris was reconfigured during the Plan Programme de L'Est de Paris (1983) [7]. After its inclusion in the scheme, a competition transformed the top of the infrastructure into a linear park, while the vaulted spaces underneath were given a makeover and transformed into artisanal stores, coffee shops and creative workshops. Functional specificity meant a certain architectural unity for the facades, which saw the old viaduct restore its transparency with clear curtain walls. The brick and stone works were also refurbished and the only additions to the facades were shop awnings and discreet signages.

Figure 1. Two types of interventions – filling the arches (left, Viaduc des Arts) vs. adjacent construction (right, IM Viadukt), Wikipedia Commons

This type of architectural coordination can also be seen on a smaller scale at Hofbogen Viaduct in Rotterdam [8] and IM Viadukt [9], the refurbishment project in Zurich-West. The same can't be said for the Gürtel Viaduct in Vienna, even though the viaduct was part of the URBAN-WIEN GÜRTEL PLUS, a regeneration program started in 1994, meant to resolve certain problems in this area. The plan also included the renovation of several arches and bringing the facades to their original appearance. Parts of the viaduct, especially the sections between the metro stations, have damaged facades, covered windows, and graffiti painted walls. This can put off pedestrian usage and leisure strolls alongside the viaduct.

The Castlefield Viaduct, (figure 2), part of a heritage driven plan and several development guidelines during the 1990s, also had its facades renovated. Illustrations of types of **signage** were even proposed, in an effort to create "a cohesive environment" in the site area [2]. The matter of signage and branding is also common in Zurich, where IM Viadukt (figure 1) has its shops clearly marked and numbered, providing the exterior with a sleek and modern look.

3.1.2. Public space

Green spaces, promenades, and terraces

Usually running along roads and boulevards, elevated railway structures are normally separated from traffic lanes by vegetation or pedestrian paths. Planting rows of trees and green spaces adjacent to the viaduct has been a frequent method of integrating it with the surrounding vicinities. Promenade Plantée took things a step further by converting the top into a linear park along the Avenue Daumesnil. Having a place with gardens and promenades passing through the dense residential neighborhood of the 12th Arrondissement has been embraced by the locals and it became a popular destination for tourists and urban explorers.

The **linear park effect** which also inspired the popular High Line had also appealed to the city of Manchester. In 2022, a private-public partnership launched the city's "first skypark" [5], a year-long pilot project which offered access to a segment of the viaduct. The results of the project will determine the future of the viaduct, with many wanting it to become permanent [5].

At first, stakeholders had a different approach to the Hofbogen viaduct, in Rotterdam. Renovating the roof of the former train station allowed them to transform it partly into a community garden and an event space. The latter was cautiously welcomed by the locals after experimental events on a small scale. The next phase of the project will see the viaduct's top transformed into a linear park inspired by Paris' Promenade Plantée.

Figure 2. Linear parks inspired by the Promenade Plantée. Left is Castlefield viaduct, right is Hofbogen viaduct, Source: Twelve Architects, www. rotterdammakeithappen.nl

Increasing the quality of public space can also occur by encouraging local businesses such as café bars, bistros, and restaurants to open up to the street. In Manchester, during the 1990s, the viaduct saw an increase in coffee shops after its redevelopment [2] and many are still operational, especially around Deansgate station. Similarly, the Swiss viaduct has open eating areas adjacent to the structure and beneath some of its arches. This can create a more pleasant transition between public and private space.

While the Parisian viaduct proved to be a successful intervention, the Gürtel avenue's public space still needs to be improved. Bike paths are discontinued alongside the viaduct, and the sidewalks suffer from neglect. The viaduct is still largely seen as a physical barrier [10] with few crossings underneath the arches, supporting mostly longitudinal movement and lacking transversal circulation.

Ease of access

We cannot talk about a structure designated for either railway circulation or pedestrian flows without including accessibility. Elevated uses such as parks and promenades need lifts, ramps, or stairs to guide the passerby to the top. The Parisian project is appreciated for having ease of access and thus improving movement both on the horizontal plane and on the vertical plane. On the other hand, fences, confusing opening/closing hours and few access points can greatly diminish the user experience [11]. Transversal connectivity is also important for increasing permeability and consequently ease of access. IM Viadukt in Zurich has reasonably spaced empty arches for allowing pedestrian and car traffic to pass through (figure 3). This distance is optimal for the construction to be on a more human scale, instead of just a long, monumental barrier of brick and glass.

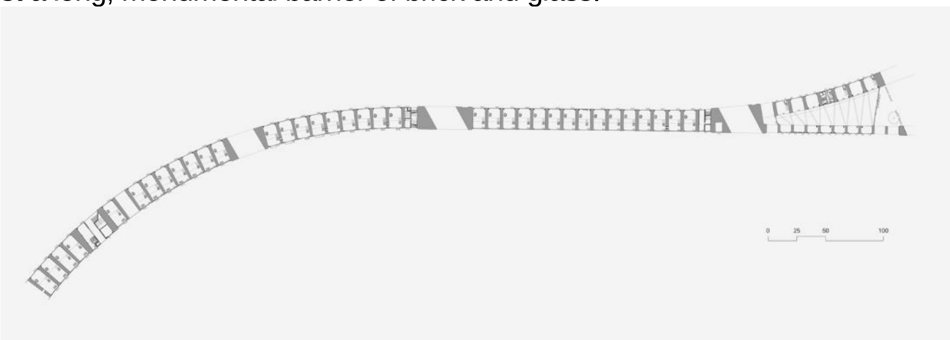

Figure 3. Ground floor plan of the IM Viadukt project., Source: EM2N architects via www.archdaily.com

The nearness of the viaduct is also important for people to feel more connected to the structure. Participants of a survey in Rotterdam mentioned that they feel closer to the Hofbogen viaduct than the train station because of the shorter distance, even though both were part of the same development project [11].

3.2. Economic displacement

Economic displacement is a typical characteristic of many urban regeneration and renewal projects. This involves the replacement of an area's present activities with more advantageous ones for the local economy.

Seeing that railway viaducts are ultimately associated with industrial sites, the vaulted spaces are also used to host industry-related uses. Storages, garages, warehouses, workshops filled these spaces, many of them leased by the railway companies. When talking about urban development, these economic activities didn't rate well for the local authorities and investors. It is worth noting that in some cases, such as the Rotterdam one, gentrification happened since the beginning of the construction of the line as the railway was designed to facilitate the access to the waterfront in Hague of the middle class and upper-class residents. Thus, the line passed through former industrial zones which changed their functionality and ultimately displaced their former working-class tenants [12].

A former industrial city, Manchester began its regeneration action in Castlefield by replacing a good part of its storage and warehouse facilities with more attractive commercial activities. The viaduct had several of its auto repair shops and garages relocated to other parts of the city [2]. The 1990s transformed the viaduct into an architectural piece fit for nightlife and café culture [2] which attracted locals and tourists evenly. Ultimately a lack of maintenance and insufficient investments in tourism infrastructure made the viaduct lose its appeal, but change is still happening nowadays with residential and office development taking place adjacent to the viaduct or even on top of it [13].

Both the Hofbogen line and the Zurich viaduct relied on commercial activities, the former being described as "an elongated commercial building" [12]. This appealed to the local population of the adjacent Agniesebuurt neighborhood because it served their needs [11]. In Zurich, part of the Zurich West regeneration strategy, the viaduct not only had its arches partly filled with shops, but also had an infill between the railway line and the smaller, pedestrian viaduct. This allowed for a diversity of uses and the project thrives on this, calling it "the most exciting street to shop in Zurich" [14].

Figure 4. Commercial activity in Hofbogen's arches, Rotterdam, Source: https://www.lonelyplanet.com/articles/live-local-rotterdam

3.3. Insertion of creative-cultural activities

The emergence of a culture led regeneration in former industrial parts of a city certainly indicates economic displacement. Many cities treat creative cultural activities as catalysts for the regeneration of an urban area, regardless of its past usage or scale. Most commonly found in former industrial areas, this type of adaptive reuse can create a phenomenon of socio-economic effects. The Hofbogen was planned with the residents' needs in mind and people actually took part in participatory design process, and both shops and spaces for young entrepreneurs in creative-cultural activities were also proposed [12].

The popular Viaduc des Arts, had its arches filled with high end stores, galleries, workshops, and similar activities. These changed the former industrial character of the neighborhood whose social structure was altered as well. After the development and coupled with other investments in the area of Bercy, population started to grow, and vacant housing units began to fill [4]. Industrial workers were replaced with those hired in the knowledge economy, with a different economic status. Land use value grew, and the area is known to have had a growth in population with a "high cultural capital" [4], during the 1980s and 1990s. These effects are common causes of gentrification.

In Castlefield, during the 1990s, authorities promoted a heritage-based regeneration, encouraging the creation of an "outdoor museum", with regulations and guidelines which for many remains a model of success. Lofts and studios were one of the common infill types in old warehouses and the adjacent buildings next to the viaduct line. The industrial use of the vaulted spaces of the viaduct endured until the 1990s which afterwards, many were rented out as new clubs and cafes, creating a sort of alternative lifestyles for different countercultures [2].

In the last decade, the viaduct has been included in other urban development projects, such as the Viadux project: two towers built over the structure of the viaduct, a luxury residential block of apartments and a smaller, office building. The team behind the project described the viaduct as "redundant" [15], but its future impact upon the adjacent area will remain to be seen, given the fact that many such luxury projects can favor the appearance of gentrification [16]. The original intention of an outdoor museum with cultural activities seems to be put on the back burner in favor of residential and office development.

The Gürtel boulevard acts as a physical barrier between several districts of the city of Vienna. According to the Urban Development Plan Vienna 2005, the Gürtel was intended to be a key zone for urban renewal, in hope of increasing the quality of life for all inhabitants [17]. Using clubs and leisure, the URBION project aimed to open the viaduct and become a point of reunion for residents, although the improvements have been very little. The vicinity of the viaduct has a very infamous reputation as the city's red-light district, and the utilization of the clubs at night may create the impression that neither the viaduct nor its intended audience are made up of a diverse range of demographics.

3.4. Public-private partnerships

In most urban regeneration and urban renewal projects, private-public partnerships are a way to efficiently involve the private sector from the start. This cooperation can improve the outcome of the developing proposal and policies [18].

Establishing **corporation entities** proved a big step in securing a more thorough regeneration process. This was the case for Manchester, with the creation of The Central Manchester Development Corporation which paved the road for the creation of a "comprehensive re-imaging strategy for Castlefield" [2].

In Rotterdam, the company Hofbogen B.V. was established by the union of four housing associations, in 2006 [19]. A key factor in the success of the project is the company accessing national and European Union funding. But, difficulties can also occur. The effects of the economic crisis of 2008 delayed the Hofbogen project a considerable amount and too high costs threatened the future of the project [12].

It is also important for these companies to consider the will of the other actors involved – such as the community. Part of a wider city strategy, the Bastille-Vincennes Viaduct was a great pawn in transforming the eastern part of Paris [4].

Different from other grandiose projects of the Mitterrand era, the development was guided by the citizens' wishes which the planners transformed into a green corridor with creative and cultural amenities.

IM Viadukt is another example of a good partnership. Its development was part of the renewal of Zurich West. For this strategy, collaboration was fundamental in developing a clear framework which the municipality revised afterwards, with feedback from a diverse set of actors [20].

3.5. Community involvement

Having a voice in local urban developments has become more and more important for the interested communities which live in places directly affected. Such a group of locals was Castlefield Forum, led by a group of residents which opposed residential development in the area. Nowadays it is a charitable organization which was also involved in the pilot project of the Skypark on top of the viaduct [21].

Involving the community through the development phases of a project turned out to be quite a success for IM Viadukt. In terms of decision making, the public was invited to participate since the beginning of the planning process and before the competition for the refurbishment of the arches was held. This involved having **workshops** for the design process [22] and to help express the population's needs and wants for the place [23].

The Hofbogen viaduct refurbishment was done in several phases, starting with the discontinuation of the railway traffic in 2010 and taking into account the former train station to the south of the line. A year before, inspired by the High Line projects, some of the residents created the group "Friends of the Hofpleinlijn" in order to get the community involved by holding lectures and debates [24]. Temporary exhibitions and events were also hosted in the vaulted spaces of the viaduct in order to promote the structure.

On a micro-level though, the situation presented itself differently. The community involvement in the first development phase was scarce [11]. This may be due general disinterest in public activities or uncertainty caused by the project's financial delays and overall complicated financial process [24]. On the upside, the transformation of the station roof into an even space and community garden turned out to be welcomed. The direct involvement of the community is by participating in the upkeep of the vegetable garden and green spaces. The authorities also keep the public informed using mail and social media and they are keen to hear their opinions regarding complaints and suggestions [11].

The complex nature of the structure's ownership was also a factor which delayed the project [24] and caused uncertainty with the local community [11]. The municipality had a big role in selecting the actors involved in the project, but many residents felt that there was some poor management regarding the design process [24]. Also, multiple owners can affect the way a project is undertaken and can cause friction between them and the various other actors. In his master thesis on the Hofbogen, Tim Vleesenbeek proposes a more "clear expectation management for the participation process", a better communication and transparency with both the actors and the local community, but also "attention to park management" [24].

4. CONCLUSIONS

Railway viaducts have been used in urban development projects in recent years with the goal of healing former scars in the urban fabric. Seen as physical or economical barriers, these viaducts have greatly impacted on the areas they cross.

Before the implementation of an urban development project, the only type of physical intervention for a viaduct was the occasional cleaning of the facades. This was possible by renovating the arches and demolishing improvisations which people built over time, while having appropriated these spaces. But this was proved to not be enough to effectively “clean” an area and therefore, authorities called for **architectural and socio-economic studies** to be done in order to figure out the best plan of action regarding the viaducts. This way, they could ensure a well-researched plan which can further improve the quality of urban life.

A method which proved to be effective for all viaducts was the creation of **transparent arches**, many of which had this appearance from their very beginning (Gürtel, Hofbogen, Viaduc des Arts). Thus, they reverted to their former state of appearance. Even though its initial arches were left open, IM Viadukt had its arches partly filled with a modern design, leading to uniformity and transparency.

The visibility of a viaduct’s facades is clearly related to the needs of the local entrepreneurs that occupy the vaulted space. **Strong guidelines and regulations** can help improve or alter their features and, in many cases, make the viaduct appear not so much of a physical barrier, but a lively corridor of social interaction.

Many times, struggles were encountered in **reweaving former neighbourhoods** which have been separated by them. Only a part of the Gürtel viaduct in Vienna was included in the URBION project and therefore, the remaining sections still have some functional and aesthetical problems [25]. The Castlefield viaduct in Manchester is also in need of improvement, seeing that there are several sectors remaining with disused facades, blocked access, and inactive uses.

Even though most of the mentioned viaducts were implemented by phasing the project, it is worth noting that the success rate is much higher when the **entire viaduct is included in the strategy**, otherwise many issues may not be resolved on a unitary scale.

Fortunately, projects have had a high success rate when it comes to socio-economic benefits and the urban landscape has improved as well. Regarding Promenade Plantée, J. Heathcott mentions that the project managed to remake “space into place” [4]. This was made possible by making the formerly derelict viaduct respond to the needs of its surrounding neighborhoods, where the barrier effect decreases with the emergence of human experience and activities.

Public space can be improved with connections and ease of access. Underneath the arches of a viaduct, transversal movement can be increased by letting them empty when needed. Thus, the permeability of the structure grows and people don’t perceive the structure as a barrier.

Greening the viaducts by creating a linear park on top of it has been the most popular method of revitalizing a former railway viaduct. Promenade Plantée created the concept, while High Line in New York popularized it. Inspired by the French project, both Castlefield and Hofbogen viaducts have had plans made for implementing such intervention, while the Hofbogen station has had its roof transformed in this manner already.

Many of the viaducts were transformed into a livelier urban setting, with a **diversity of uses and attractive commercial spaces**. Cafes, bars, artisan shops or galleries are just several of the most popular uses encountered in all of the viaducts. Each viaduct can be characterized by one or two predominant uses. While Gürtel is the scene of clubs and nightlife, Viaduct des Arts is a place for artisans and artists to exhibit and work at their ateliers. Both IM Viadukt and Hofbogen have plenty of commercial space and eateries, whereas Castlefield Viaduct has a tradition of being a hub of café bars. **Economic displacement** seems to be a useful tool for improving former industrial areas with low land use values. Moreover, inserting **cultural creative amenities** appears to be a trend that won't stop too soon, but effects such as gentrification should be controlled with stricter social policies.

Good cooperation between the private sector and the public can lead to a successful urban regeneration project. Most thriving cases are the ones which had the private sector included from the start of the development.

Both IM Viadukt and Hofbogen maintain today a good relationship between the residents, entrepreneurs, and authorities. In the case of Castlefield, the public-private partnership initiated in 1988 has been an **important driver** in its regeneration process. The idea of utilizing the railway infrastructure for historical tourism helped Castlefield's economy and heavily increased its popularity. **Community involvement** is also a big factor in an effective private-public cooperation. In the Hofbogen project, the collaboration of institutions, stakeholders and the people transformed the project into a complex process of decision-making which managed to integrate the viaduct into the urban fabric of the city [12].

Without a doubt, including railway viaducts into urban development projects has had a significant impact on the urban fabric, with outcomes ranging from economic growth and social changes to physical transformations of public space and built area. However, no regeneration is without risks, which marks the importance of a solid relationship between the public and private sectors, with social policies and community engagement. When combined, they have the potential to improve the city's and its citizens' quality of life.

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DETERMINATION OF THE BOLT YIELD MOMENT FOR STEEL-TIMBER COMPOSITE CONNECTIONS

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Abstract

Dowel-type connections in steel-timber composite structures are common in practice because of their simple construction and installing, without need for special tools or skilled workers. Such connections are not limited to steel and timber, but may be applied for concrete-timber and timber-timber connections. The most common dowel-type fasteners are bolts, screws, and nails. Calculation of the connections performed by mentioned fasteners requires knowing of the geometric and material characteristics of those elements. Some of the possible failure modes at composite connections include plastic hinges on the fastener, so its yield moment is one of the significant factors for strength calculation of the connection. Depending on requirements and possibilities, values of the fastener yield moment may be obtained analytically, numerically and experimentally. Topic of this paper is determining the bolt yield moment in four ways: according to the classical Theory of Plasticity, according to the procedure prescribed in Eurocode 5, applying the Finite Element Method (FEM), and experimentally. The results of the analytical procedures and numerical analysis have been compared with the results of the experimental analysis as the most reliable. Based on the obtained results, conclusions of the performed research are drawn, and recommendations for practical calculation of the bolt yield moment are given.

Key words: *Composite Connection, Bolt, Yield Moment, FEM, Experimental Analysis*

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1. INTRODUCTION

The development of construction in the world is related to the development of structural materials, as well as to the methods for analyzing their properties. Steel-timber composite structures are increasingly used as structures that are more environmentally friendly than traditional concrete or steel structures. An example of a cross-section of a composite structure made of steel and timber is shown in Fig. 1. Two panels made of cross-laminated timber (CLT panels) are connected by two cold-formed steel profiles, with screws or bolts as composite connectors [1].

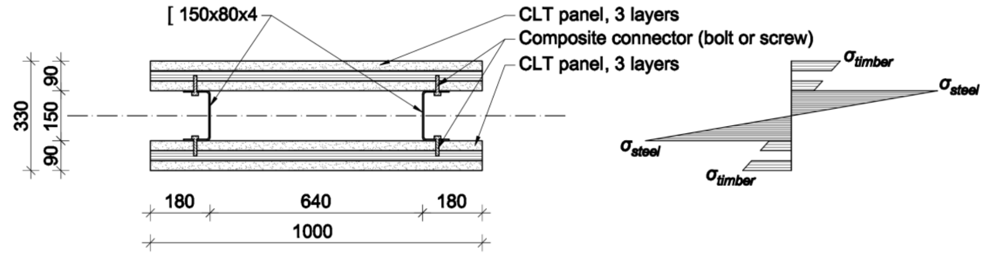


Figure 1. Steel-CLT composite structure and distribution of normal stress [1]

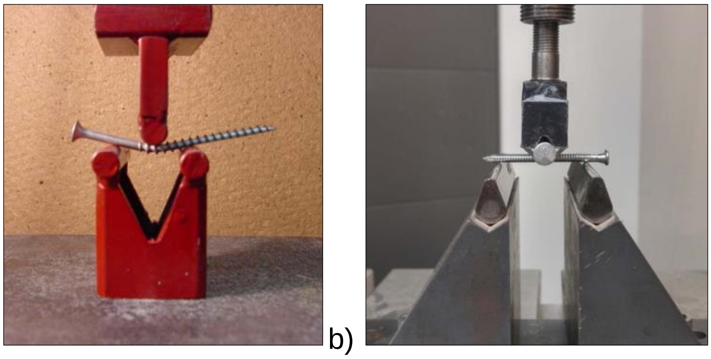
The mechanical behavior of the composite connectors, in this case the bolts, has a great influence on the behavior of the composite structure as a whole. In the case of a composite structure, it is necessary to achieve an efficient transfer of the shear force between the steel profiles and the CLT panels. When the calculation of bolts under shear load is conducted, one of the most important parameters is the bolt yield moment, which depends on the failure mode and the bearing capacity of the bolted connection [2-5].

The bolt yield moment can be determined using different methods. The simplest one is the application of the Theory of Plasticity [6]. Although simple to use, this method has only historical significance because it gives insufficiently accurate results due to the assumption of small deformations.

The introduction of large deformations into the analysis, along with the complexity of the theoretical base for the analysis, gave much better results [7] than the previous method. The solution is simplified for practical application, by reducing it to a single relation that directly calculates the bolt yield moment. This solution is also included in Eurocode 5.

With the development of the Finite Element Method (FEM) and the engineering software, numerical methods for structural analysis are gaining importance. To apply this method, it is necessary to define or apply already defined constitutive model of the material. Since the material model of steel has been extensively researched, with adequate modeling, results comparable to real values can be obtained using the FEM.

The experimental method stands out as the most reliable for determining the yield moment. The bolt yield moment is experimentally determined by applying the bending method, where the bolt is a simple supported beam loaded by vertical force, in the midspan (Fig. 2) [8, 9].



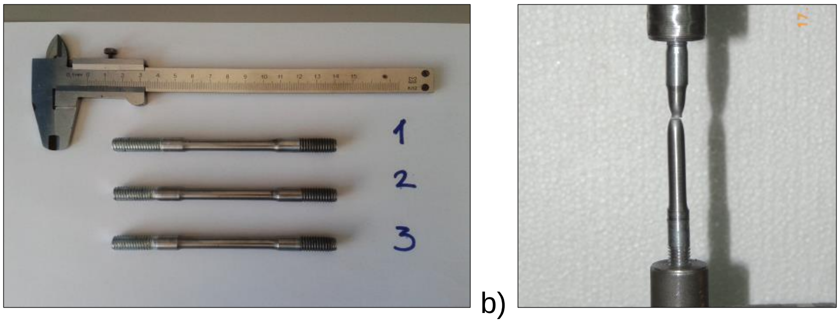
a) b)

Figure 2. Bending test: a) self tapping screw [8], b) annular ring shank nails [9]

In this paper, the bolt M10x120, with class 8.8, which was used for the connection of a steel cold-formed profile and a CLT panel, was examined [10]. The bolt yield moment was determined analytically, numerically, and experimentally, and a comparative analysis of the results was made and conclusions drawn.

2. METHODOLOGY

The bolt yield moment is determined in four ways: by applying the Theory of Plasticity, by applying the relations from Eurocode 5, by numerical calculation based on the FEM, and by the experimental method. First, the bolt material was tested experimentally. Three specimens with a diameter of Ø8 mm were made, and examined by tensile test (Fig. 3). The yield strength and ultimate strength obtained from this test were used as input parameters for further calculation.



a) b)

Figure 3. Tensile testing of steel: a) specimens, b) specimen failure after testing

2.1. Yield moment determination by Theory of Plasticity

According to the Theory of Plasticity, the cross-section of the bolt is plasticized in the way that one half of the cross-section is compressed and the other one is tensioned (Fig. 4). At all points, there is a stress that is equal in absolute value to the yield strength f_y.

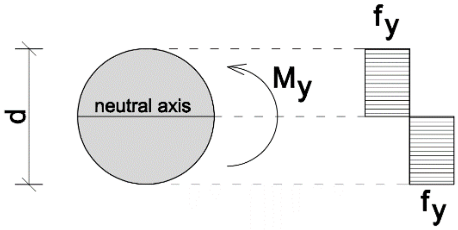


Figure 4. Stress distribution in the bolt cross-section

Considering that the bolt has a circular cross-section, the yield moment can be determined using the relation:

$$M_y = f_y \cdot W_{pl} = f_y \frac{d^3}{6} \tag{1}$$

where: M_y is bolt yield moment, f_y is the yield strength of bolt steel, W_{pl} is plastic section modulus, and d is bolt diameter.

2.2. **Yield moment determination by Eurocode 5**

The calculation of the bolt yield moment according to Eurocode 5 [5] is based on the research of Blass, Bienhaus and Krämer [7]. According to that research, the bolt yield moment depends on the ultimate strength of the bolt material and the bolt diameter, but the deformation of the bolt shaft was also taken into account in the research. Therefore, this methodology should give more accurate results than the methodology based on the Theory of Plasticity. The value of the yield moment is obtained by applying the expression:

$$M_y = 0.3 \cdot f_u \cdot d^{2.6} \tag{2}$$

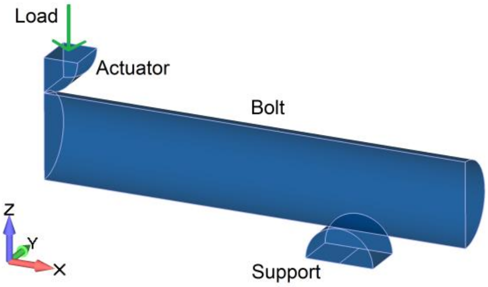
where f_u is ultimate strength of bolt steel.

2.3. **Yield moment determination by FEM**

Determining the bolt yield moment using the FEM was done by testing a simple supported beam with a span of 70 mm, loaded in the midspan by concentrated force. Due to the existence of double-plane symmetry, a quarter of the sample was modelled. The load was applied onto the sample via a cylindrical actuator with a diameter of 8 mm. During loading, the actuator gradually moves downwards by 15 mm in total. The support was modelled analogously to the actuator, but with fixed boundary conditions. Contact surfaces between the bolt and the actuator, and between the bolt and the support part, with a friction coefficient μ=0.20 were modelled.

Modelling of the bolt, actuator, and support was done with 8-node SOLID finite elements (Fig. 5). The material model of the bolt was adopted based on the results of the steel tensile test, and the linear-elastic model was adopted for the actuator and support. The software Femap with NX Nastran [11] was used for numerical analysis using the FEM.

The used analysis type, SOL601, included geometrical and material nonlinearity. The analysis was done for three mesh densities. Only the bolt mesh was varied, with element sizes of 1.67, 1.25, and 1.00 mm (Fig. 6). The actuator and support finite elements had smaller sizes in all three analyses (0.50 mm), because of the contact reasons.



a)

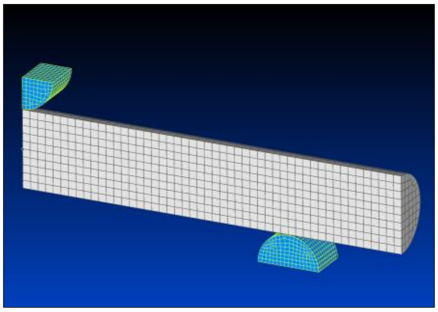

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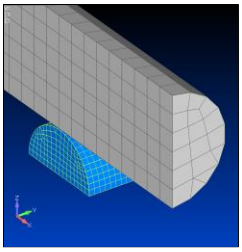
Figure 5. FE model: a) geometry, b) elements

a)

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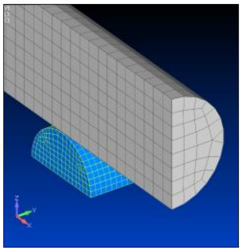
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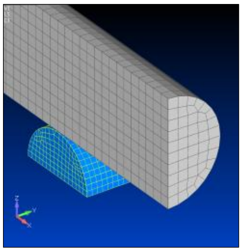


Figure 6. Different bolt mesh densities: a) 1.67 mm, b) 1.25 mm, 1.00 mm

2.4. **Yield moment determination by experimental method**

The bolt yield moment testing was performed using the three-point bending test. For this purpose, the accessory shown in Fig. 7 was made. The accessory enables that the bolt behaves like a simple supported beam with 70 mm span, loaded by force in the midspan.

A press „Matest“, with a capacity of 50 kN, was used for testing, and the deflection was measured using an electronic deflection meter with an accuracy of 0.001 mm. The test was done in the Laboratory of Geotechnics at the Faculty of Civil Engineering and Architecture in Niš.

Figure 7. Bolt testing using three-point bending test

3. RESULTS

The results of the tensile test of steel are shown in Fig. 8. The yield strength and the ultimate strength f_y/f_u = 760/850 MPa were obtained. The results are in good agreement with the nominal characteristics of the bolt class 8.8 (f_y/f_u = 640/800 MPa).

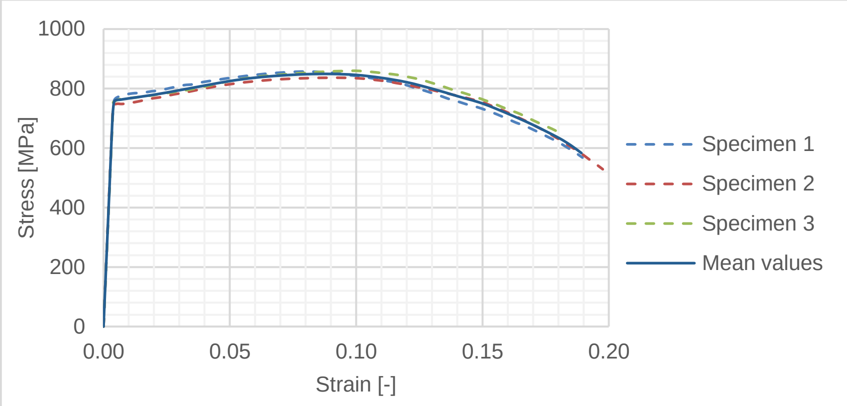


Figure 8. Results. Stress-strain diagrams for tested bolt steel 8.8

The results of the numerical and experimental analysis are shown in the following figures. Fig. 9 shows the comparison of the deformation obtained by numerical and experimental analysis, while Fig. 10 shows load-deflection dependences for different mesh sizes of finite elements and load-deflection dependence for the experimentally tested bolt.

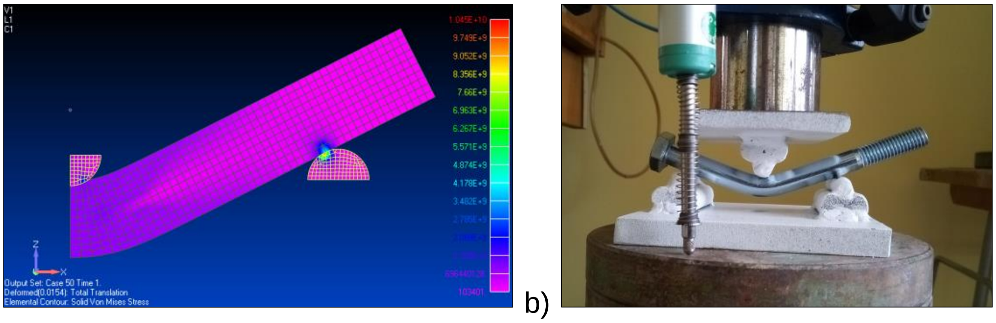
a)  b)

Figure 9. Bolt plastic deformation: a) FE model, b) experiment

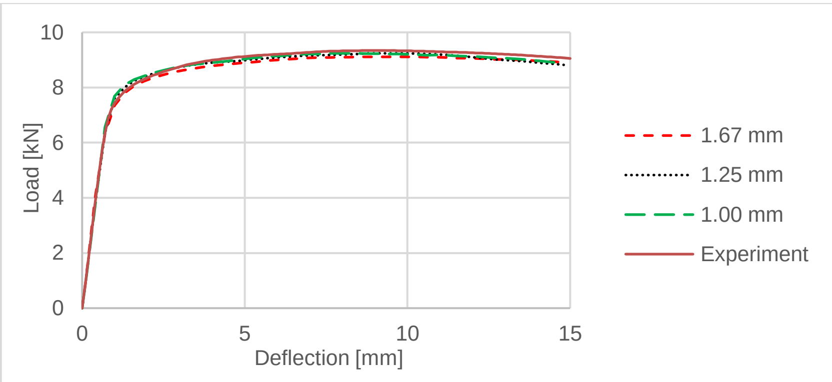


Figure 10. Results. FEM and experiment

Table 1 shows the values of the bolt yield moment determined by the applied methods. Applying the Theory of Plasticity and the procedure given in Eurocode 5, the values of the yield moment were determined directly. Applying the FEM and experimental methods, these values were determined indirectly, by the magnitude of the applied load.

Table 1. Results. Load and bolt yield moment by different methods

Method	*Max. load [kN]*	*Bolt yield moment [kNm]*
Theory of Plasticity	/	*0.1267*
Eurocode 5	/	*0.1015*
FEM (1.67 mm)	*9.112*	*0.1595*
FEM (1.25 mm)	*9.240*	*0.1617*
FEM (1.00 mm)	*9.236*	*0.1616*
Experiment	*9.339*	*0.1634*

4. DISCUSSION

Applying the FEM, the diagram of the bolt behavior under bending for three mesh densities was obtained. The diagrams are in good agreement with each other, and the model behaves as expected. In addition, the diagrams obtained using the FEM match well with the experimentally obtained diagram in the elastic as well as in the plastic domain. The forms of bolt deformation in the numerical model and the experiment are the same, which means that the numerical model is verified and validated. The values of the bolt yield moment obtained numerically and experimentally show good agreement mutually. The deviations of the results obtained by FEM analysis from the experimental results are only 1-2%.

Larger deviations occur between the analytical results and the experimental results. Thus, the value of the yield moment calculated according to the Theory of Plasticity deviates from the experimental value by 22%, and the value calculated according to Eurocode 5 by 38%.

5. CONCLUSION

Bolted connections can be used for the effective transfer of shear in steel-CLT composite structures. In this regard, it is necessary to accurately and precisely define their mechanical properties. One of the most important factors in defining the bearing capacity of a bolt is the yield moment.

The determination of the bolt yield moment was done analytically, numerically, and experimentally. The analytical calculation was done using the Theory of Plasticity and the procedure given in Eurocode 5. The numerical calculation was done using the Finite Element Method. Finally, the bolt was tested experimentally, using the three-point bending test.

The results show that there is a good agreement between the numerical and experimental methods, while the results of the analytical procedures and the experimental method deviate significantly from each other. The bolt yield moment obtained by analytical procedures is largely on the side of safety so these methods result in over-dimensioned connections.

Since the agreement between the results of numerical analysis using FEM and experimental analysis is good, and considering the results of the experimental analysis to be correct, numerical analysis using the Finite Element Method is shown to be the most accurate of the computational methods for determination of the bolt yield moment.

ACKNOWLEDGMENTS

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BIAS CORRECTION OF CLIMATE DATA BY THE QUANTILE MAPPING FOR TWO RIVER CATCHMENTS IN THE JUŽNA MORAVA RIVER BASIN

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Abstract

Planning and design in water resources management and hydraulic engineering is based on climate data in the river catchments of interest. Global climate models (GCM) were originally used to construct climate scenarios for assessing the climate change impact. The improvements in data downscaling are nowadays bringing GCMs close to more precise Regional climate models (RCMs), that could be used in planning and design. Numerous techniques of bias correction for data models have been developed, and four of them are discussed and applied in this paper: quantile mapping with linear transformation function (LTF), delta mapping (DM), mapping using normal (ND) and gamma distribution (GD). Bias correction is performed on the GCM EC-Earth for mean daily temperatures and monthly precipitation sums. Four data gauge periods are used, two per each climate variable, one for data calibration and one for validation. Periods considered for temperature are 1950-2000 and 2001-2010, and for precipitation, 1979-2000 and 2001-2009. The study focuses on two river catchments of the hydrological stations (HS) in the Južna Morava river basin: HS Visoka/ Kosanica and HS Sijarinska Banja/Jablanica. To assess the suitability of the applied techniques, three error measures were used: MAE, MSE and RMSE. The analysis of the bias correction of precipitation data shows that the best results are provided by LTF, slightly worse by GD, and poor results are obtained by applying DM. In the analysis of temperatures, LTF also gave the best results, good results are provided by DM, while ND does not have a good agreement with the gauged data

Key words: *GCM EC-Earth, bias correction, quantile mapping, daily air temperature, monthly precipitation*

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1. INTRODUCTION

The hydrological cycle, as the basic process on the planet Earth, is sensitive to climate change. Therefore, by disrupting the climate, the hydrological cycle is also disrupted, representing a potential threat to humanity. The governments and authorities worldwide develop strategies for climate change adaptation in their territories that rely upon climate change information. Such information can be obtained by using global climate models (GCM) that simulate climate processes with a low spatial resolution (150 - 300 km). However, this coarse spatial resolution is not suitable to perform analysis at a regional or local level [1]. For this reason, a downscaling procedure is performed to derive high spatial resolution of climate parameters at the regional/local level, which are the basis for various climate change studies. For example, hydrological rainfall-runoff models require climate parameters such as temperature and precipitation with a fine spatial and temporal resolution, which can be obtained from GCM [2]. Therefore, in addition to the spatial downscaling, temporal downscaling is also used in practice, which, for example, represents the downscaling of monthly data into daily values.

GCM and regional climate models (RCM) simulations have systematic errors called bias, which need to be corrected. It is necessary to remove the bias from the models output for projecting the future hydrologic and climatic scenarios correctly [3]. In scientific practice, the term bias correction (BC) is used ambiguously. In some cases, BC is mentioned as a method intended for the correction of raw model data, while in others it is classified as a group of statistical methods of downscaling. It can be said that both understandings are correct, however, the problem is that BC will not allow a 'finer' structure of the change of some quantity in the future, which is potentially conditioned by local characteristics, or even if obtained, it will be insignificant. For this reason, it can be said that BC is a pseudo version of statistical downscaling [4].

In general, there are two techniques of downscaling, dynamic (DD) and statistical (SD), although some sources [1, 5] mention a third group that includes a combination of dynamic and statistical techniques (combined method).

The SD relies on the statistical relationship between the large-scale climate derived from GCM and the local-scale climate obtained from observations, assuming that such a relationship does not change through time. Statistical methods can be divided into three groups: 1) Methods based on time schemes, 2) Time generators, 3) Regression methods.

Nowadays, there is a large number of SD methods, and in [6] alone, 22 different SD techniques were applied. The paper [7] used a combination of all three mentioned groups of statistical methods, using Bayesian Model Averaging. The results of the work [7] are in favor of the fact that more accurate results are provided by the combination of these methods, than the application of each of them separately.

Given that there are many developed BC techniques, it is important to choose the appropriate ones for a given assignment. Using SD is much simpler compared to DD, which is the reason for their more often application in practice. The application of SD is conditioned by the existence of historical (gauge) data, which makes it unsuitable for areas that do not have a dense enough observation network.

DD on the other hand uses the RCM embedded in the GCM to generate fine resolution climate information. Using DD is complex, requires the use of high-performance computers, and is limited to a spatial resolution of 20-50 km [8, 9]. For the hydrological study of an area, it is recommended to use an ensemble of several RCMs if possible, especially in air temperature analyses, because the data of individual RCMs deviate significantly from observed data [10].

In this paper, the BC is used for downscaling data from the GCM EC-Earth for mean daily temperatures and monthly precipitation sums. Four different BC techniques were applied: quantile mapping with linear transformation function (LTF), delta mapping (DM), mapping using normal (ND) and gamma distribution (GD).

SD established a connection between GCM, which has a low resolution with ~ 200 km cells, taken from the Copernicus platform for climate change [11], with observed raster data from the E-OBS database, which has cells of 10 x 10 km, downladed from the Digital Atlas platform of Serbia [12]. Downscaling focuses on two river catchments of the HS in the Južna Morava river basin: HS Visoka/ Kosanica and HS Sijarinska Banja/ Jablanica.

2. METHODOLOGY

2.1. Spatial data processing

The first phase of this research is spatial data processing, performed in the software Quantum Geographic Information System (QGIS), version 3.16. The two catchment borders are taken from previous research [13, 14]. The downloaded raster data of mean daily temperatures and monthly precipitation sums from GCM EC-Earth and observed from E-OBS, were assigned to the two studied basins. In the procedure of overlapping the raster data of these basins, it was concluded that one cell of GCM covers both basins (Figure 1), while on the other hand, 9 cells from the E-OBS database include HS Visoka, and three cells, HS Sijarinska Banja (Figure 1).

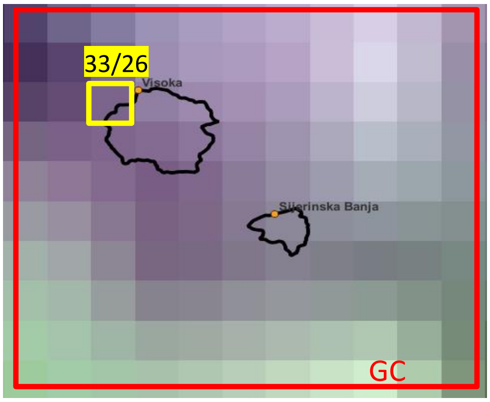

Figure 7. Raster data coverage for the HS Visoka and HS Sijarinska Banja. The red square represents the GCM cell, and the yellow represents the 33/26 cell that covers a part of the HS Visoka. The first number in the label represents the row of the cell, and the second the column of the cell in the E-OBS raster grid.

The Value tool in QGIS is used to ‘read’ the data of each individual cell for the studied climate variables. The data of the cells that cover the studied basins were copied from QGIS and processed in Excel.

2.2. Bias Correction and Spatial Downscaling

Statistical downscaling is based on the establishment of the connection between low resolution data originating from GCM and observed data with fine resolution. In this way, it is possible to establish a connection between GCM - observed data for the reference period, whereby the established connection is maintained for the period of prediction of future climate data contained by GCM.

The reference periods for establishing links between GCM and observed data for temperature and precipitation in this paper, are as follows:

- Calibration period from 1950. to 2000. for temperature;
- Verification period from 2001. to 2010. for temperature;
- Calibration period from 1979. to 2000. for precipitation;
- Verification period from 2001. to 2009. for precipitation.

When linking GCM data to the observed data, chronological data are providing poor results (Figure 2 - left) in contrast to sorting data in the ascending order [13] (Figure 2 - right).

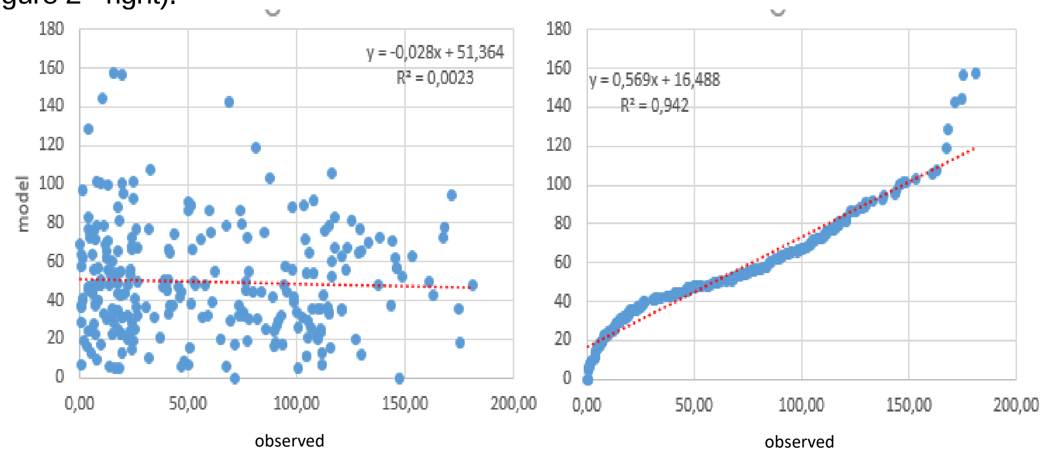

Figure 2. Quantile mapping with raw data (left), and with data sorted in ascending order (right)

From Figure 2 – right it can be seen that the greatest uncertainty in establishing the link between GCM and observed data occurs in the upper and lower zones, respectively, for the occurrence of upper and lower extremes. BC is the process of correcting the output climate model data in order to reduce the effects of systematic errors in climate models and to provide a suitable data source for hydrological models [15]. Four BC techniques with quantile mapping were used in this paper, which are discussed below.

2.2.1. Quantile mapping with linear transformation function

The flexible BC methods adjust the variance of the model distribution to better match the observed variance. Quantile mapping (QM) techniques are among the most popular BC methods. In general, quantile mapping implements statistical transformations for post-processing of climate modeling results. Linear QM establishes a linear relationship between the quantiles of the observed and modeled values of the considered parameters in the reference period:

$$X_{o,h} = a + b * X_{m,h} \quad (1)$$

where $X_{o,h}$ and $X_{m,h}$ represent values of the observed (o) and modeled (m) variables (*x)* for historical period (*h*). The coefficients *a* and *b* are linear regression parameters determined for the historical period. The requested corrected value of the model *Xc,f* at time *t* from the prediction period is obtained from:

$$X_{c,f} = a + b * X_{m,f} \tag{2}$$

where $X_{m,f}$ is the modeled value of the parameter *X* at time *t* from the prediction period.

2.2.2. **Delta mapping**

The simplest BC technique is the delta mapping technique, which establishes the relationship between observed and modeled data as:

$$X_{o,h} = X_{m,h} * \overline{X_{o,h}}/\overline{X_{m,h}} \tag{3}$$

where $X_{o,h}$ and $X_{m,h}$ represent value of the observed and modeled variables for histrorical period, and $\overline{X_{o,h}}/\overline{X_{m,h}}$ is ratio of the mean values of series of observed and modeled data for histrorical period. Sometimes, this technique is not considered as the one from a group of BC, but only uses the model's response to climate change to modify the observations [17].

The corrected value of the considered parameter at a certain moment in the future is obtained as follows:

$$X_{c,f} = X_{m,f} * \overline{X_{o,h}}/\overline{X_{m,h}} \tag{4}$$

where $X_{c,f}$ is the bias-corrected future projection value of model at time *t*, $X_{m,f}$ is the projected value of the model at time *t*, and, and $\overline{X_{o,h}}/\overline{X_{m,h}}$ is ratio of the mean values of series of observed and modeled data for historical period. Therefore, when correcting the model data in the prediction period, the ratio $\overline{X_{o,h}}/\overline{X_{m,h}}$ is used from reference period.

2.2.3. **Mapping using normal distribution**

Quantile mapping using normal distribution was conducted for mean daily temperature. First, Normal distribution parameters (mean and variance) are estimated separately for the observed *Xo,h* and modeled *Xm,h* data during the historical period. The bias-corrected future projection at time *t* is given by:

$$X_{c,f} = F_{o,h}^{-1}\left[F_{m,f}\left(X_{m,f}(t)\right)\right] \tag{5}$$

Therefore, the corrected value of the model at some time *t* from the prediction period is obtained as the inverse function of the normal cumulative distribution for the specified mean value and standard deviation from the historical period.

To correct the bias of the temperature data, it is suitable to use normal distribution because of the negative values that this climate parameter can have.

2.2.4. **Mapping using gamma distribution**

The two-parameter gamma distribution is recommended for BC of precipitation data [18, 19]. This distribution has the following distribution parameters:

$$\alpha = \frac{\overline{X_{o,h}}^2}{\sigma^2}; \quad \beta = \frac{\sigma^2}{\overline{X_{o,h}}} \tag{6}$$

where $\overline{X_{o,h}}$ is the mean value of the series of data from the historical period, and σ^2 is the variance of this series.

In the same way as for the normal distribution, via equation (5), the corrected value of monthly precipitation at some point *t* in time in the future is obtained, using the parameters of the gamma distribution in the calculation. The diagram shown in Figure 3 illustrates how simulated value, a quantile of the simulated distribution, is replaced by the quantile of the observed distribution corresponding to the same probability.

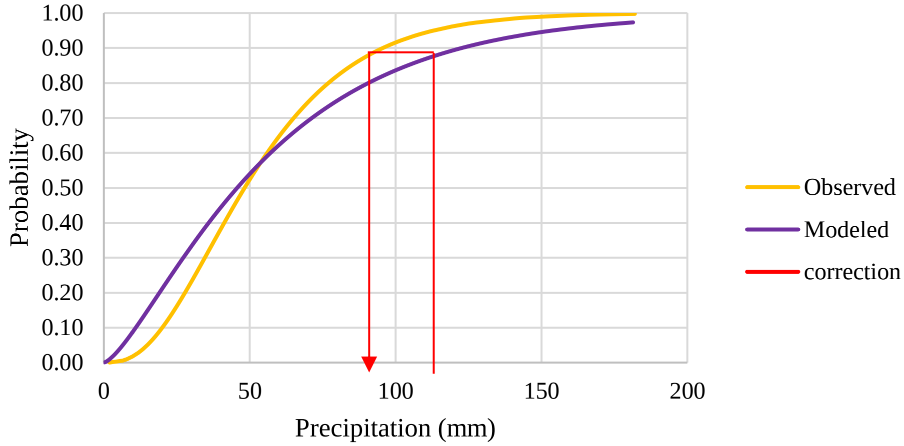

Figure 3. Precipitation bias correction by gamma distribution of modelled and observed values corresponding to the same probability.

2.3. **Assessment of the suitability of applied techniques**

After calibrating the data using four different BC techniques, the suitability of each technique for fitting the modeled data (from GCM EC-Earth) to the observed values (from E-OBS base) throughout the verification period is assessed by the three error measures: mean absolute error (MAE), mean square error (MSE) and root mean square error (RMSE):

$$MAE = \frac{1}{n}\sum_{i=1}^{n}\left|X_{m,v} - \overline{X_{o,v}}\right| \tag{7}$$

$$MSE = \frac{1}{n}\sum_{i=1}^{n}\left(X_{m,v} - \overline{X_{o,v}}\right)^2 \tag{8}$$

$$RMSE = \sqrt{\sum_{i=1}^{n}\frac{\left(\overline{X_{o,v}}^2 - X_{m,v}\right)}{n}} \tag{9}$$

where $\overline{X_{o,v}}$ the mean value of the data series from the verification period, $X_{m,v}$ represents modeled/corrected data values.

3. RESULTS

The results of the research are presented for each grid cell covering two studied basins through RMSE, MAE and MSE in the GCM validation period. The BC GCM results obtained by the three techniques are shown in parallel to the uncorrected GCM results for temperature (Figure 4) and precipitation (Figure 5). The blue bars in Figure 4 and Figure 5 show error measures of the uncorrected GCM outputs, while green, red and purple bars show corresponding error measures of bias corrected GCM outputs.

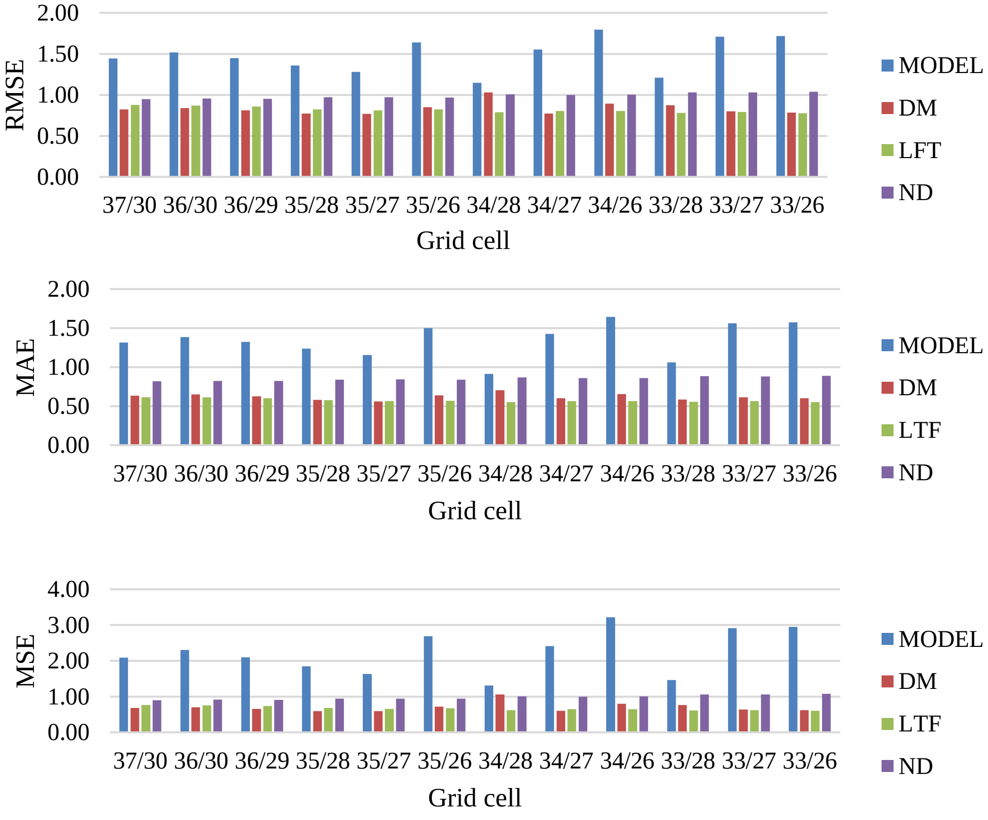

Figure 4. RMSE, MAE and MSE for uncorrected and bias corrected model outputs for temperature data

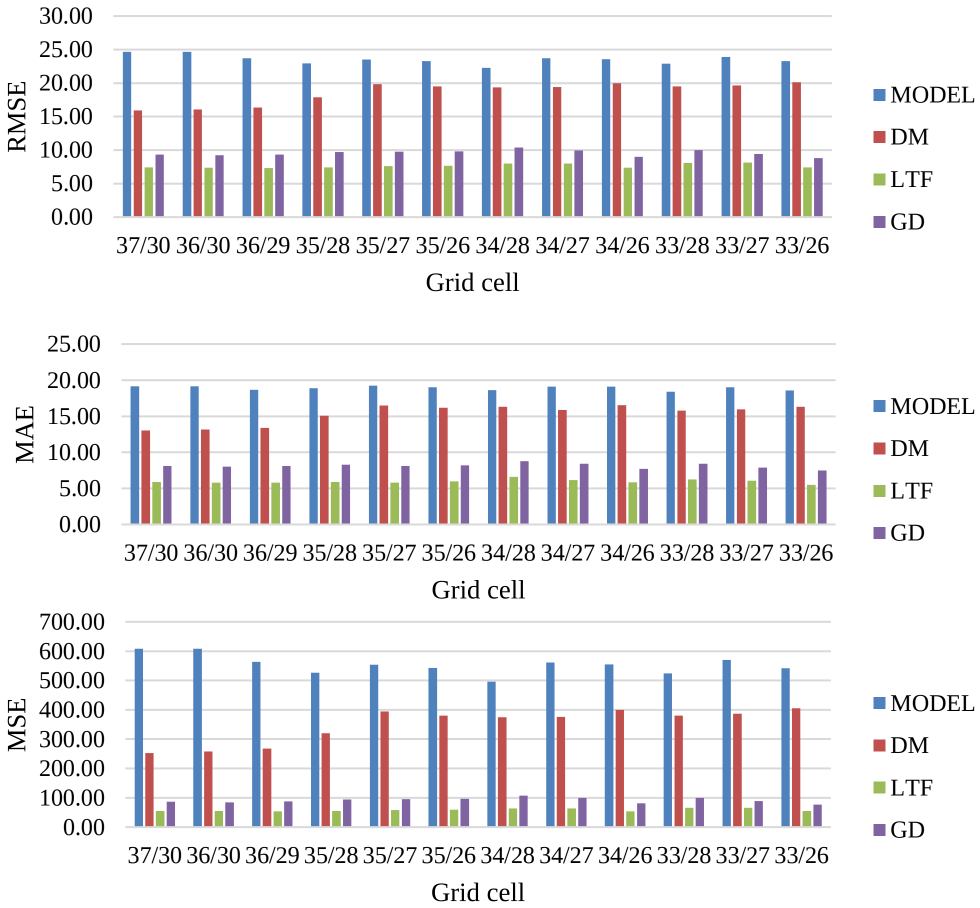

Figure 5. RMSE, MAE and MSE for uncorrected/corrected model outputs for monthly precipitation data

4. DISCUSION

Based on the obtained error measures shown in the Figure 5. and Figure 6., it can be seen that by correcting the bias of the raw output data of the model, better agreement with the observed values is achieved in all cases. In the temperature analysis (Figure 4), the difference between the three used BC techniques was not large, i.e. all three techniques were equally successful in the process of adapting the data model outputs to the observed values. In the case of precipitation, the DM (red bar) slightly corrected the model data, but not enough to be reliably used for future precipitation projections. On the other hand, GD and LTF gave very good results, where GD was slightly better compared to LTF.

Luo et al. [20], used 7 BC techniques for the correction of RCM precipitation: 5 techniques for the correction of average, and one per minimum and maximum daily temperatures for the period 1965-2004. The results of the research [20] indicated a poor fit of precipitation in wet seasons, and also that original RCM outputs are very biased. All used methods, such as Linear Scaling, Distribution mapping, Empirical Quantile Mapping and others, give correct results in the correction of RCM bias.

Bigger differences are obtained in the analyzes of precipitation, which is generally also shown in this paper [20]. The methods based on probability distribution performed best [20], which is the case in this research as well. Beyer et al. [21] found an excellent performance of the DM method, which proved to be better than quantile mapping techniques. The paper also mentions the accuracy of techniques based on probability distributions. This technique performed relatively well in higher latitudes and elevations where there is less precipitation, which brings about less uncertainty compared to humid and subtropical areas [22] .

A Q-Q (P-P) plot in Figure 6 shows precipitation values for the historical period for cell 33/27, where observed monthly precipitation values are plotted on the x-axis, and the uncorrected values from the model on the y-axis, together with the corrected model values of the three different BC techniques. The diagonal represents ideally fitted data with observed values. The values above the diagonal represent higher values compared to the observed ones, and values below the diagonal represent lower precipitation values compared to the observed values. By correcting the data from the model, they approach the diagonal. DM provides better results only for extremely high precipitation compared to LTF and GD, and for precipitation lower than 55 mm/month it performs worse even when compared to uncorrected model values. The precipitation values obtained by the LTF method are located closest to the diagonal (purple circles). However, as already discussed (Figure 2), these techniques give poor results when considering extremes. For the lower extremes, only the GD technique proved to be solid, while with LTF, departure from the diagonal can be seen in the lower part of the diagonal.

Figure 7 shows a Q-Q (T-T) plot for the daily temperatures in the verification period for the cell 33/27. Given that the historical period has a large amount of data (18263), and a much smaller range of variation of values compared to precipitation, the plots are different. The differences between the corrected values and the observed values for extreme cases are not as pronounced as for precipitation, moreover, ND gives excellent results. Here, ND proved to be the best of the BC techniques used. The model itself, as expected, gives the largest deviation from the diagonal, and between LTF and DM, the DM technique better adapts the model values to the observed values at temperatures below 10℃, while for higher values, LTF is better. Here, the DM method proved to be somewhat more acceptable for model correction unlike in the case of precipitation.

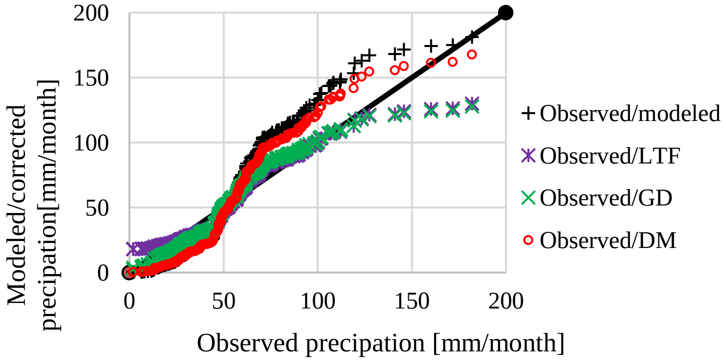

Figure 6. Q-Q plot for observed and modeled/corrected data of precipitation for the historic period

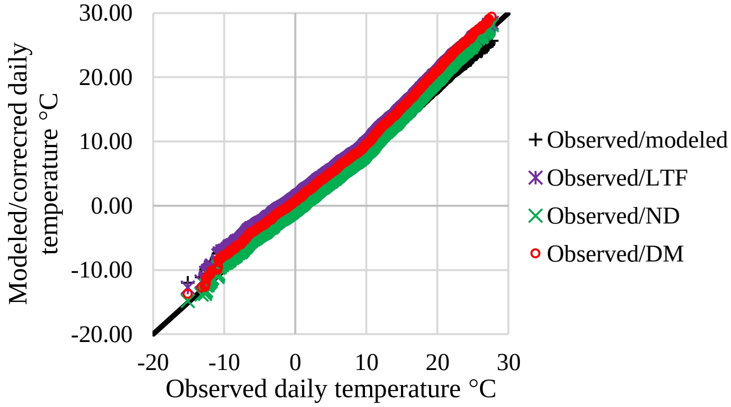

Figure7. Q-Q plot for observed and modeled/corrected data of temperature for the historic period

5. CONCLUSION

The efficiency of four BC techniques on the temperature and precipitation output data of GCM EC-Earth was investigated for two catchments in the Južna Morava river basin. The results show that all investigated techniques provide much better match to the observed values compared to the raw GCM output data.

The results of the obtained error measures indicated that BC methods based on theoretical probability distributions provide good, and in the case of temperatures, the best agreement of the model data with the observed values. DM was poorest for precipitation, while it gave acceptable results in temperature analyses. LTF performed best in precipitation analyses.

In general, it was shown that the extreme values significantly differ from the observed values, especially in the case of precipitation, which indicates that the zones of extremes should be treated separately, i.e. additional action is needed in these zones.

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RECONSTRUCTION OF TIGAR SETTLEMENT IN PIROT ACCORDING TO THE PRINCIPLES OF SUSTAINABLE DEVELOPMENT – PART I

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Abstract

The residential area of Tigar factory workers, which has garnered significant tourist attention in recent years, was built in the 1960s. The Tigar factory realized a combination of apartments and traditional houses, modelled after English working-class neighbourhoods, in the form of 880 units. However, the urban design and organization of the apartments had several project-related issues. Coupled with poverty, this led to the construction of completely new houses in the yards at the end of the 20th century. The need for three generations to live in one apartment required the expansion of apartments, compromising the shape and form of the settlement. Curiously, the potent idealization of the historic settlement was of such magnitude that none of the researchers directed their attention towards the pursuit of sustainable development within this residential zone. Today, with improved housing comfort, there is also an increased need for energy efficency. This energy footprint certainly reflects on the appearance of the settlement, so it is necessary to reconstruct it according to the principles of sustainable development. The first part of the research presents and analyses the architectural problems of this settlement. The second part presents the expected changes in energy use and demographic development. The research investigates how architecture can absorb these changes. The aim of the study is to create recommendations for improving the settlement, envisioning a more optimistic shared future for its residents in Pirot, Serbia.

Key words: *Reconstruction, Sustainable development*

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1. INTRODUCTION

Today, we are facing an urgent need to reduce CO_2 emissions and mitigate the negative consequences of climate change. Human settlements, as the epicentres of human activity, play a crucial role in this process. The challenges of reducing the CO_2 footprint in settlements require innovative approaches and sustainable strategies to create low-carbon and environmentally sustainable places to live. Reducing the CO_2 footprint in settlements is becoming increasingly urgent due to the increase in urban populations, dependence on fossil fuels for energy, and the growth of transportation [1]. High energy consumption, inefficient construction, underutilization of renewable energy sources, and a lack of sustainable transportation options are key factors contributing to increased CO_2 emissions. Strategies for reducing the CO_2 footprint in settlements can include improving the energy efficiency of buildings, using renewable energy sources such as solar and wind energy, implementing sustainable urban planning and transportation systems, as well as promoting a sustainable lifestyle and energy awareness among residents of the settlements [2,3]. Reducing the CO_2 footprint in residential areas not only contributes to global efforts to combat climate change but also brings numerous local benefits. Sustainable settlements have the potential to reduce energy costs, improve air quality, alleviate traffic congestion, create green spaces, and support the local economy [4–9].

In recent decades, the concepts of smart cities and smart buildings have become increasingly significant in the field of urban development and sustainable architecture. Integrating new services and tools into the energy and ecological design of smart cities and smart buildings allows for more efficient resource utilization, reduced carbon emissions, and improved quality of life for residents. Smart cities are defined as urban concepts that use information and communication technologies and sensor systems to enhance the efficiency of city management and provide advanced services to citizens. Smart buildings, employ the same technologies to optimize energy efficiency, comfort, security, and building management, as the conditions for better energy efficiency for buildings naturally follow from the conditions outlined in the smart city concept. The integration of new services and tools into the design of smart cities and smart buildings offers opportunities for enhancing their functionality and sustainability [10].

Some key trends in this field include the application of smart grids for more efficient energy management, the implementation of energy monitoring and control systems, the use of renewable energy sources, the integration of Internet of Things (IoT) technologies for resource connectivity and optimization, and the development of digital platforms for infrastructure management [11,12].

The integration of new services and tools into the energy and ecological design of smart cities and smart buildings brings numerous benefits. These innovations enable reduced energy consumption, resource optimization, increased energy efficiency, improved quality of life for residents, decreased carbon emissions, and the creation of a sustainable urban environment [13].

The topic of retrofitting and sustainability is closely related, especially during times of energy crisis [14,15]. The literature has shown that sustainable development is better served by the retrofitting of settlements rather than their new construction [16–19]. If a residential space is used in the usual manner, the amount of energy consumed over a period of 25 years exceeds the required energy and environmental impact of a completely new house with additional insulation and more efficient heating and cooling systems. However, if an old house is retrofitted with ecological insulation that achieves a negative environmental impact over 25 years, it can be concluded that sustainable retrofitting of settlements makes more sense than building new ones and continuing to use the old ones.

It is clear that if old houses are not used or new ones are not built, there would be no issue with the CO_2 footprint. However, as the population increases, as is the case in cities, it becomes necessary to retrofit old houses according to sustainability principles. There is a limited number of scientific papers related to the topic in the literature specifically focused on the context of Serbia. In a study examining the retrofitting of a mountain house, it was shown that the application of ecological insulation materials significantly reduces the overall energy demand [20] The results of this study are highly applicable as they provide information on the CO_2 footprint associated with hemp and sheep wool panels. However, the application of sustainability principles to entire settlements in Serbia has not been extensively explored in the literature, indicating a scientific justification for further research on this topic [21–23].

The aim of this study is to analyse the issues of the Tigar Factory settlement in Pirot, which represents one of the main landmarks of this city in south-eastern Serbia. After reviewing the current organization of housing and existing infrastructure, opportunities for improving energy efficiency, reducing greenhouse gas emissions, and creating a living space in harmony with the natural environment are identified. The underlying assumption is that the reconstruction of the settlement can contribute to the revitalization of old and significant areas, improve the quality of life for residents, and create a sustainable community. In other words, this study aims to create a model of sustainable settlement design, which is a key component for creating a sustainable future.

2. METHODOLOGY

The research was conducted in several phases. The first phase involved an assessment of the architectural and urban concept of the Tigar settlement in Pirot. Deficiencies in spatial organization, transportation issues, and environmental impacts were documented. The second phase briefly showcases examples of best practices. The third phase proposes a model for the reconstruction of the settlement based on the conducted analyses and the principles of sustainable development. This third phase describes the objective of this study, which is to propose the revitalization of the Tigar settlement in Pirot. The second and third phases are presented in the second part of the paper, which is divided into two sections due to its length.

The analysis of the Tigar settlement is undertaken within the framework of sustainable development, with a primary focus on energy efficiency. Initial attention is given to issues related to the apartment layout, which serves as the cornerstone of the entire settlement. It is observed that design principles were not fully adhered to, resulting in the improper orientation of the living room, thereby hindering the energy efficiency of the row houses. Subsequently, a comprehensive assessment of the architectural forms of the entire settlement is conducted, encompassing challenges related to parking and unauthorized constructions.

Aligned with the research objective, instances of successful practices are drawn upon to formulate recommendations aimed at optimizing apartment organization, refining the architectural and urban layout of the entire settlement, and enhancing the energy efficiency of the structures.

The domains of architecture, urban planning, transportation, and energy are strategically utilized to identify both impediments and possibilities for rejuvenating the neighborhood. Importantly, this research is not conducted as part of an educational curriculum or a scientific project. Rather, it is driven by the need to establish guidelines that can directly reshape the existing settlement in preparation for an international housing exhibition (Housing 2023). This scientific paper serves as the foundation upon which a conceptual plan for the reconstruction and expansion of the Pirot settlement is subsequently executed.

The selection of Pirot as the study area is based on a personal connection, as one of the authors resides in this city. Additionally, the significance of this particular settlement has not been acknowledged within Serbian academic circles, providing further impetus for the authors to delve into the fusion of sustainable construction and cultural heritage. Owing to various circumstances, the housing model that thrived in Pirot during the last century now emerges as the most sought-after form of housing in the city. This observation substantiates the pursuit of this style of housing research within the described conditions.

3. THE TIGAR FACTORY SETTLEMENT IN PIROT

The Tigar Factory settlement in Pirot has been a social asset of this city for half a century. Situated amidst surrounding mountains, rivers, and lakes, the Nisava River flowing through Pirot and its promenade serve as one of the city's landmarks. The other is precisely this settlement, built to the pride of all people from Pirot. In the 1960s, the Tigar tire factory formed a housing cooperative with the aim of constructing affordable housing for its employees. In 1964, the factory built 880 apartments for its workers. Tigar engaged the renowned Yugoslav architect Mihajlo Mitrovic, among other experts, to participate in the endeavour, constructing a combination of apartments and classic houses inspired by worker settlements in Wembley, UK (Figure 1). This research supports Aleksic's viewpoint that row housing is the most rational form of residential construction for Pirot and provides residents with a very decent level of comfort [24]. In contrast to economical high-rise buildings, the Tigar Factory settlement apartments come with their own yard, parking, two entrances, and their own roof. Block housing construction actually requires more green spaces, extensive parking lots, playgrounds, etc., which may make this type of construction appear better, but in reality, none of these mentioned amenities are adequately provided in any of the blocks. If we compare the situation during socialism and the present-day capitalism, such space within high-rise housing is incomparably better in the case of the former. In Pirot, and probably beyond, it is unheard of for an investor to take care of the yard instead of building more units of their product [25,26].

The apartments had 3 or 4 rooms spread over 2 levels. Apartments on the 3rd level had a narrower front. This type of settlement concept quickly became a model for worker housing throughout the country. Everything was well-defined, from the height of the living fences to the type of flowers, trees, and fences. The yards were actually expanded with the greenery of the promenade and the avenue of trees that separated the rows. Modest houses with pitched roofs blended well with the terrain, suiting the environment and the concept of worker housing. The end houses in the rows had a significant portion of the side yard, making them more exceptional but with an additional heating energy load. However, while urban design flourished, the organization of the apartments faced several design issues. In conjunction with poverty, this problem escalated to the construction of entirely new houses within the yards by the end of the 20th century. Of course, the law protected the original design, but its enforcement failed. The need for three generations to live in one apartment necessitated their expansion, disrupting the form and character of the settlement. Interestingly, the ideal image of the old settlement was so strong that no researcher delved into this phenomenon. The newly expanded apartments actually exacerbated the problems initially encountered. Rooms were often built without windows, and the organization became so degraded that it was evident that the fight for square footage had triumphed over comfort and architecture. Nevertheless, it can be concluded that the problems of the interior apartment organization were overshadowed by the successful urban design. It can be said that in good urban design, average architecture gains greater value [27]. In this case, the value of the apartments equalled the value of the settlement, which later influenced the redesign of public spaces in Pirot. The area next to the river was naturally perceived as highly attractive, and in addition to flood protection, the promenade along the Nisava River became a city walkway. After decades in the dark, street lighting was installed in the tree-lined streets, creating a new landmark for the city. However, this intervention, besides giving a new look to the old ambiance, also shed light on the initial problems, which later continued with the expansion of the Tigar Factory settlement on the left side of the Nisava River.

Figure 1. Houses plan- a) Wembley, College Road HA9; b) Pirot, Tigar old housing, Drawings: M. Stanimirovic

The main problem in the organization of this apartment is the position of the living room in relation to the cardinal directions and the lack of natural light in this crucial space of the house. In contrast to the exemplary solution, the Tigar Factory settlement introduces novelties that significantly degrade the basic concept of row houses. In an English-style apartment, there is direct sunlight in all rooms, whereas in the case of the Pirot settlement, the living room is enclosed by the garage space towards the backyard, with a veranda installed at the front, significantly reducing the amount of light entering the space. In other words, the living room becomes a dim area. Apart from this architectural problem, the living room is open to public circulation through a small garden, lacking an intimate interior courtyard within the block. Lastly, the orientation of the living room in relation to the cardinal directions is not only poorly defined but also copied and rotated based on the street grid, without considering the sunrise and sunset (Figure 2). In contemporary architectural design, such an approach is unacceptable and indicates a disregard for fundamental compositional principles.

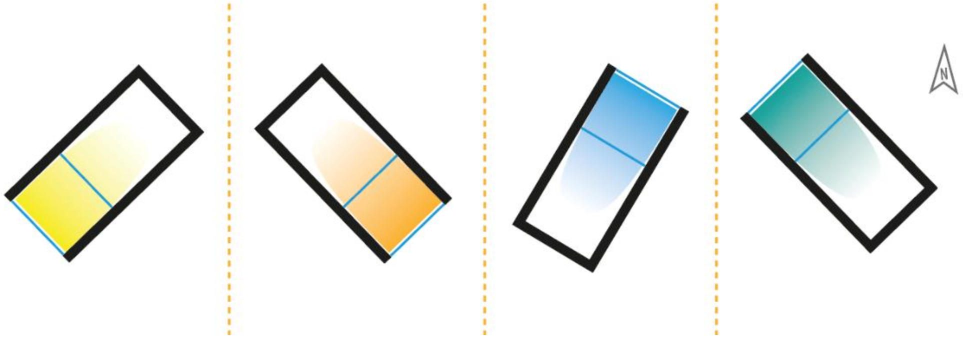

Figure 2. Positions of the living room in relation to the north, Drawings: M. Stanimirovic

In addition to the problems in the organization of the apartment, deficiencies can also be found in the neighbourhood or settlement layout (Figures 3 and 4). The original concept was designed so that residents accessed the garage from narrower residential streets. The width of the garage was determined based on the dimensions of smaller cars at that time, such as the Zastava 750. This means that modern cars have difficulty fitting into such small garages. As a result, residents park their vehicles outside their plots, on the street, or on sidewalks. Since many families have multiple cars, the streets have become one-way, and the garages have been converted into extended living or service spaces. Even public spaces have been encroached upon by private boundaries, exclusively used for various purposes. The reduction of yards is also facilitated by the unplanned construction of storage spaces, new garages, and entirely new houses, all within the interior courtyards. Over time, residents and their successors have deviated from landscaping regulations, resulting in many houses acquiring new iron fences, additional structures, and updated facade colours. In other words, the shape of the settlement has significantly deteriorated due to unplanned reconstruction and expansion practices.

As much as the greenery and proximity to the river are pleasant in spring and autumn, this settlement is known for its smog during winter. The apartments are not connected to the city's heating system because that generation of houses did not have it in the plan. Residents mostly rely on wood for heating, which leads to several issues. The first is air pollution, which is noticeably evident in winter. The second issue is visual, as firewood is often dried in public spaces during the summer. The third problem relates to energy and environmental conservation. There is a genuine lack of a more efficient heating system that incorporates good wall insulation and effective thermal protection for doors and windows. Significant amounts of energy are released from these houses, which not only decreases air quality but also contributes to environmental degradation.

Figure 3. Tigar settlement in Pirot, Photo: https://a3.geosrbija.rs

Figure 4. Tigar settlement in Pirot, Photo: M. Stanimirovic

4. CONCLUSION

The present time is often described as the era of investor-driven urbanism in capitalist society. The situation that architects aspire to is the collaboration of multiple investors towards a shared solution involving packaging, green spaces, and architectural form. The challenge of architectural design for residential settlements depends on creating a certain value of the product being traded. Therefore, it is more crucial for the investor to create as many units constituting their product. Units refer to the square meter area of a dwelling. This concept leads to less attention given to green spaces, parking, or overall living quality. It can be concluded that today, private investors cannot build their residential products on plots similar to those by the river in Pirot. Only when old buildings are demolished can the most attractive plots fulfill the investor's goal. This is a nightmare feared by all architects, whether in the realm of architectural design or environmental protection.

By drawing these conclusions, the Tigar factory settlement from the last century becomes an ideal housing model reserved for the elite. Row houses undoubtedly offer more comfort than apartment living. Part of the houses share heating, resulting in reduced energy needs for heating. On the other hand, private yards represent the essence of house living, which cannot be replaced by shared green spaces. Common parks are diminishing, as their construction is unjustified for the investor's objective – to build and sell as many square meters of residential space as possible. However, based on the analysis of the internal organization of apartments conducted in the previous chapter, the concept of living by the Nišava river in Pirot needs improvement to achieve the set ideal. In the continuation of the research, in the second part, suggestions for the reconstruction of this settlement are derived based on this analysis and examples of sustainable development-compliant living.

Figure 5. Tigar settlement in Pirot, Photo: M. Stanimirovic

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RECONSTRUCTION OF TIGAR SETTLEMENT IN PIROT ACCORDING TO THE PRINCIPLES OF SUSTAINABLE DEVELOPMENT – PART II

Mirko Stanimirovic[1], Ana Momcilovic - Petronijevic[2], Milanka Vasic[3], Luka Zavisic[4], Nemanja Randjelovic[5]

Abstract

The settlement next to the Nišava River in Pirot was built in the 1960s, intended for the workers of the Tigar factory. Based on research in the first part, it was determined that these row houses feature an irregular positioning of the living room in relation to the cardinal directions and other living functions. Due to various circumstances, this housing was significantly altered by the end of the 20th century, with nearly every yard gaining an additional structure. Building upon the analysis of the internal organization from the first phase of research and the examination of selected examples that were realized following sustainable construction principles in the second phase of the study, recommendations for the reconstruction of this settlement were formulated. In addition to these proposals, the aim of this research is to document the existing state of the row (terraced) houses in Pirot.

Key words: *Reconstruction, Sustainable development*

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1. ECOVILLAGE AT ITHACA IN NEW YORK

EcoVillage at Ithaca in New York (Figure 1) is a reconstructed settlement that is self-sustaining and has minimal impact on the environment. It is a sustainable, community-oriented, and beautiful place to live. Some of the advantages of living in EcoVillage at Ithaca are reduced environmental impact, a strong sense of community, opportunities for learning and personal growth, a picturesque setting, security, affordability, and diversity.

EcoVillage at Ithaca is intentionally designed as a sustainable community, prioritizing the reduction of its environmental footprint. The community utilizes renewable energy sources, practices recycling and composting, and cultivates its own food. Residents of EcoVillage at Ithaca form a close-knit community, dedicated to collaboratively creating a sustainable and equitable way of life. Various opportunities exist for residents to actively engage in communal activities, such as shared meals, work parties, and social events.

EcoVillage at Ithaca fosters a culture of continuous learning, where residents continually expand their knowledge on sustainability, community building, and personal development. Residents have access to classes, workshops, and research projects, providing ample opportunities for growth.

Situated on 100 acres of land in Ithaca, New York, EcoVillage at Ithaca enjoys a stunning natural backdrop comprising forests, fields, and streams. Residents have abundant opportunities to immerse themselves in the outdoors. The community is gated and equipped with security cameras, ensuring a sense of safety and security for its residents.

EcoVillage at Ithaca offers a range of housing options, including co-housing units, apartments, and cottages. Financial assistance programs are also available for eligible individuals, enhancing affordability. The community is home to a diverse group of people from various backgrounds, enriching the community with a multitude of experiences and perspectives. It fosters a welcoming environment for all residents [1–6].

Figure 1. EcoVillage at Ithaca, Photo: https://ecovillageithaca.org

2. MASDAR CITY IN ABU DHABI

Masdar City is a planned urban district located in Abu Dhabi, United Arab Emirates, that relies on solar energy and other renewable energy sources. The city was designed by Foster + Partners and developed by Masdar, a subsidiary of the Mubadala Development Company, which is a state-owned enterprise of Abu Dhabi. It is situated adjacent to the Abu Dhabi International Airport and is also the headquarters of the International Renewable Energy Agency (IRENA). Originally scheduled for completion in 2016, the project's timeline was shifted to the period between 2020 and 2025 due to the impact of the global financial crisis (Figure 2).

Masdar City aims to become a global hub for research and development in renewable energy and a home for companies involved in clean technologies. The city is designed to be energy-efficient and sustainable, relying on 100% renewable energy sources. Masdar City holds significant importance for the United Arab Emirates for several reasons. Firstly, the city serves as a symbol of UAE's ambitious plans for the future. The UAE aims to become a global leader in renewable energy, and Masdar City is crucial to achieving that goal. Secondly, Masdar City presents an opportunity for the UAE to attract international companies and talent in the renewable energy sector. The city already houses several leading global companies in this field and is expected to attract more in the future. Thirdly, Masdar City has the potential to transform the way we build and live. The city is designed to be energy-efficient and sustainable, principles that can be applied to other cities worldwide 7–10].

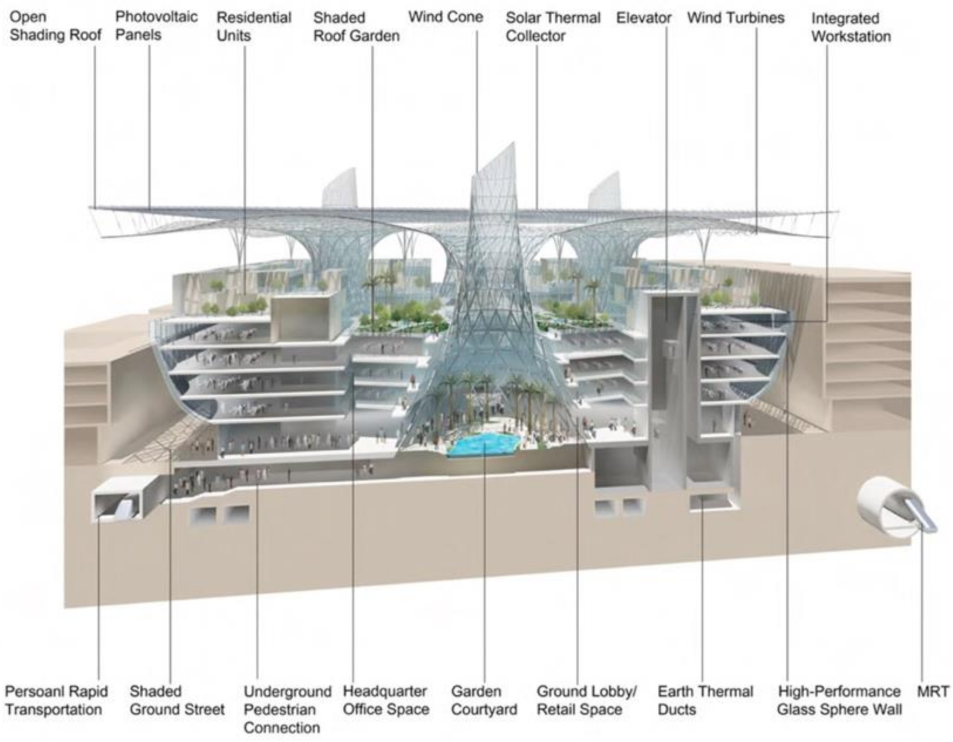

Figure 2. Masdar City in Abu Dhabi, Photo: https://www.carboun.com

3. DISCUSSION

According to the research goal, based on the identified shortcomings of the neighbourhood in the previous chapter, its improvement lies in addressing issues related to architecture, urban planning, transportation, and energy. As the aim is to preserve the original landscape of the row houses and prioritize renovation over new construction, the issue of the living room can be resolved through the transformation of the garage. It significantly blocks the living room from the intimate backyard. This problem can only be solved by relocating the garage towards the street entrance. The insertion of an atrium will enable necessary circulation of light and air. Further transforming the garage involves its elimination and creating a workspace. After the COVID-19 pandemic, working from home has become crucial for various reasons. Hence, it makes sense to allow residents to work from home for part of their working hours [11]. In addition to introducing this new function, it is necessary to provide an intimate yard in this area of the spatial organization. In the case of end houses in the block, the living room space is moved to the former garage position, ensuring full illumination from the south side (Figure 3). The workspace can easily be converted into a guest room or a bedroom. Its direct access from the outside is suitable for a family in which the older child has their own entrance to the home and unrestricted access to the bathroom. The attic space can also be upgraded by converting it into a residential or workspace. In this case, only roof windows and stairs connecting the first and second levels need to be added, which does not require significant intervention. The existing gable roof shape aligns with this spatial organization. It also corresponds to the idea of preserving the original form as much as possible to maintain visual consistency and the neighbourhood's identity. Furthermore, the two-sided roof design is compatible with the installation of solar panels, enhancing the reconstruction in terms of utilizing renewable energy sources.

Figure 3. Internal organization change, Drawing: Authors

According to the mentioned study [12], during the reconstruction phase, it is necessary to insulate walls and roofs with natural materials such as hemp or sheep wool. Both products have been used in the Pirot area in the past. In the case of reviving milk and sheep production, there is a justifiable tendency to commercialize sheep wool panels. In that case, the environmental impact of insulation materials would be significantly reduced. Windows and doors with glass and profiles that adhere to sustainability principles also contribute to energy conservation. Finally, the topic of energy should be completed by using water-to-water heat pumps, considering that the area around the river is rich in groundwater. The space required for the functioning of pumps utilizing groundwater temperature corresponds to half of the previous garage space. This situation represents a limitation of this study, and it is suggested for future research.

The shape of the garage roof matched the shape of the house roof. However, the collision of a larger house and a smaller garage results in a less favourable architectural composition. The importance of green roofs in drainage has long been demonstrated in literature. Additionally, green roofs also reduce temperatures during the summer months. Based on this knowledge and with the aim of creating a better composition of masses, the roof above the workspace can be designed as a green roof (Figure 4). The potential for energy savings in green roofs is strongly influenced by design elements and is heavily dependent on the prevailing climatic conditions [13–17]. Green roofs play a significant role in the reconstruction phase of residential houses. Apart from their aesthetic and ecological aspects, they provide numerous benefits in terms of energy savings and improved quality of life. Green roofs contribute to thermal insulation, reducing the need for heating in winter and cooling in summer. They also absorb rainwater, reducing the risk of floods and facilitating the maintenance of drainage systems. These roofs additionally provide an additional sound insulation layer, reducing noise from the surrounding environment. Moreover, green roofs enhance air quality by filtering harmful substances and reducing CO_2 emissions. Therefore, incorporating green roofs in the reconstruction of residential houses can lead to significant energy savings and environmental improvements.

Figure 4. First floor plan, Drawing: Authors

In relation to the changes in the living room area, a more radical approach must be applied to the context of the settlement. This would preserve the original idea of the workers' settlement, who were brought to Pirot from surrounding villages to work in the Tigar factory. Half a century ago, this task was quite demanding and risky. People accustomed to rural life had a negative attitude towards migrating to urban areas. Therefore, the appearance of the settlement was given a touch of humane living, with greenery and surroundings where residents have everything they need. Indeed, the school and sports hall are very close to this settlement. The kindergarten has been located within the settlement since its inception. Additionally, the shopping centre was originally situated in the middle, where residents could purchase groceries and carry out administrative tasks at the bank and post office. Over time, the idea of the shopping centre was forgotten, replaced by smaller shops that exclusively offer food today. The presence of such shops gradually suppressed the need for workers to have their own gardens in house yards, where they grew fruits and vegetables. However, following the pandemic in the past few years and during a time of major global crisis, the need for the return of these functionalities has emerged. Besides existential problems, home farming also represents a form of occupational therapy, which is particularly beneficial for older people to stay in shape [18,19].

The implementation of such a concept requires, first and foremost, the dismantling of unplanned structures in the yards of the houses in the Tigar factory workers' settlement in Pirot. Without this radical move, the settlement cannot be returned to its original form, and further steps in the reconstruction process will not be possible. The first step is to introduce new street profiles with parking spaces on the sides. One solution is to preserve the authenticity of the settlement facing the river while reorganizing the other side of the main road to create new park areas and necessary functionalities, such as housing for older individuals on the ground floors of multi-story buildings, a shopping centre with integrated food stores, a bank, a post office, a hairdresser, a pharmacy, and a medical centre. Some of these facilities are entirely new compared to the original concept. However, they are necessary because the workers have since had descendants who now belong to the older generation and require certain assistance. Constructing new functionalities is only possible at the expense of the part of the settlement that will be sacrificed for new needs. As the block of houses along the river is the most representative part of the settlement, it should be restored to its original state as much as possible. The part of the settlement extending towards the north cannot be considered the result of careful architectural and urban planning, thus justifying the mentioned radical intervention.

Figure 5 shows a proposal for the reconstruction of this settlement. Firstly, all the added structures in the yards of the houses are demolished. Houses that deviate from the original concept are transformed into a form that aligns with the new reconstruction. Such cases are marked with yellow markers. New green areas are represented in green, while new multi-story residential buildings are coloured blue. These buildings replace the demolished houses in the new green areas. Additionally, since they are multi-story buildings, these structures represent potential expansion of the residential space for new residents. Parking is planned in the basement and on the ground floor. Solar panels are installed on the roofs. In the area where multi-story buildings already exist, two additional buildings have been added to accommodate shops, a bank, a medical centre, a dentist's office, and a post office. An extra floor is added to the kindergarten, as there are many children in this settlement. On the right side, instead of housing for workers, a nursing home is established, around which therapeutic gardens can be organised.

Figure 5. Reconstruction of the Tigar settlement, Drawing: M. Stanimirovic

4. CONCLUSION

It can be emphasized that the reconstruction of Tigar Settlement in Pirot was carried out with the aim of meeting the increased energy needs while respecting the principles of sustainable development. The reconstruction aimed to restore the former significance of the original settlement, which had suffered from the disruption of its architectural composition due to unplanned construction of additional buildings.

By implementing new elements within the internal organization of space, including new streets and parking areas, a new urban matrix was achieved. In terms of energy efficiency, the roofs were equipped with solar panels, and insulation made from natural materials was used, while openings were replaced with the goal of reducing the required energy for heating and cooling. Additionally, green spaces were prioritized, with the construction of new multi-story buildings in the northern part of the settlement to compensate for the loss of space due to the removal of certain structures.

This reconstruction of Tigar Settlement in Pirot serves as an example of how to achieve harmony between energy needs, preservation of architectural integrity, and sustainable development. The implementation of sustainability principles through the use of renewable energy sources, natural materials, and the enhancement of green areas contributes to energy efficiency, the quality of life for residents, and environmental protection. This approach can serve as a model for the reconstruction of other settlements in line with the principles of sustainable development.

Figure 6. Tigar settlement in Pirot, Photo: Pirot - MOJ GRAD [20]

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IMPACT OF FAÇADE WINDOW DESIGN ON THERMAL COMFORT AND ENERGY EFFICIENCY OF RESIDENTIAL BUILDINGS

Nemanja Ranđelović[1]

Abstract

Increased energy consumption and global climate change have introduced the concept of bioclimatic architecture into the world of construction. The principles of sustainable development emphasize the importance of using solar energy as one of the renewable energy sources. Windows and other glazed surfaces directly transmit heat and thus majorly affect the passive solar design of the building. The aim of this research is to show the importance of geometry, i.e. the size, shape, and position of windows in the architectural design of a residential building and their impact on thermal comfort and energy efficiency. Climatic conditions in the area of Southeastern Serbia were used for the purposes of the subject analysis.

Key words: *geometry, windows, energy efficiency, thermal comfort, bioclimatic architecture, residential architecture*

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1. INTRODUCTION

Energy demand is increasing at a spectacular rate with the acceleration of urbanization and the innovation of technological levels [1]. Buildings are accounting for more than 40% of global primary energy use, produce substantially more carbon emissions than those in the transport sector, and so they are the largest energy-consuming sector in the world [2]. As the concern about environmental impacts of buildings is increasing, private and public organizations are progressively requiring the building industry to design and construct buildings with minimal environmental impact [3]. Consequently, many studies have been done regarding the energy-efficient building design. In this regard, windows are responsible for more than 10% of the building energy load and so are revealed to have considerable influence on the total energy consumption [2]. Windows perform many functions such as natural lighting and ventilation as well as outside visibility. They also play an essential function in the architectural appearance of the building [4,5]. Due to their structural properties and their position within the building envelope, windows constitute the most vulnerable points on the facade, as they facilitate the transfer of heat between the interior and exterior environments [6].

The current regulations in the Republic of Serbia define the percentage of openings and thermal properties of building materials, including the heat transfer coefficient of transparent and opaque construction materials. The Regulation on Energy Efficiency of Buildings [7] specifies the heat transfer coefficient of transparent surfaces, as well as their thermal gains and losses during the summer and winter periods. However, the Regulation on Conditions and Norms for the Design of Residential Buildings and Apartments [8] defines the minimum glassing area of facade openings, which amounts to 15% of the net floor area of a room. These regulations and norms do not take into account the window geometry and its position within the building envelope. The research focuses on glazed openings on the facade, which may include both doors and windows. However, in further analysis, only windows will be considered, while doors will be excluded from this research.

An analysis conducted within the scope of this study is based on the impact of window design on thermal comfort and energy efficiency of family houses in Serbia provided in the publication "Atlas of Family Housing in Serbia"[9]. The analyzed building belongs to the category of detached houses with a sloping roof under which is non usable space, and it has a small number of openings, each occupying less than 50% of the facade area.

The aim of this research is to assess the influence of window design on the amount of energy required for optimal thermal comfort in family houses, considering the position of the openings within the building envelope. The study involves evaluating the impact of windows with fixed area and various positions within the building envelope.

2. MATERIALS AND METHODS

The objective of this research is to assess the impact of window design on the building's energy load. Since the building's energy load is influenced by a combination of various window design factors, including size, position, and orientation, it is also important to consider the proportion of the windows, specifically the aspect ratio defined as the ratio of width to height. In this study, the window size is a constant value representing the minimum required glassing area of facade openings specified by regulations. The window orientation is determined based on the functional scheme of the building taken from the publication "Atlas of Family Housing in Serbia" [9] and therefore, it remains unchanged (Figure 1). The window position and proportion will be examined by creating various scenarios. The results are expected to provide guidelines for designers, demonstrating how window factors impact the building's energy load. In the context of this study, energy load implies to the annual heating load and cooling load. The lighting load has a fixed value. Within the scope of the energy load analysis of the building, the energy for heating and cooling is maintained at a constant level, representing the energy required to meet the thermal comfort of the occupants of the family house.

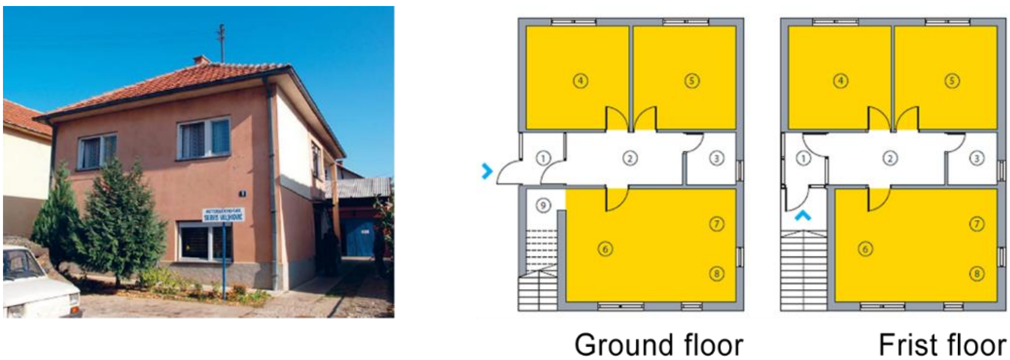

Figure 1. Family house in Niš, Atlas of Family Housing in Serbia [9]

In this paper, window size refers to the minimum required glassing area of facade defined by regulations, which amounts to 15% of the net floor area of the room. Window orientation relates to the facing direction of the window, which is north, east, south, and west. In this case, these factors are considered constant and do not directly impact the calculation of the building's energy load. Window position refers to the height of the window from the floor and it is divided into high, middle, and low positions. High position indicates that the top of the window is aligned with the top of the wall, middle position means the midpoint of the window is positioned in the middle of the wall, and low position signifies that the bottom of the window is placed at the bottom of the wall. Window proportion represents the ratio of width to height, defining the relationship between the horizontal and vertical dimensions of the window. In this research, eight different scenarios have been created, encompassing changes in window shape, ranging from square-shaped to horizontally-oriented rectangular and vertically-oriented rectangular windows. In the context of the building's energy load analysis, where energy for heating and cooling, as well as window area, are constant values, the obtained results will consequently represent solar gains.

The research methodology is presented in Figure 2. The BIM model of the house was developed based on the available graphical references and photographs from the "Atlas of Family Housing in Serbia"[9]. The chosen type of building exhibits a simple geometry without shading devices or external structures that would affect the analysis of the building's energy load. Therefore, simplification of the energy model was not necessary for the purposes of this study. All properties relevant to energy load were properly set and maintained throughout the research to isolate the effects of factors other than window position and proportion. Subsequently, an energy analysis was conducted, encompassing eight different windows with varying dimensions and three different window positions, resulting in a total of 24 scenarios (Figure 3). The objective of this analysis is to identify the optimal combination of window proportion and position that leads to minimal energy load. The BIM model was created and modified using Revit® software, while the energy simulation was performed using the integrated Green Building Studio® software.

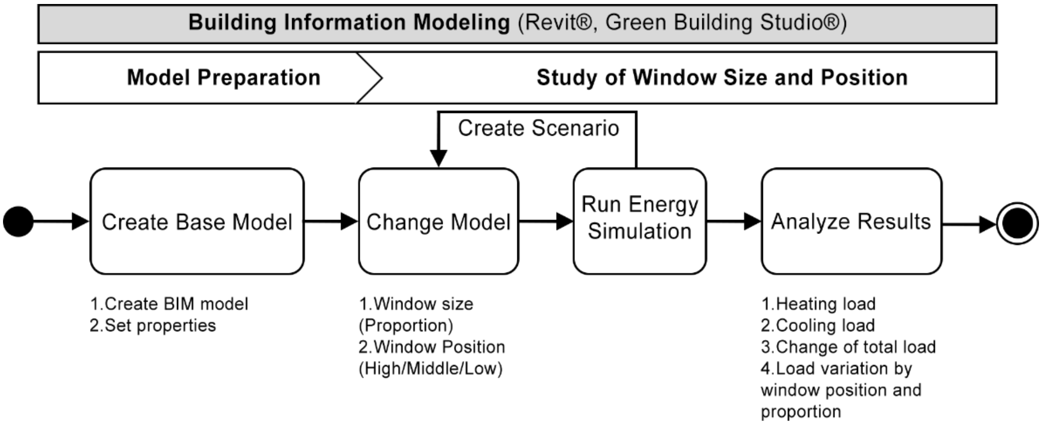

Figure 2. Research methodology, (Author: N. Ranđelović)

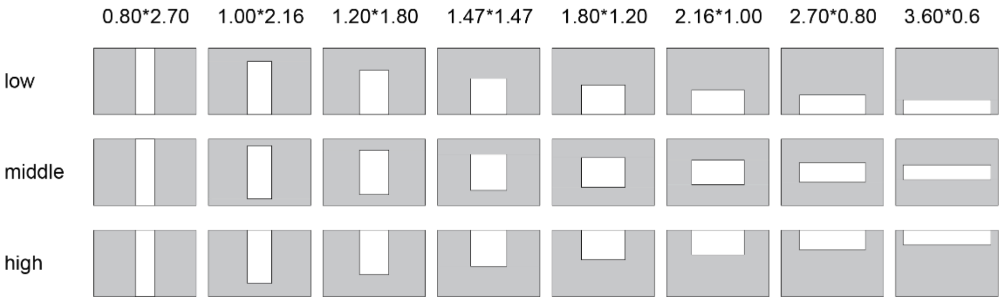

Figure 3. Window size and position, (Author: N. Ranđelović)

3. RESEARCH ACTIVITIES

3.1. Base Model

To conduct an energy analysis, a BIM model was created based on graphic attachments and photographs from the "Atlas of Family Housing in Serbia"[9] (Figure 4(b)). The sample model represents a semi-detached family house with a ground floor and one upper floor, divided into two housing units horizontally. The building has a compact, approximately square-shaped footprint. There is no basement, and the attic space under the sloping roof is not utilized. The house was constructed with brick in the 1970s. The walls that have a thickness of 25 cm are plastered on both sides. The intermediate floor structure between the two units is a lightweight reinforced Avramenko-type ceiling, while the roof structure is wooden with a groove tile covering. The facade openings consist of individual windows with relatively small surface and they satisfy the minimum glassing area of facade openings requirement defined by regulations, which amounts to 15% of the net floor area of each room [9]. As shown in Figure 4(a), room properties such as occupancy schedules, lighting loads, and equipment loads are fixed in every scenario.

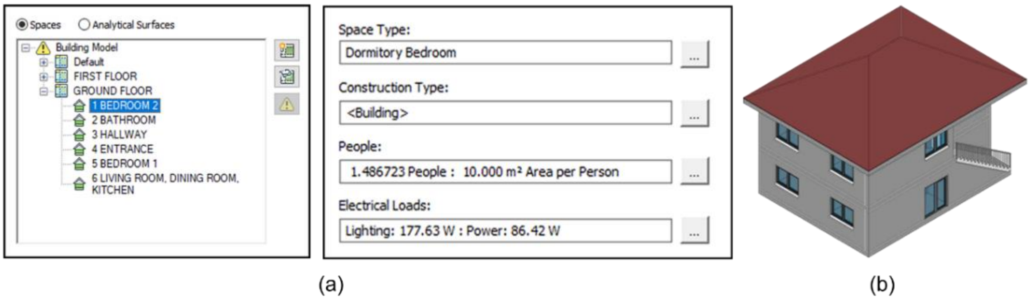

Figure 4. (a) Properties setting; (b) BIM model, (Author: N. Ranđelović)

3.2. Energy Analysis Process and Results

3.2.1. Impact of window position on energy load

Changes to the window position were implemented in 24 scenarios to evaluate their impact on the building's energy load. The window position varied from high to middle to low. This change in window position was applied only to residential spaces such as the living room, dining area, kitchen, and bedrooms. The windows in the entrance area and other non-residential spaces remained unchanged, thus not affecting the energy load of the building. After creating each scenario model, energy simulations were conducted, and the results were collected. Figure 5 illustrates that there is no significant difference in the annual energy load due to window position changes. The maximum difference in energy load resulting from window position change was observed in windows with a width of 3.6 meters and a height of 0.60 meters, amounting to only 4 kWh. This difference represents a very small value compared to the annual energy consumption, indicating that window position has a negligible impact on the building's energy load.

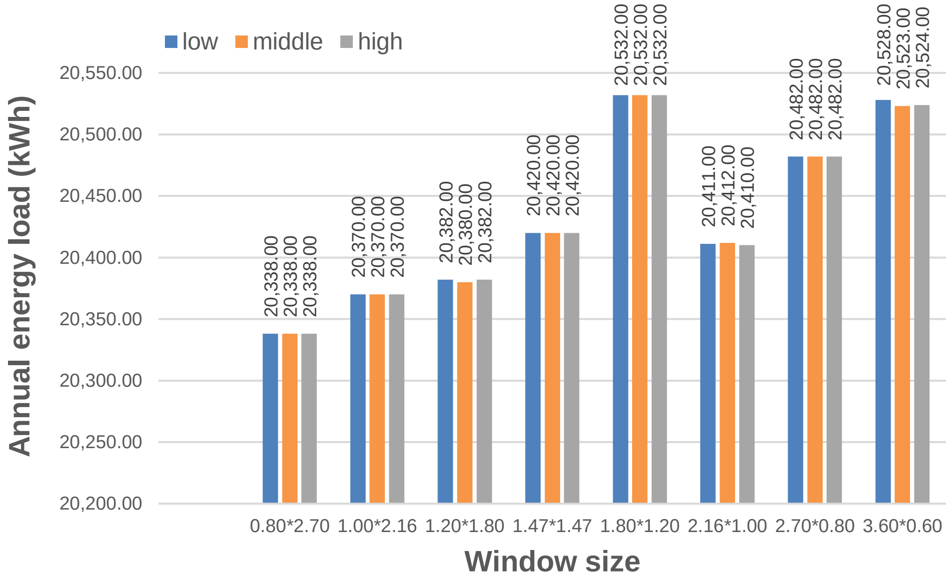

Figure 5. Annual energy load by window position, (Author: N. Ranđelović)

3.2.2. **Impact of window proportion on energy load**

In the second part of the study, the influence of window position was disregarded, as it was found to have a negligible impact on the annual energy consumption. The focus was shifted towards examining the effect of window proportion on the annual energy consumption. The impact of proportion on energy consumption was investigated through eight scenarios, where the windows were positioned centrally with proportions of 1:3.37, 1:2.16, 1:1.5, 1:1, 1.5:1, 2.16:1, 3.37:1, and 6:1. The windows in the entrance area and other non-residential spaces remained unchanged, thus not affecting the energy load of the building. Various window proportions were explored, ranging from those emphasizing verticality to square-shaped windows and those emphasizing horizontality.

In Figure 6, it is apparent that the annual energy consumption increases with a change in the aspect ratio of the windows. The minimum energy consumption is observed for windows with the most pronounced verticality, characterized by a width-to-height ratio of 1:3.37, amounting to 20,338.00 kWh per year. Furthermore, a linear increase in energy consumption is observed as the width-to-height ratio decreases from 1:2.16, through 1:1.5, to 1:1. For windows with a width-to-height ratio of 1.5:1, a sharp increase in energy consumption is noticed compared to the 1:1 ratio, resulting in an additional 112 kWh and a total of 20,532.00 kWh. Following this increase, there is a subsequent decline in energy load for windows with a width-to-height ratio of 2.16:1, and a subsequent linear increase from 3.37:1 to windows with a ratio of 6:1. The maximum energy consumption is observed for rectangular windows with a width-to-height ratio of 1.5:1, featuring window dimensions of 1.8m in width and 1.2m in height, resulting in an increase of 194 kWh compared to the minimum value, totaling 20,532.00 kWh.

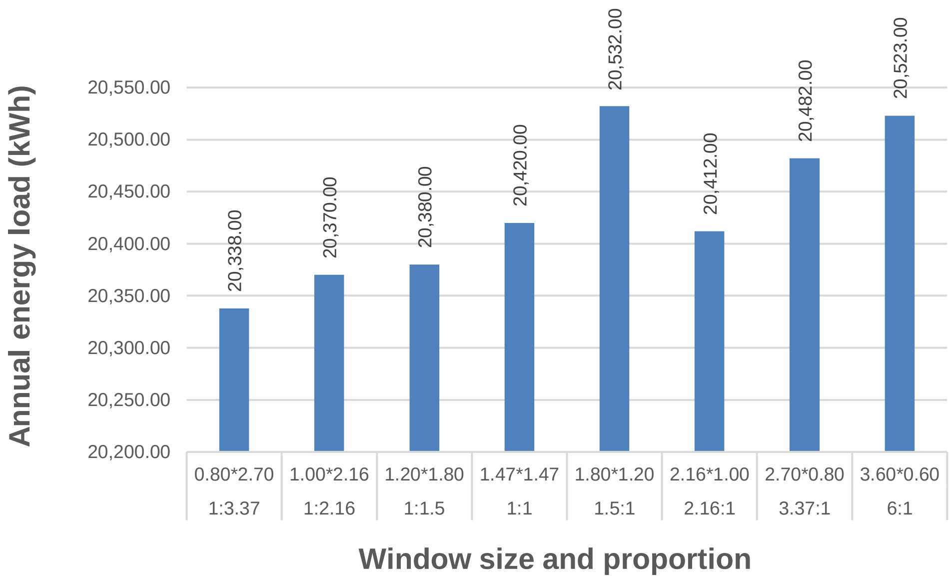

Figure 6. Annual energy load by window proportion, (Author: N. Ranđelović)

4. CONCLUSION

To analyze the impact of façade window design on thermal comfort and energy efficiency of residential buildings, the position and proportion of windows were changed in 24 scenarios, and then the energy load was analyzed for each of these scenarios. At the beginning of the research, eight scenarios were defined with different length-to-height ratios of windows, after which the position of the defined windows was changed. By changing the position of the previously defined windows, 24 scenarios were created for the research. The results of the energy simulation show that changing the position of windows does not have a significant impact on the annual energy load of family houses, but changing the proportion of length and height of windows can affect the annual energy load of the building. The load is lowest when the verticality of the windows is emphasized, with a length-to-height ratio of 1:3.37, and highest for windows with a length-to-height ratio of 1.5:1. The maximum variation in energy load per proportion is less than 1% of the total energy consumed for a year, but it is expected to increase for larger buildings. Based on the presented research, it can be concluded that windows with a vertical length-to-height ratio have lower energy load on the building, therefore their implementation is recommended in the design of family houses.

5. LIMITATION AND FURTHER RESEARCH

As this study is based on a small-scale building, the total energy load is relatively small, so the energy load variation is insignificant when it is interpreted as to cost. If the same methodology is applied to a bigger scale building, the energy load variation would be higher and this might lead to considerable cost savings. Therefore, further research is needed to assess the impact of window design on the energy load of larger buildings. Additionally, this research is limited to a case study of a building located in the city of Niš, Serbia. Changing the location would also entail changes in external influencing factors such as sun position and solar angles, consequently affecting the energy load of the building. More studies in various locations should be conducted. In addition, visual comfort is neglected in this research to consider the heating and cooling load exclusively. In a real project, visual comfort should be considered when the window is designed. The lighting load is also not considered, mainly because the required lighting load was relatively small in the initial design. However, if there are changes in the building scale or if users demand increased lighting, the lighting load should be carefully considered.

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EFFECT OF ZEOLITE AND SULPHATE SOLUTION ON REPAIR CEMENT-BASED MORTAR BARS LENGTH CHANGES

Tiana Milović[1], Mirjana Malešev[2], Vesna Bulatović[3], Ivan Lukić[4], Vlastimir Radonjanin[5]

Abstract

The durability problems in reinforced concrete structures exposed to aggressive environment, such as the soils or groundwater containing high concentration of sulphate ions, lead to damages in the structures before ending their expected service life. The application of pozzolan as supplementary cementitious material reduces the calcium hydroxide content in cement paste that could react with sodium sulphate to form gypsum, and also reduces the permeability of the hardened cement-based composite through the pore refinement. The aim of an own experimental research presented in this paper was to monitor the exposure of six types of repair cement-based mortar to sulphate ions for a period of 3 months. Portland cement was substituted with 0%, 10% and 20% natural zeolite by mass. Mortars were prepared with two water-to-binder ratios (0.5 and 0.4). The standard exposure solution that contains 352 moles of Na_2SO_4 per m^3 was used as sulphate solution. Sulphate resistance was monitored through the length change and the mass change of the mortar bars after 0, 7, 14, 21, 28, 56 and 91 days of the exposure.

Key words: *repair cement mortar, natural zeolite, ASTM C 1012, Na_2SO_4, length change, mass change*

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1. INTRODUCTION

The exposure of the reinforced concrete structures to aggressive environments, such as the soils, groundwater, rivers, seawater and industrial wastes containing high concentrations of sulphate ions [1], could lead to the deterioration of the structures before ending their expected service life. In order to restore the original condition of the damaged concrete structures, different types of repair mortars could be used, such as mortars based on inorganic binders like ordinary Portland cement (OPC). Besides the environmental benefits, a partial replacement of OPC with supplementary cementitious materials (SCMs) in repair mortars has durability advantages. The application of pozzolan as SCM reduces the calcium hydroxide content in cement paste that could react with sodium sulphate to form gypsum, and also reduces the permeability of the hardened cement-based composite through the pore refinement.

Generally, the usage of natural zeolite (NZ) as SCM in repair cement mortars increases their resistance to sulphate attack. Canpolat [2] investigated the effect of sulphate attack (5% Na_2SO_4) on the sulphate durability of mortars produced with NZ as SCM in amount of 0%, 5%, 10% and 15 %. It was found that NZ as SCM caused a significant increase in sulphate durability of mortars up to 90 days of exposure. Furthermore, in specimens with NZ, no softening, cracking or crushing was observed for the same period. For applied sulphate solution and the test period, the most effective NZ addition rate was found to be 15%.

Shon and Kim [3] evaluated the effectiveness of NZ as SCM in term of sulphate resistance. The expansion test of the mortar bars was performed in accordance with ASTM C 1012 [4]. One control mortar mixture and two different ones (with 10% and 20% NZ) were prepared with a water-to-binder ratio of 0.48. The specimens were exposed to 1 M Na_2SO_4 solution during 175 days. Control specimens had a low initial expansion, up to 28 days, and then accelerated increase occurred. At the end of exposure to sulphate solution, the mixture with 20% NZ had the lowest expansion, followed by the mixture with 10% NZ, in comparison to the referent one.

Janotka and Krajči [5] exanimated sulphate resistance of the mortars made from pozzolan cement - CEM IV/A (P) type, i.e. NZ blended cement with 60.82 mass% of Portland cement clinker, 35.09 mass% of NZ and 4.09 mass% of gypsum, and compared with results obtained for mortar prepared only with OPC as binder. Resistance tests were performed in water and 5% sodium sulphate solution (both 20°C) for 720 days. After the expiration of the exposure period, the compressive strengths of specimens were determined. It was found that the sulphate resistance of mortars containing NZ was significantly higher in comparison to reference mortar.

The aim of an own experimental research was to monitor the exposure of six types of repair cement-based mortar to sulphate ions for a period of 6 months (in this paper are presented results up to 3 months of exposure). Portland cement was substituted with 0%, 10% and 20% NZ by mass. Mortars were prepared with two water-to-binder ratios (0.5 and 0.4). The standard exposure solution that contains 352 moles of Na_2SO_4 per m^3 was used as sulphate solution. Sulphate resistance was monitored through the length change and the mass change of the mortar bars for 0, 7, 14, 21, 28, 56 and 91 days of the exposure.

2. MATERIALS AND METHODS

2.1. Component materials and mortar mixtures

In order to examine the effect of NZ as SCM on length and mass changes of the repair blended cement mortar bars, due to exposure to the sulphate solution, the following component materials were used for the repair mortars preparation:

- Ordinary Portland cement CEM I 42.5R (Lafarge-BFC Serbia),
- NZ with particle diameter size less than 125 μm, from the quarry "Igroš-Vidojevići" (Brus, Serbia),
- CEN standard sand, in accordance with EN 196-1 [6],
- Superplasticizer (HRWRA) SikaViscoCrete 3070,
- Deionized water.

True densities of PC (3.126 g/cm^3) and NZ (2.386 g/cm^3) were determined in accordance with EN 1097-7 [7], while the specific surface of PC (4188.6 cm^2/g) and NZ (8293.0 cm^2/g) were determined in accordance with the procedure specified in standard EN 196-6 [8]. The NZ activity index was determined in accordance with the standard EN 450-1 [9], and after 28 and 90 days NZ activity indexes were 93 % and 103 %, respectively.

Six different cement/cement-based repair mortars were made with 0%, 10% and 20% of NZ as SCM, by mass, and two different water-to-binder ratios (0.4 and 0.5). Composition of mortar mixtures is shown in Table 1. Superplasticizer was added as needed.

Table 1. Composition of cement-based repair mortar mixtures that contain NZ as SCM

Component material	*PCa*	*NZ10a*	*NZ20a*	*PCb*	*NZ10b*	*NZ20b*
CEM I 42.5 R (g)	*450*	*405*	*360*	*450*	*405*	*360*
NZ (g)	*-*	*45*	*90*	*-*	*45*	*90*
Standard sand (g)	*1350*	*1350*	*1350*	*1350*	*1350*	*1350*
Deionized water (g)	*225*	*225*	*225*	*180*	*180*	*180*

2.2. Methods

The expansion of cement-zeolite mortar bars immersed in a sulphate solution was determined in accordance with the procedure defined by the standard ASTM C 1012 [4], which is applied in the case of mortars made with a mixture of OPC and pozzolan. For the purposes of the above-mentioned testing, it was necessary to simultaneously make 6 specimens in the form of bars with dimensions 25mm×25mm×285mm and up to 21 cubes with edges of 50 mm per mortar mixture (in this case 3 prisms with dimensions 40mm×40mm×160mm were made instead of cubes per mortar mixture). After embedding the mortar in the molds, the molds were adequately sealed and placed in the curing tank in water at (35±3)°C for accelerated hardening of the mortar during 24h.

On the following day the molds were removed from the curing tank, and then the bars and prisms were unmolded, Figure 1.

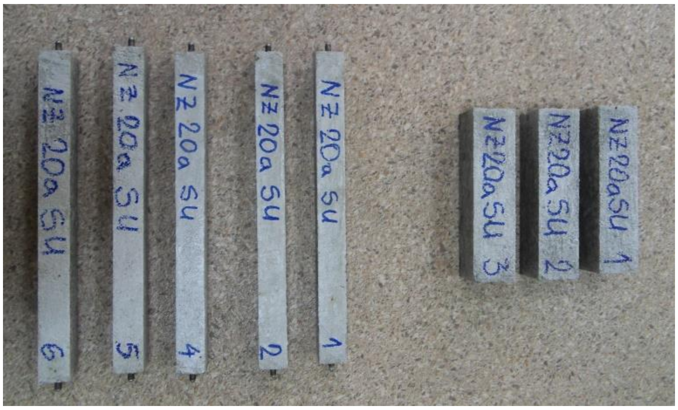

Figure 1. Unmolded NZ20a mortar bars and prisms

Six mortar bars (or less, i.e. during removal from the mold, one NZ20a and PCb mortar bar and two NZ10a mortar bars were broken) and two prisms per mixture were immediately placed for curing in a tank with saturated limewater at (23±2)°C, while one prism (in one place) was tested for compressive strength. When the obtained compressive strength was a higher than 21 MPa (the standard prisms were used instead of the 50 mm edge cubes), the other half of the prism was also tested, and the mean strength was recorded, and then the test bars were taken out of the curing tank with saturated limewater, covered with a damp cloth and left to cool to ambient temperature. When they were cooled down, the change in their length in relation to the reference rod (initial measurement) was determined, and mortar bars were transferred to the tanks with sulphate solution (352 M Na_2SO_4 per m^3 i.e. 50 g/l, Figure 2).

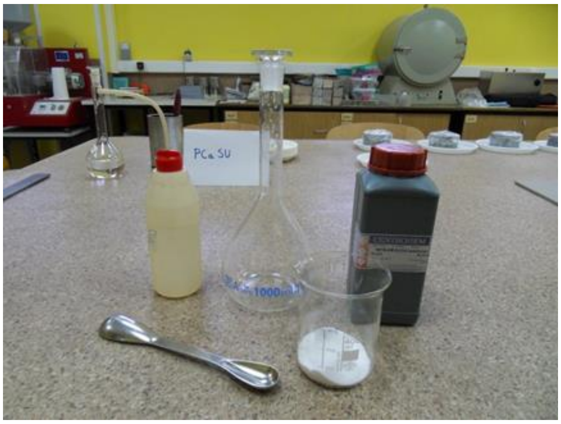

Figure 2. Preparing the sulphate solution

In case that strength of 21 MPa was not achieved, half of the prism was placed in saturated limewater and it was determined when the next test would be repeated. The tests were repeated until strength of 21 MPa was reached, and then the mortar bars were initially measured, after which they were placed in the sulphate solution.

For 1 volume of mortar bar (cca178 ml) came about 4 volumes of sulphate solution, i.e. from 625 ml to 800 ml was prescribed per one mortar bar.

The day when the mortar bars were transferred to the sulphate solution was marked as zero, and in relation to it the time was further measured, i.e. the changes in the length (Figure 3) and mass of the mortar bars exposed to the sulphate solution were followed for 0, 7, 14, 21, 28, 56 and 91 days.

Figure 3. Determination of the length change of mortar bars due to exposure to the sulphate solution

The sulphate solution was changed after the end of each measurement cycle. Meanwhile, the reference mortar bars, as well as the mortar bars containing NZ, were kept in separate tanks with sulphate solution.

3. RESULTS AND DISCUSSION

3.1. Length change of mortar bars

The results of the length change (i.e. expansion) of the cement-zeolite mortar bars subjected to sodium sulphate solution during 91 days are shown in Figure 4. Generally, during the first 28 days of exposure, there were certain oscillations in the length change of mortar bars. At 28-day, the range of expansion was from 0.007-0.013% for mortars made with a water-to-binder ratio of 0.5, and from 0.004-0.012% in the case of mortars made with a water-to-binder ratio of 0.4. After 91 days of exposure to sulphate solution, the ranges of expansion were from 0.007-0.015% and from 0.004-0.013%, for mortars made with water-to-binder ratios of 0.5 and 0.4, respectively.

With the reduction of the water-to-binder ratio from 0.5 to 0.4, there was an increase in average length change of the exposed reference cement mortar bars (by 9%), while in the case of mortars with 10% NZ and 20% NZ there was a decrease, by 27% and 11%, respectively. After 91 days of exposure, mortar with 20% NZ showed the highest decrease (by 44%) in length change with reduction of the water-to-binder ratio, followed by mortar with 10% NZ (by 42%), while reference mortar showed an increase of length change (by 7%) with reduction of water-to-binder ratio from 0.5 to 0.4.

In the case of mortar prepared with a water-to-binder ratio from 0.5, after 28 days of exposure mortar containing 10% NZ had the highest value of length change (0.013%, by 15% higher than PCa), while reference mortar and mortar with 20% NZ had lower values of length change, i.e. 0.011% and 0.007% (by 36% lower than PCa), respectively. Furthermore, at 91-day of exposure mortar with 10% NZ still had the highest length change (0.015%, by 25% higher than PCa), followed by reference mortar (0.012%), while mortar with 20% NZ had the lowest value of length change (0.007%, by 40% lower than PCa).

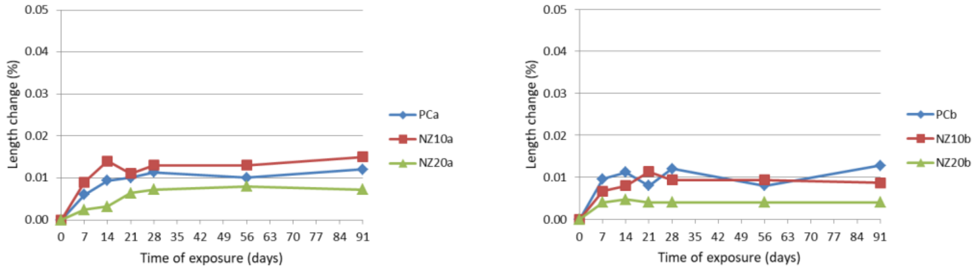

Figure 4. Length change of cement-zeolite mortar bars, made with w/b=0.5 (left) and w/b=0.4 (right), exposed to the sulphate solution

In the case of mortar prepared with a water-to-binder ratio from 0.4, after 28 and 91 days of exposure to sulphate solution reference mortar had the highest values of length change (0.012% and 0.013%), followed by mortar with 10% NZ (0.009% and 0.009%, by 22% and 32% lower than PCb), while and mortar containing 20% NZ (0.004% and 0.004%, by 67% and 69% lower than PCb) had the lowest length changes, respectively.

3.2. **Mass change of mortar bars**

The mass change of the cement-zeolite mortar bars exposed to sodium sulphate solution during 91 days are shown in Figure 5. At 28-day, the range of mass change was from 0.30-0.63 % for mortars made with a water-to-binder ratio of 0.5, and from 1.12-1.27 % in the case of mortars made with a water-to-binder ratio of 0.4, while after 91 days of exposure, the mass change ranges were from 0.79-1.11% and 1.24-1.50%, respectively.

With the reduction of the water-to-binder ratio from 0.5 to 0.4, there was a significant increase in average mass change of mortar bars during the exposure time, primarily in reference cement mortar (by 385%), and then in mortars containing 20% NZ (by 120%) and 10% NZ (by 79%), respectively. After 91 days of exposure, mortar with 20% NZ had the highest increase (by 56%) in mass change with reduction of the water-to-binder ratio, followed by reference mortar (by 55%), while mortar with 10% NZ showed the lowest increase of mass change (by 36%).

In the case of mortar prepared with a water-to-binder ratio from 0.5, after 28 days of exposure mortar containing 10% NZ had the highest value of mass change (0.63%, by 113% higher than PCa), while mortar with 20% NZ and reference mortar had lower values of mass change, i.e. 0.50% (by 70% higher than PCa) and 0.30%, respectively. Furthermore, at 91-day of exposure mortar with 10% NZ still had the highest mass change (1.11%, by 26% higher than PCa), followed by reference mortar (0.88%) and mortar with 20% NZ (0.79%, by 10% lower than PCa), respectively.

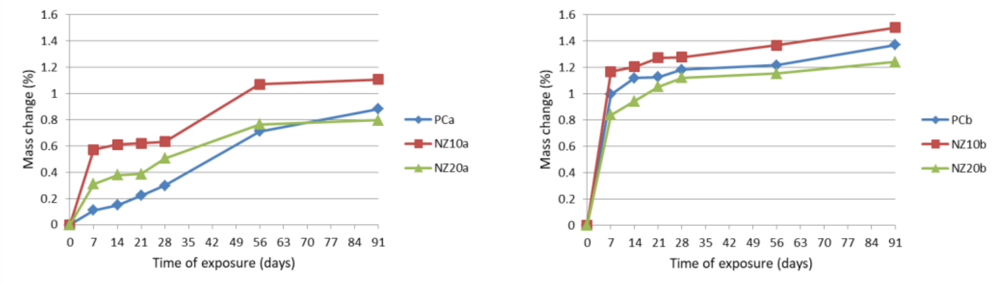

Figure 5. Mass change of cement-zeolite mortar bars, made with w/b=0.5 (left) and w/b=0.4 (right), exposed to the sulphate solution

In the case of mortar prepared with a water-to-binder ratio from 0.4, after 28 and 91 days of exposure to sulphate solution mortar with 10% NZ also had the highest values of mass change (1.27% and 1.50%, by 8% and 10% higher than PCb), while reference mortar (1.18% and 1.37%) and mortar containing 20% NZ (1.12% and 1.24%, by 5% and 9% lower than PCb) showed lower mass changes, respectively.

3.3. Visual examination of mortar bars after measuring their length and mass changes

During the 91 days of exposure to the sulphate solution, no warping of the mortar bars was observed; also there were not any cracks, nor the appearance of surface deposits, mottling or exudations, which is accordance with results published by Canpolat [2].

4. CONCLUSION

Based on the obtained experimental results, in terms of the length and mass changes of the repair cement mortar bars that contain 0%, 10% and 20% NZ as SCM, prepared with water-to-binder ratios of 0.5 and 0.4, after the 91 days of exposure to the sulphate solution, the following can be concluded:

For mortars made with water-to-binder ratios of 0.5 and 0.4, the ranges of expansion were from 0.007-0.015% and from 0.004-0.013%, respectively;

With the reduction of the water-to-binder ratio from 0.5 to 0.4, mortar with 20% NZ showed the highest decrease (by 44%) in length change, followed by mortar with 10% NZ (by 42%), while reference mortar showed an increase of length change (by 7%);

In the case of mortar prepared with a water-to-binder ratio from 0.5, mortar with 10% NZ had the highest length change (by 25% higher than reference one), followed by reference mortar, while mortar with 20% NZ had the lowest value of length change (by 40% lower than reference one);

In the case of mortar prepared with a water-to-binder ratio from 0.4, reference mortar had the highest value of length change, followed by mortar with 10% NZ (by 32% lower than reference one), while and mortar containing 20% NZ had the lowest length change (by 69% lower than reference one);

For mortars made with water-to-binder ratios of 0.5 and 0.4 the mass change ranges were from 0.79-1.11% and 1.24-1.50%, respectively;

With the reduction of the water-to-binder ratio from 0.5 to 0.4, mortar with 20% NZ had the highest increase (by 56%) in mass change, followed by reference mortar (by 55%), while mortar with 10% NZ showed the lowest increase of mass change (by 36%);

Mortar with 10% NZ had the highest mass change, while mortar with 20% NZ had the lowest mass change, regardless of the applied water-to-binder ratio (0.4 or 0.5).

Based on the presented results, it can be concluded that 20% NZ as SCM contributed the most to the reduction of the length and mass changes of repair cement mortar bars up to 91 days of exposure to sulphate solution, regardless of the applied water-to-binder ratio (0.4 or 0.5), in comparison to the reference values.

ACKNOWLEDGMENTS

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MECHANICAL AND PHYSICAL PROPERTIES OF REPAIR CEMENT MORTARS MODIFIED WITH SLAG

Tiana Milović[1], Vesna Bulatović[2], Mirjana Malešev[3], Milan Marinković[4], Anka Starčev-Ćurčin[5]

Abstract

Worldwide, the estimated costs for rehabilitation and reconstruction are staggering. In order to restore the original conditions of the damaged concrete structures, different types of repair mortars could be used, such as mortars based on organic binders or ones containing inorganic binders. In the case of repair cement mortars, replacing the part of cement with SCM material, especially the waste or by-product, has in the first place environmental benefits, but it could also have mechanical, physical and durability advantages. The objective of this work was to evaluate the mechanical and physical properties of repair cement-based mortars that contain 0%, 10%, 20% and 30% ground-granulated blast furnace slag as SCM, prepared with a water-to-binder ratio of 0.5. Applied slag was a by-product from the company Hesteel Serbia, located in Smederevo, Serbia. Following the standard EN 1504-3, compressive strength and capillary absorption of investigated mortars were determined at the age of 28 days. Additionally, flexural strength was also determined, while the unrestrained shrinkage of mortars was followed up to the same age of 28 days.

Key words: *Repair cement mortar, EN 1504-3, Ground-granulated blast furnace slag, Compressive strength, Flexural strength, Capillary absorption, Unrestrained shrinkage*

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1. INTRODUCTION

Worldwide the estimated costs for infrastructure rehabilitation and reconstruction are staggering. In order to restore the original conditions of the damaged concrete structures, different types of repair mortars could be used, such as mortars based on organic binders or ones containing inorganic binders. In the case of inorganic binder such as cement, the replacement of its part with supplementary cementitious materials (SCMs) in repair mortars has in the first place environmental benefits, especially when the wastes or by-products are used as SCM, but it could also have mechanical, physical and durability advantages.

Ground-granulated blast furnace slag (SL) represents a waste material from iron and steel production, and therefore, it is considered the one of the green construction materials. Due to its chemical and physical properties, SL is commonly used as a partial replacement of ordinary Portland cement (OPC) in mortar or concrete production, i.e. as type II addition in accordance with standard EN 206 [1]. Hammat et al. [2] examined the compressive strength, total and autogenous shrinkage and capillary water absorption of self-compacting mortars containing SL. A total of seven mortar mixes were prepared. The control mix had a proportion of 1 (cement): 1.8 (sand): 0.38 (water). In the other mixes, the cement was partially replaced with 15% and 30% SL of three different finenesses (3500 cm^2/g, 4200 cm^2/g and 5000 cm^2/g). Incorporating SL, compressive strength of mortars was reduced at early age, while the long-term compressive strength of mortars containing SL was higher than that of control mortar. At later ages, mortars with higher SL fineness had higher compressive strengths for substitution of 15%. However, for 30% replacement, the compressive strengths of mortars were similar regardless of the SL fineness. The results showed a reduction in the total shrinkage and an increase in the autogenous shrinkage of mortars as the content and fineness of SL increased. It was also observed that the amount of absorbed water (initial and final absorption) decreased with the increase in SL content, regardless of the SL fineness. Furthermore, the results indicated a lower sorptivity of SL mortars compared to that of the control. Islam et al. [3] investigated the effects of SL on strength development of mortar. Cement was partially replaced with six different percentages (up to 60%) of SL by weight. OPC mortar was prepared as reference mortar. Compressive as well as tensile strength of the mortar specimens were determined at curing age of 3, 7, 14, 28, 60, 90 and 180 days. Test results showed that strength increased with the increase of SL up to an optimum value, beyond which, strength values started to decrease with further addition. The optimum amount of OPC replacement with SL in mortar was around 40%, and that provided 22% higher compressive and 23% higher tensile strength compared to OPC mortar, after 180 days of curing.

The aim of the research presented in this paper was to evaluate the mechanical and physical properties of repair cement-based mortars that contain 0%, 10%, 20% and 30% SL as SCM, prepared with a water-to-binder ratio of 0.5. Applied slag was a by-product from the company Hesteel Serbia, located in Smederevo, Serbia. Following the performance requirements given in the standard EN 1504-3 [4], 28-day compressive strength and capillary absorption of the tested mortars, were determined in accordance with standards EN 12190 [5] and EN 13412 [6], respectively. Additionally, flexural strength was also determined, while the unrestrained shrinkage of mortars was followed up to the same age of 28 days.

2. MATERIALS AND METHODS

2.1. Component materials and mortar mixtures

In order to examine the effect of SL as SCM on compressive strength, capillary water absorption of the repair blended cement mortars as well as flexural strength and unrestrained shrinkage, the following component materials were used for the repair mortars preparation:

Ordinary Portland cement CEM I 42.5R (Lafarge-BFC Serbia),

- SL, sieved (through a sieve opening 125 μm) and additionally ground, from the company Hesteel Serbia, located in Smederevo, Serbia,
- CEN standard sand, in accordance with EN 196-1 [7],
- Deionized water.

True densities of OPC (3.126 g/cm^3) and SL (2.766 g/cm^3) were determined in accordance with EN 1097-7 [8] while the specific surface of OPC (4188.6 cm^2/g) and SL (5855.3 cm^2/g) were determined in accordance with the procedure specified in standard EN 196-6 [9]. The SL activity index was determined in accordance with the standard EN 15167-1 [10], and after 7 and 28 days SL activity indexes were 74% and 87%, respectively.

Four different cement/cement-based potential repair mortars were made with 0%, 10%, 20% and 30% of SL as SCM, by mass, to determine their compressive strength, flexural strength, capillary water absorption and unrestrained shrinkage. Mortar mixtures were prepared with a water-to-binder ratio of 0.5 according to EN 12190 [5]. Composition of mortar mixtures is shown in Table 1.

Table 1. Composition of cement-based repair mortar mixtures that contain SL as SCM

Component material	*PC*	*SL10*	*SL20*	*SL30*
CEM I 42.5 R (g)	*450*	*405*	*360*	*315*
SL (g)	*-*	*45*	*90*	*135*
Standard sand (g)	*1350*	*1350*	*1350*	*1350*
Deionized water (g)	*225*	*225*	*225*	*225*

2.2. Methods

2.2.1. Flexural strength

The flexural strength of the mortars was determined according to the standard EN 196-1 [7] using prism-shaped for specimens with dimension of 40 mm × 40 mm × 160 mm, at the age of 28 days, after recommended curing resume (covered in film for 24 h, demoulded after 24 h and cured under water at (21 ± 2)°C for 27 days). The mean strength values were obtained by testing the three prisms per mortar mixture. The load at failure was determined using the Michaelis scales.

2.2.2. Compressive strength

The compressive strength of the mortars was determined according to the standard EN 12190 [5] on the halves of the prisms remained from flexural strength testing, at the age of 28 days. The mean strength values were obtained by testing the six prism halves per mortar mixture. The load at failure was determined using a hydraulic press with a capacity of 150 kN.

2.2.3. Capillary water absorption

Capillary water absorption of mortars was determined according to the standard EN 13057 [6] on discs with a diameter of 100 mm and height of 25 mm, at the age of 28 days, after recommended curing resume and conditioning. After preparing mortar mixtures and embedding in moulds, they were covered in film for 24 h, demoulded after 24 h and cured under water at (21 ± 2)°C for 27 days. At the end of required curing period, the specimens were dried in the oven for a minimum of seven days at (40 ± 2)°C, and conditioned for 24 h under the standard laboratory climate, at (21 ± 2)°C and (60 ± 10)% RH.

During the examination, the specimens were placed in separate shallow flat-bottomed trays on knife-edge supports to achieve a depth of water immersion of (2.0 ± 1.0) mm, as it is shown in Figure 1. The mass of the specimens was measured immediately before their exposure to the deionized water, as well as after 12', 30', 1h, 2h, 4h and 24h from the beginning of the test. Between measurements, the trays were covered with a lid, and after each specimen weight measurement, the water level was checked and corrected if it was necessary.

Figure 1. Determination of mortar capillary water absorption

2.2.4. Unrestrained shrinkage

Unrestrained shrinkage of the reference and SL blended cement mortars was determined in accordance with the method described in EN 12617-4: Chapter 6 [11]. The standard mortar prisms were used for this purpose. After demoulding, the specimens were stored in a climate chamber at a temperature of (21 ± 2) °C and (60 ± 10) % RH, as it is shown in Figure 2. Unrestrained shrinkage of specimens was measured after 1, 3, 7, 14, 21 and 28 days from demoulding.

Figure 2. Mortar specimens in standard drying climate

3. RESULTS AND DISCUSSION

3.1. Compressive strength

The 28-day compressive strengths of mortars containing SL as SCM, prepared with a water-to-binder ratio of 0.5, are shown in Figure 3.

Based on the obtained results at the age of 28 days, the mortars made with SL as SCM fulfilled the requirement for class R4 of structural repair mortars according to the standard EN 1504-3 [4] in terms of compressive strength [5] i.e. their mean compressive strength values were higher than 45 MPa.

The range of compressive strength was from 50.16-52.92 MPa. It can be seen that mortar containing 20% SL as SCM had the highest compressive strength, i.e. 5.5% higher in comparison to the reference one. Mortars with 10% and 30% had strengths at the same level as the reference cement mortar. Considering that the differences in compressive strength of cement-slag mortars were less than 10% compared to reference cement mortar, it can be concluded that the level of substitution of OPC with SL up to 30% did not have a significant impact on the 28-day compressive strength of blended cement mortars made with the water-to-binder ratio of 0.5.

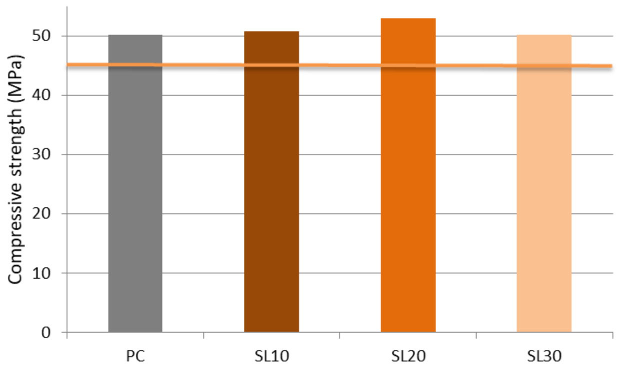

Figure 3. 28-day compressive strength of tested mortars

3.2. Flexural strength

The 28-day flexural strengths of mortars containing SL as SCM, prepared with a water-to-binder ratio of 0.5, are shown in Figure 4.

The range of flexural strength was from 9.01-9.77 MPa. As in the case of compressive strength, mortar containing 20% SL as SCM had the highest flexural strength. Mortar with 10% SL had lower flexural strength by 5.5% in comparison to the reference mortar, while mortars with 20% and 30% had higher strength by 2.4% and 1.1%, respectively. Since the differences were less than 10% compared to reference cement mortar, it can be concluded that the level of substitution of OPC with SL up to 30% did not have a significant impact on the 28-day flexural strength of blended cement mortars made with the water-to-binder ratio of 0.5.

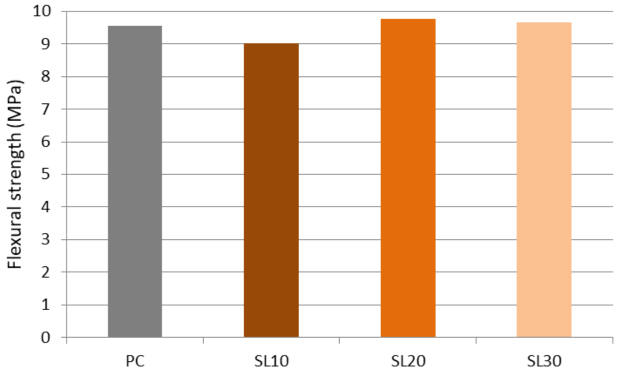

Figure 4. 28-day flexural strength of tested mortars

3.3. **Capillary water absorption**

The kinetics of capillary water absorption of the 28-day age mortars containing SL as SCM, prepared with a water-to-binder ratio of 0.5, are shown in Figure 5. Based on the shape of the presented diagrams, it can be concluded that the kinetic of the absorption was influenced by the level of OPC substitution with SL.

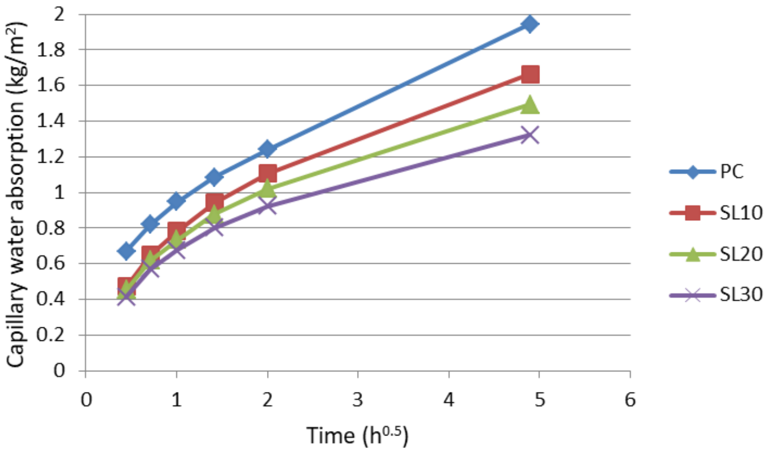

Figure 5. Capillary water absorption of 28-day age mortars

The mean value of capillary absorption (after 24h of exposure) of reference mortar PC was 1.944 kg/m^2, for mortars containing up to 30% SL it was in the range of 1.324 - 1.662 kg/m^2. Reference mortar PC had the highest capillary absorption of water, while the capillary absorption of water decreased with an increase in the proportion of SL. In comparison to the capillary water absorption of the reference PC mortar, measured after 24 hours from the beginning of the test, the relative values of the capillary water absorptions of the 28-day old mortars SL10, SL20 and SL30 were lower by 14.48%, 23.24% and 31.90%, respectively.

Based on the 28-day sorption coefficient of tested mortars, shown in Table 2, all mortars containing SL as SCM met the criteria for class R4 structural repair mortar, i.e. their sorption coefficients at the age of 28 days were ≤ 0.5 kg/(m^{2}h$^{0.5}$).

Table 2. Sorption coefficient of tested blended cement mortars

Mortar type	*Sorption coefficient (kg/(m²h⁰·⁵))*	*Resulting line*
PC	*0.2728*	*Linear*
SL10	*0.3393*	*Non-linear*
SL20	*0.3046*	*Non-linear*
SL30	*0.2702*	*Non-linear*

3.4. Unrestrained shrinkage

The effect of SL on unrestrained shrinkage dilatations of blended cement mortars was followed up to the age of 28 days. The obtained results are presented in Figure 6. As it can be seen, the application of SL as a SCM in blended cement mortars led to a decrease in unrestrained shrinkage. At the age of 7 days, the highest value of unrestrained shrinkage had mortar SL10, for 38% higher than referent value, while mortars SL20 and SL30 had lower unrestrained shrinkage by 8% and 31% in comparison to the referent one, respectively. At the age of 28 days, the unrestrained shrinkage of SL10 was slightly lower (by 8%) than that of the reference mortar, while in the case of SL20 and SL30, shrinkage was lower by 16% and 34%, respectively.

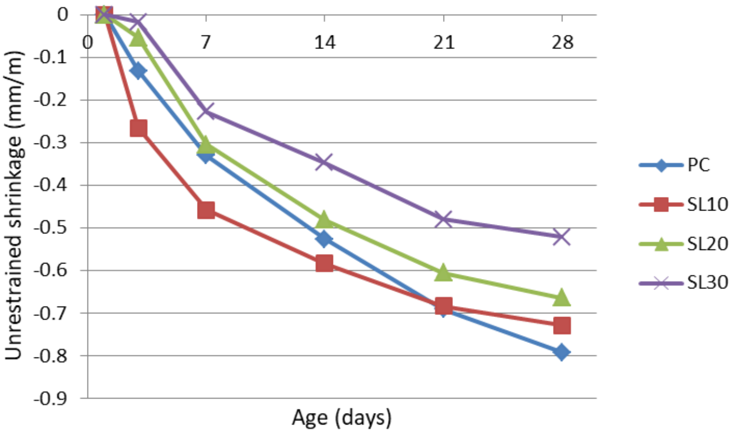

Figure 6. Unrestrained shrinkage of blended cement mortars up to the age of 28 days

Based on the presented results, it can be concluded that mortar with 10% SL as SCM had 28-day unrestrained shrinkage value in the range of referent mortar, while the substitution of OPC with 20-30% SL had a significant effect on decreasing the unrestrained shrinkage.

4. CONCLUSION

Based on the obtained experimental results, in terms of the compressive strength, flexural strength, capillary absorption and unrestrained shrinkage of the repair cement mortars that contain 0%, 10%, 20% and 30% SL as SCM, prepared with water-to-binder ratio of 0.5, the following can be concluded:

Mortars containing up to 30% SL as SCM fulfilled the requirement for class R4 of structural repair mortars according to the standard EN 1504-3:2005 in terms of compressive strength and capillary absorption;

Level of substitution of OPC with SL up to 30% did not have a significant impact on the 28-day compressive and flexural strengths of blended cement mortars compared to reference cement mortar;

Reference mortar had the highest capillary absorption, while with an increase in the proportion of SL as SCM up to 30% the capillary absorption of water decreased;

Mortar with 10% SL as SCM had 28-day unrestrained shrinkage value in the range of referent mortar, while the substitution of OPC with 20-30% SL had a significant effect on decreasing the unrestrained shrinkage, i.e. shrinkage was lower by 16% and 34%, respectively.

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EVALUATION WITHIN ARCHITECTURAL COMPETITIONS IN BELGRADE: CO_2 FOOTPRINT ISSUE

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Abstract

The issue of aligning new architectural structures with sustainable development is currently a very relevant topic. A smaller CO_2 footprint is sought as one of the conditions for architectural competitions in Belgrade, Serbia, which were first implemented with this requirement in 2022. However, based on the selected works, it can be concluded that this requirement was only sought to satisfy current recommendations. Therefore, the awarded designs were analysed in terms of their CO_2 footprint and ranked according to their compliance with this requirement. The synthesis of the research proves the initial hypothesis that the awarded solutions are only loosely connected with this principle, and suggests a more serious implementation of this principle for evaluating competition entries.

Key words: *CO_2 footprint, architectural competitions*

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1. INTRODUCTION

Architectural competitions play a pivotal role in driving innovation, fostering creativity, and pushing the boundaries of design. They provide a platform for architects and designers to showcase their visionary concepts, tackle complex challenges, and address critical issues like sustainability, spatial efficiency, and community engagement. These competitions not only promote healthy competition but also contribute to the evolution of the architectural discourse, leading to the realisation of groundbreaking ideas that shape the future of our built environment.

The carbon footprint of buildings plays a significant role in global greenhouse gas emissions. In response, there has been a growing focus on sustainable architectural design practices aimed at reducing the carbon footprint of buildings. The importance of energy efficiency has also seen a notable increase in recent years, with the community, regulatory bodies, and various industries recognizing its significance [1]. The carbon footprint has emerged as a crucial metric for estimating greenhouse gas (GHG) levels [2]. Governments and policymakers across the globe have recognized the need to address global warming and have been actively implementing initiatives to mitigate GHG emissions.

With the increasing global demand for energy, there has been a corresponding rise in environmental difficulties and challenges related to energy supply. Consequently, the focus has shifted towards the primary objective of constructing energy-efficient buildings in today's world. The key objectives of energy-efficient buildings include minimizing energy consumption and reducing environmental impact. The utilization of fossil fuels has been identified as a major contributor to severe environmental issues. Notably, the emission of greenhouse gases resulting from the combustion of fossil fuels is one of the primary concerns. It is evident that promoting energy use, development, or transportation without significant environmental consequences is a formidable task. Moreover, a substantial portion of a community's ecological footprint is directly associated with its energy resource utilization. Ideally, a society aspiring for economic progress should exclusively rely on energy resources that have no adverse environmental effects, including the absence of greenhouse gas emissions [3].

Modern buildings and settlements face increasing expectations for higher levels of performance. They should embody sustainability, zero-net energy usage, provide a healthy and comfortable environment, be grid-friendly, and remain cost-effective. The European Union (EU) has set ambitious goals in its 2030 Framework for climate and energy [4], surpassing the 2020 targets. These goals include a 40% reduction in greenhouse gas emissions compared to 1990 levels, a minimum 27% share of renewable energy consumption, and at least 27% energy savings compared to the business-as-usual scenario. The EU has even more ambitious targets for 2050, aiming for an 80% reduction in domestic greenhouse gas emissions compared to 1990 levels, as outlined in the 2050 Roadmap [2]. The EU also has climate change adaptation targets defined in its strategy, which aims to enhance preparedness for current and future climate impacts [5]. The EU building stock contributes significantly to energy consumption (40%) and greenhouse gas emissions (36%). While renovating existing buildings holds potential, there are limitations hindering their achievement of high performance. On the other hand, more than a quarter of the buildings that will exist in 2050 are yet to be constructed. To meet the EU's ambitious targets, the energy consumption and greenhouse gas emissions of these new buildings must approach zero [6].

In light of the ongoing challenges posed by climate change and resource scarcity, the construction industry recognizes the pressing need for sustainable solutions. As such, it is actively engaged in exploring and adopting more environmentally friendly practices and materials. The primary objective of this shift is to mitigate the negative environmental impacts of material production, increase the longevity of structures, and reduce resource consumption. To achieve these goals, researchers, industry professionals, and policymakers are joining forces to create and advocate for innovative technologies, materials, and strategies that can significantly decrease carbon emissions, energy usage, and waste generation within the construction sector [7].

The report titled "Global Energy Sector 2050 Net-Zero Emission Pathway" by the International Energy Agency (IEA) emphasizes that the majority of countries have established net-zero emission targets in alignment with the global trend. Net zero is recognized as a promising avenue for future economic growth. Currently, 137 countries or regions have made commitments to achieving net-zero emissions, which collectively account for 88% of global greenhouse gas emissions [8]. Given that the building sector is a significant consumer of energy and the second-largest emitter of greenhouse gases globally, accounting for 16% of emissions, there is a crucial opportunity for substantial impact [9]. If buildings can successfully achieve net-zero emissions, they have the potential to make the most significant contribution to reducing global greenhouse gas emissions, surpassing the industrial and transportation sectors [10]. The potential reduction from buildings alone amounts to 25% of global greenhouse gas emissions [11].

Numerous studies have made significant contributions to the advancement of sustainable building practices and principles [12]. Most reviews have focused on green building [13], LCA for building rehabilitation [14,15], the carbon emissions of buildings [16], holistic sustainability assessments [17] and sustainability rating tools [16–20].

In 2015, the Government of the Republic of Serbia submitted its Intended National Determined Contributions (INDCs), defining a 9.8% greenhouse gas emissions reduction by 2030 compared to base year emissions (1990) [21]. The Republic of Serbia has signed the Stabilisation and Association Agreement with the European Union in 2012. Thus, the country has committed to aligning its legislation on climate change to the EU acquis that will significantly contribute to the greenhouse gas emission reduction [22]. In line with the given objective, the Republic of Serbia has incorporated the significance of CO_2 footprint into the announcements of public architectural competitions over the past few years. Although the ecological concept represents one of the criteria for evaluating competition entries, the awarded projects do not demonstrate a serious application of sustainable construction principles. Instead of a substantial commitment to nature preservation, the competition entries mostly refer to alternative energy sources without a strong connection between design and sustainability principles. As known to the authors of this scientific paper, the topic of CO_2 footprint in Serbia is not represented in the literature. Certainly, the analysis of competitions is not presented in the aforementioned context, which contributes to the originality of this work. The need for improving the evaluation of competition entries arises from the observation that the competition practice in Serbia, in recent times, considers sustainability ideas at a very low level, which only satisfies the formal requirement of including an ecological preservation condition in the competition programs.

Evaluating architectural projects in competitions is a highly significant topic that has yet to find its rightful place within architectural discourse. Evaluation is undeniably comprehensive, with intricate interconnections among criteria. Conversely, participants' approaches in competitions vary widely. The theme of achieving a zero CO_2 emission, as part of sustainability, is multifaceted and necessitates a holistic consideration within other elements. Taking the example of a competition in Belgrade, the jury prioritized contextual integration and flexibility as the foundation and direction for overall sustainability. However, within the same competition for the Faculty of Applied Arts in Belgrade, the CO_2 footprint issue was insufficiently addressed with seriousness.

2. METHODOLOGY AND MATERIALS

The subject of this research is an open public one-stage architectural competition for the preliminary design of the new building of the Faculty of Applied Arts in Belgrade. It was conducted in 2022 and represents the only competition institution that publicly disclosed all submitted entries. This paper analyses all the entries within the CO_2 theme. In the second phase, the ecological concept within the awarded projects is analysed. The fundamental assumption at the beginning of the research is that the mentioned sustainability ideas were approached in a formal manner, without a real connection between architectural design and the need to minimize negative impact on the environment. The synthesis of the research findings is used to document the current competition practice in architecture in Serbia, as well as to form assumptions for improving this institution.

The competition for the new building of the Faculty of Applied Arts in Belgrade was announced based on the need to enhance the capacity of university education, which was emphasized within the project "Improvement and strengthening of university education capacity." [23,24]. The competition organiser is the Government of the Republic of Serbia, Ministry of Education, Science and Technological Development. The competition is supported by the United Nations Development Programme. The competition is implemented by the Union of Architects of Serbia [25]. The jury consisted of the following members: Professor Emeritus Branislav Mitrovic (Chairman), Prof. Aleksandar Vuja, Prof. Marusa Zorec, Marko Stojcic (Chief Urban Planner of the City of Belgrade), and Prof. Goran Cpajak (representative of the Faculty of Applied Arts). A total of 25 anonymous entries were submitted through the website portal https://konkurs-fpu.rs. According to the competition announcement, the jury evaluated the entries based on the following criteria: spatial concept and architectural expression, functional solution, compliance with spatial requirements outlined in the program brief, sustainability, energy efficiency, and potential for further project implementation. Within the third criterion, the following aspects were considered:

- How the characteristics of proposed solution relate to environmental and social sustainability and its compliance with the goals of sustainable development.
- How the building design relates to energy efficiency and efficient operations during operation. In which way it deals with the goals of sustainable development.

- Cost-effectiveness of the solution in building and

exploitation, application of sustainable solution in terms of environment and energy for the purpose of preserving and improving environmental quality (eco-design implementation).

In the competition announcement [26], among other things, it is stated that besides achieving a high standard in terms of microclimatic conditions, facility maintenance with minimal CO_2 footprint from construction and use of the facility, the following objectives need to be achieved:

- Unity of architectural and energy concept of the facility, as well as rationality of the proposed structural system, construction, and operational costs of the facility.
- Enhancing the quality of social life for students, teachers, and researchers within the facility and its immediate surroundings.
- Connectivity with the immediate environment.
- Adequate design of open and green spaces.

It is also mentioned that the accompanying document with textual explanations should include, among other things:

- Description of the construction materials used, considering the CO_2 footprint.
- Environmental concept.

After several meetings, the jury awarded three prizes and three honourable mentions. The jury's rationale was published in the edition titled "The Faculty of Applied Arts in Belgrade: Open Public One-Stage Architectural Competition for the Preliminary Design of the New Building of the Faculty of Applied Arts in Belgrade" in June 2022 (without a catalogue record) [27].

The evaluation of the assessment was conducted in two phases. In the first, all submissions were evaluated based on their connection to the CO2 footprint. In the second, only the awarded submissions were linked to meeting the requirement of designing a new structure in relation to the CO2 footprint. The assessment was carried out in both phases as follows: if the competition entry in any way relates to a specific criterion under consideration (e.g. CO2 footprint, Ecological concept, etc.), it is rated as "yes". If it does not mention the specific criterion at all, the competition entry receives a "/" mark. In the final column (Fulfillment of Conditions), the implementation of the observed categories is considered. They are rated as "yes" and "/". If the conditions are applied only to fulfill predefined assessment criteria, and the solution is not connected to the CO2 footprint theme, such a submission is evaluated as "formal". This indicates that while the formal conditions are met, the submission isn't actually linked to this theme. In this manner, this study highlights some severe issues regarding construction principles commonly used in our local practice, especially the absence of ecological and sustainability demands in new construction. The comparative analysis of the competition proposals provides clear perspectives on these issues.

3. RESULTS

Without questioning the jury's work, Table 1 indicates whether the competition entries mention CO_2 footprint, describe the applied construction materials considering the CO_2 footprint, and describe the ecological concept of the facility. The last column provides an assessment of the formal or actual fulfilment of these criteria. These results were obtained through an analysis of the mandatory competition submission, referred to as the document with textual explanations and graphic presentations [26].

Table 1. Overview of Entries in Relation to CO2 Footprint

	Codes of Competition Entries	*CO_2 footprint*	*Description of Materials*	*Ecological Concept*	*Fulfilment of Conditions*
01	*AA10611*	*/*	*/*	*/*	*/*
02	*AA11235*	*Yes*	*/*	*Yes*	*Formal*
03	*AA26292*	*/*	*/*	*Yes*	*/*
04	*AD22022*	*Yes*	*Yes*	*Yes*	*Yes*
05	*AP91677*	*/*	*/*	*/*	*/*
06	*AR50122*	*Yes*	*v*	*Yes*	*Yes*
07	*AS20046*	*Yes*	*/*	*Yes*	*Formal*
08	*BE21198*	*/*	*/*	*Yes*	*/*
09	*BO00392*	*/*	*Yes*	*Yes*	*/*
10	*BR01022*	*Yes*	*Yes*	*Yes*	*Yes*
11	*DA00011*	*/*	*/*	*Yes*	*/*
12	*ET11333*	*/*	*/*	*Yes*	*/*
13	*FT56398*	*Yes*	*Yes*	*Yes*	*Yes*
14	*JM58008*	*/*	*/*	*/*	*/*
15	*MB31061*	*Yes*	*Yes*	*Yes*	*/*
16	*MP55672*	*/*	*/*	*Yes*	*/*
17	*RA20022*	*/*	*/*	*/*	*/*
18	*RL01201*	*Yes*	*Yes*	*Yes*	*v*
19	*SK23756*	*/*	*/*	*Yes*	*/*
20	*VS67810*	*/*	*/*	*Yes*	*/*
21	*XX00502*	*/*	*/*	*Yes*	*/*
22	*II00100*	*Yes*	*Yes*	*Yes*	*Yes*
23	*IP20202*	*/*	*/*	*Yes*	*/*
24	*MK11216*	*Yes*	*Yes*	*Yes*	*Yes*
25	*MK94988*	*/*	*/*	*/*	*/*

Table 2 presents the results obtained from the analysis of the jury reports, which are displayed for the awarded and honoured entries in the competition catalogue [28]. According to the competition guidelines, the competition entries were evaluated based on the following categories:

- Spatial concept and architectural expression,
- Functional solution, fulfilment of spatial requirements stipulated in the programme assignment,
- Sustainability, Energy Efficiency and
- Potential for further project implementation.

Each of these categories contains several subcategories. Within the third category, six subcategories are mentioned, as mentioned in the previous section. According to the jury's decision, the first prize was awarded to entry number 12 (ET11333). This is followed by the second prize for entry number 07 (AS20046), and the third prize for entry number 02 (AA11235). Three equal mentions were given to entries with codes number 05 (AP91677), number 08 (BE21198), and number 21 (XX00502). The jury's justifications for each of the awarded and honoured entries are published in the catalogue. As individual scores are not presented according to the evaluation criteria, an overview of this group of entries can be derived from the analysis of the justifications.

Table 2. Overview of Awarded Entries (CO2 Footprint in the Jury's Justifications)

	Awards	*Codes of Competition Entries*	*CO_2 footprint*
02	*3. Award*	*AA11235*	*/*
05	*Redemption Award*	*AP91677*	*/*
07	*2. Award*	*AS20046*	*/*
08	*Redemption Award*	*BE21198*	*/*
12	*1. Award*	*ET11333*	*/*
21	*Redemption Award*	*XX00502*	*/*

4. DISCUSSION

The presented findings clearly indicate that the consideration of the CO^2 footprint, despite being one of the evaluation categories for the competition entries, is not being taken seriously. Among the 25 competition entries, a significant portion of 15 entries completely omit any mention of the term "CO_2 footprint" in their justifications. Moreover, 18 of these entries lack a realistic connection to the concept of sustainability. Surprisingly, the jury's justifications also do not incorporate any reference to the CO_2 footprint. Based on our analysis, it can be inferred that the second and third prize-winning entries superficially incorporate the sustainability concept, while the first prize-winning entry completely disregards it.

Consequently, it can be concluded that the jury prioritized architectural expression in terms of function, organization, and design, rather than sustainable construction principles. The evaluated entries successfully explored the relationship between the educational institution and the city, which was their main contribution. The primary merit of the first prize-winning entry lies in its ability to seamlessly integrate the new faculty building into a complex urban location. Additionally, this solution offers flexibility in the utilization of working and public spaces. The jury also noted that this entry creates a stimulating atmosphere for the creative processes of its users.

Regarding the second and third prize-winning entries, the jury highly valued the spatial organization model, which was accompanied by a logical arrangement of the school's public spaces. The diverse and layered dialogue between the new building and its surroundings was also of great importance in their evaluation. As for the honored entries, various aspects were appreciated, including the analysis of the broader urban context, the utilization of a rooftop terrace and inner courtyard, the connection between the inner courtyard and the street, and the respect for the existing urban structure, among other factors.

While we acknowledge and support the jury's decision within their respective categories, we are concerned that the awarded solutions failed to adequately address the requirement of reducing the CO_2 footprint. This reinforces our initial assumption that the association of the CO_2 footprint concept with the awarded solutions was superficial at best. This situation raises questions about the credibility of the competition awards, as they do not align with the predetermined criteria.

It can be inferred that the jury consciously overlooked the principles of sustainable construction in their evaluation of the competition entries. Our analysis indicates that only a small number of solutions (approximately 7) genuinely incorporated sustainable construction principles and offered strategies to reduce the CO_2 footprint. This suggests that participants in the competition were not entirely unaware of this category. However, these solutions may have been compromised during the evaluation process due to a misalignment with the judging criteria. It appears that focusing solely on architectural form without considering the environmental impact of construction is the easier path to take.

Endorsing solutions that completely neglect the topic of sustainability raises significant concerns, as it sends a message to the professional community that environmental protection has not yet found its rightful place in current construction practices. In contrast, the existing literature emphasizes the importance of sustainability, placing it above architectural form and spatial organization. The principle of sustainability encompasses construction techniques, technologies, and the use of materials that minimize the CO_2 footprint.

Similar to our study, Sizirice et al. believe that construction is among the leading industries/activities contributing the largest carbon footprint. According to these authors, the application of alternative additives/materials or techniques/systems can reduce up to 90% of CO_2 emissions at different stages in construction and building operations. They advocate that their research promotes consciousness of the environmental impacts of fabrication, transportation, and operation [28].

Huang et al. propose that the consumption of a substantial quantity of non-renewable energy leads to significant CO_2 emissions. In order to address this issue, they highlight three key opportunities for reducing carbon emissions in the construction sector:

- Promotion of Low Embodied Carbon Building Materials and Services,
- Enhancing Energy Efficiency of Construction Machines and
- Increasing Renewable Energy Adoption.

In summary, the authors emphasize that by promoting the adoption of low embodied carbon building materials and services, enhancing the energy efficiency of construction machinery, and increasing the use of renewable energy, the construction sector can seize three pivotal opportunities to effectively reduce its carbon emissions [29].

Harvey introduced this significant topic over 10 years ago through his comprehensive handbook on low-energy buildings and district-energy systems, covering a wide range of topics and including exemplary buildings and techniques from around the world [30]. However, based on this research, it can be concluded that this subject is still insufficiently addressed among architects and requires further promotion.

5. CONCLUSION

Architectural competitions hold a crucial role in promoting and advancing sustainable construction practices. We endorse the inclusion of criteria that evaluate the reduction of CO_2 footprint in new construction projects. However, it is essential for the jury to approach this issue with greater seriousness to ensure that the awarded projects truly reflect sustainable construction ideas.

Based on the analysis of the competition entries, it is evident that architects are combining the field of energy-efficient buildings with efforts to reduce CO_2 emissions. However, their overall interest in sustainable construction principles appears to be limited. We understand that the influence of private investors can present challenges in achieving sustainability goals. Nonetheless, when the state is involved, particularly in the construction of facilities for the education of young people through public competitions, it becomes of utmost importance to prioritize construction principles that minimize environmental impact.

In such cases, where public interests and educational purposes are at stake, the integration of sustainable construction practices should be a significant consideration. By doing so, we can set a positive example for future projects and demonstrate a genuine commitment to environmental preservation and the well-being of future generations.

The topic of CO2 footprint should be seriously incorporated within architectural design, particularly in the context of architectural competitions. Hence, this criterion should be studied as part of the broader theme of sustainable construction, allowing future generations to utilize it as a prerequisite for building.

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ADAPTIVE REUSE AS AN APPROACH TO THE BUILT HERITAGE PROTECTION IN THE CONTEXT OF NOVI SAD

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Abstract

As challenges arise regarding the protection of the built heritage, it is crucial to explore new approaches to its preservation in the context of architecture, conservation, and the economy. Such an approach is adaptive reuse. Adaptive reuse as a concept involves repurposing buildings for new uses while preserving their historic and architectural significance. The approach is gaining importance in the current era of sustainability and mass production of architecture. This paper presents the benefits and challenges associated with adaptive reuse, including important social, economic, and environmental topics. The study highlights the importance of community involvement, stakeholder engagement, and policy frameworks in implementing adaptive reuse projects, both at the global and local level. The paper also highlights the specific challenges faced in project development in a specific sociocultural environment, that is of the Vojvodina province of Serbia and its capital city of Novi Sad, in which the researchers are currently developing their own adaptive reuse projects. Amongst other important topics, the paper discusses possible project phases and criteria for choosing sites for project implementation. Furthermore, the study explores the cultural and economic dimension of the approach, highlighting the potential impact on the local communities, both in urban and rural regions, as well as the economic possibilities that built heritage can provide in the context of present-day industries and services. Overall, this paper explores the concept of adaptive reuse in built heritage protection, from the viewpoints of culture, architecture, economy, and politics. It advocates for its use as a sustainable alternative to demolition and new construction. The paper concludes with recommendations for future practice and research in the field of adaptive reuse.

Key words: *Adaptive Reuse, Cultural heritage, Architecture, Built heritage, Novi Sad*

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1. INTRODUCTION

The Autonomous Province of Vojvodina is a region of the Republic of Serbia, situated in the northern part of the country, within the Pannonian basin. The province borders the eastern, western and southern parts of the country, as well as the capital city of Belgrade. Through national borders Vojvodina neighbors, the countries of Bosnia and Herzegovina, Croatia, Hungary and Romania, in the east, north and the west respectively. Roughly 1.7 million people live in Vojvodina, which makes up to 26% of the country's total population. Vojvodina of today is a unique multi-cultural entity, with more than 26 ethnic groups and 6 official languages. Novi Sad, as the capital of Vojvodina, represents the melting pot of the region's social, historical and cultural aspects, while providing a rich landscape of cultural heritage sites with potential for adaptive reuse.

As a result of overlaying of different cultures, religions and politics the region has seen a development of a unique architectural language. This language can be read through different typologies, such as: the provincial baroque church, the Salaš, the "Elbow house", summer palace...Some of the region's most prominent examples of cultural heritage are located withing Novi Sad greater area and several of them have been restored and preserved, but most of its heritage body is under serious threat due to neglect and lack of support and funding. Besides this, Novi Sad faces numerous contemporary chanllenges as a major urban center, such as: the housing crisis, over-centralization, parking issues, food production problems, wildlife protection and more. Novi Sad is a prime example of how modern problems both collide and coexist with the rich cultural history.

Adaptive reuse as an approach to safeguarding the built heritage of Novi Sad, and Vojvodina, has many potential benefits. Rooted in the principles of sustainability and continuity, this approach aims to repurpose and enrich existing buildings, while preserving their historical and architectural values. As to quote Viollet-le-Duc through his definition from 1875: "*That to restore a building is not to preserve it, to repair, or rebuild... but to re-instate it in a condition of completeness which could never have existed at any given time."* [1]. The approach of adaptive reuse can build upon these principles and help tackle current issues created by demographic shifts. Secondly, adaptive reuse could provide economic opportunities by boosting tourism and supporting creative industries, which can in turn create new capital and job opportunities in Novi Sad.

2. METHODOLOGY AND RESEARCH

In its core, this paper revolves around discussing a proposed structure and process of an adaptive reuse project for the built heritage. In this part we will discuss the proposed phases of a project, criteria for choosing potential buildings, research approaches and difficulties and opportunities that arise in researching the adaptive reuse approach in the specific context of Novi Sad, as well as the importance of these methods and approaches.

It is important to note here that adaptive reuse has potential to extend the life of buildings which may have previously been under threat of demolition. As Wong Lilian points out in *Adaptive reuse-extending the lives of buildings,* adaptive reuse can deny this end for some building or possibly postpone it indefinetely, thus immortalizing them [2]. This *quest for immortality* as the author calls it draws a parallel with lives of building and people, reffering to adaptive reuse projects as a building's afterlife. This concept can provide great insight into what adaptive reuse can actually mean for our heritage and the community, especially when we consider that many potential locations for adaptive reuse in Novi Sad are no more than simple town houses or warehouses.

2.1. The local level

The number of potential project locations in the wider region of Vojvodina is vast, given that through the approach of adaptive reuse, even an ordinary family home could be turned into a heritage site of great significance. Thus, the authors have decided to conduct their further research in the city of Novi Sad, for several reasons. Firstly, Novi Sad is the capital of Vojvodina, and its largest cultural and economic center, making it an environment which could more easily cultivate adaptive reuse projects. Secondly, the city has a plethora of built heritage sites (some of which have already undergone adaptive reuse), which can only be compared to other larger urban centers in the region – Belgrade, Zagreb or Pecs. Finally, the authors themselves currently live and work in Novi Sad, making it the most accessible and sustainable location for researching the topic.

Further methodology and research will be discussed in general terms but will take into consideration more specific urban typologies of Novi Sad as well. These are defined as linear heritage districts - streets or street systems with a wide range of heritage buildings and rich history; which have been researched in the preparation of this paper. Novi Sad hosts numerous locations, such as: The Petrovaradin's Belgrade Street, Dunavska and Zmaj Jovina streets, Futoška and Jevrejska streets, Mihajlo Pupin boulevard etc.

2.2. Top-down and bottom-up methods [3]

Prior to conducting the research and implementing the project it is crucial to consider one of the two methods which define the general approach to the project. Furthermore, these methods can determine the possible locations or buildings that could be considered as a good candidate for safeguarding through adaptive reuse. In the practice these methods are usually defined as:

1. Top-down: This approach involves the selection of a specific building or site based on its architectural and historical importance, but mostly for the potential economic value it could create. This approach is often undertaken by companies and governments looking to turn worn down locations into new capital generators. The top-down method can prove to be efficient and profitable but tends to overlook the actual needs of the community and more often than not, projects end up undermining the genius loci of a place. A good example of this approach in the local context is the old industrial zone in Novi Sad, now called "Kulturni Distrikt". The area is now an event space with bars, coffee shops and galleries, but used to be an alternative culture hub for the young during the era of the well-known "Kineska Četvrt".

2. Bottom-up: Bottom-up approach diverges from the top-down method by focusing on unmet and real community needs, such as housing or education deficiencies. Through research, this approach identifies potential sites that could be repurposed to fulfil these specific needs. A crucial aspect of this approach involves fostering open and continuous communication with the local community, prioritizing their input. By placing political and economic considerations in a secondary position, the bottom-up approach strives to empower the community and ensure that adaptive reuse projects align closely with their genuine requirements, thus fostering a more inclusive and socially driven transformation.

The authors have implemented a hybrid of the two approaches in their research, choosing the site of Jevrejska-Futoška streets as the location of their research. The reasons for the choice are two-fold. Firstly, the two streets resemble a linear extension of the city's historical center and host several preserved cultural heritage buildings (The Synagouge, "Mihajlo Pupin" school, The Thermal Spa...). On the other hand, being a linear site that is 1.5km long, the two streets could form a unique longitudinal city district that can host many yet unattended needs of the city. Various other sites have been considered as candidates for research, such as The Czech warehouse or the Industrial Zone. Through a grading system based on the criteria below the chosen location has proven to have greatest potential for adaptive reuse.

2.3. **Location choice criteria**

The above-mentioned methods are implemented in order to gather possible project locations and influence the process of adaptive reuse as a whole. In order to choose the particular location or a building that is best suited for the intended adaptive reuse it is essential to consider a broad range of criteria. Using these criteria can either help us clearly indicate the optimal location for the project or lead us to rank the considered locations in regard to the criteria that they do or do not satisfy and then choose among the best ranking ones. More broadly speaking, these criteria can help foster a better understanding of a region's cultural landscape and potential for adaptive reuse projects. As Alessandra Barresi states: *"[Italian] cultural heritage is a key resource for local development.",* stating that the cultural heritage has above all its intangible value, generated by its identity, but besides that it also possesses a more tangible *utilitarian* value, which depends on its own characteristics [4]. These characteristics are broad and can be upgraded through adaptive reuse, thus bringing additional value to the site or building.
In the context of researching the Jevrejska-Futoška street area as a possible adaptive reuse project location, this paper takes into consideration 6 different aspects:

1. Historical and cultural significance – when choosing an adequate building for an adaptive reuse project, its cultural and historical values carry the most value. Among other reasons, the more cultural and historical significance a building has the easier it is for people to identify with it and hence the project has more potential for success. Another important aspect to consider is that the governments, NGOs and other potential sponsoring bodies are more likely to allow for funding if a building has more value in terms of culture and history. The Jevrejksa-Futoška streets area is of

great importance for both the city's history and its present-day culture, hosting a plethora of buildings from different time periods, which in turn speak to various groups of people in Novi Sad. Young people, war veterans, the Jewish community and many other groups find important objects of their cultures along the two streets in question.

2. Structural integrity - a general assessment of the building's structural integrity is essential when considering it for an adaptive reuse project. Evaluating the soundness of the existing framework, load-bearing capacities, and potential limitations is crucial in determining the feasibility of the project as a whole. It is often that we find heritage buildings in such a state of decay that costs of renovation and reparation could greatly overcome the potential long-term economic benefits. In the area where research for this paper was conducted both well-preserved and badly damaged buildings are present and those in better kept conditions have been considered as more suitable candidates for a potential adaptive reuse project. It is proposed through the research of the site to create a comprehensive database in which the current state of all of the buildings on site could be documented and presented, thus creating a base for future research and project development.

3. Location and accessibility - the building's location should be carefully considered, as it is a potentially determining factor for the success of a project. Proximity to transportation networks, amenities, and community resources can greatly impact the volume of visits and the amount of interest from the local community. Additionally, accessibility for people with disabilities must be taken into account. In the case of the Jevrejska and Futoška streets, the location's proximity to the city center and its good connections to important commercial and business areas can mean a steady volume of visits and good recognition in the eyes of the broader community. We can consider the case of "KC LAB", an alternative culture center, as a good example of how the project's locations has brought success to a project. "KC LAB" is a 20th century urban villa turned into an event space and has seen greater popularity among the community in comparison to similar spaces in more remote locations.

4. Economic viability - the costs associated with acquisition, renovation, and ongoing maintenance must be carefully evaluated. Additionally, market demand for the intended reuse should be analyzed to ensure the project's long-term financial viability. A rough cost analysis should be conducted before choosing a location. It is important to note here that in most cases adaptive reuse projects bare lower expenses for the stakeholders than new-build projects, and as such can prove to be a smart investment when comparing the potential expenses and profits for the stake holders.

5. Legal considerations – as with any architectural and civil engineering project, adaptive reuse falls heavily under the influence of local and national laws and regulations. The situation with adaptive reuse in this aspect is more complicated than that of the new-build approach in that it must take into consideration both the laws regarding the building codes and heritage protection. Furthermore, it is important to consider the building's current protection status, as this can greatly limit the potential for adaptive reuse. Lastly – ownership plays an important role in choosing a

particular location for the project. In the case of the Novi Sad project location, one of the buildings with the greatest potential for adaptive reuse is practically rendered unfeasible because it is owned by the military, even though it hasn't been used for decades. The particular building in question is the Dr Archibald Reiss barrack, located at Futoška 54.

6. Community sentiment and engagement - involving the local community in the decision-making process is vital because it can give a clear vision of whether or not people would be interested in the future use of the building in the first place. Understanding their aspirations, concerns, and wishes can shape the project's direction and garner support. Public consultations, workshops, and open dialogues can foster a sense of ownership and ensure that the adaptive reuse aligns with the community's values. Built heritage in its core is the identity and common values of people translated into brick and stone, and as thus its future use should also respect the values, needs and wishes of the local community. Considering the site of Jevrejska-Futoška streets we can develop a strong identity of place within the local community, building on the elements already present at the site, such as: The military complex, The Synagogue, Futoški Park etc.

Table 1. Location choice criteria grading

Location	*Historical significance*	*Economic viability*	*Community sentiment*
Jevrejska-Futoška streets	*9*	*4*	*8*
The Czech warehouse	*7*	*8*	*7*
Industrial zone	*6*	*8*	*4*

Depending on the concrete project plan some criteria may prevail over the other. When considering multiple locations, they can be arranged into a table and graded according to the criteria taken into account, thus creating a clear visual representation of the different value aspects of potential locations. When considering the table above it is essential to understand that a vast number of aspects have been taken into account while grading potential locations. These include all the criteria mentioned before, as well as historical evidence of former preservations, subjective opinions of experts in the field, community sentiment etc. The table represents a grading system of 1-10 "points", where 1 means that the location doesn't meet the criteria at all, and 10 means it fully meets the criteria. For example, the historical significance of a site is graded a 10 if it has played a major role in the city's history, if there are numerous historical buildings and so on. Thus, the Jevrejska-Futoška steets prevail in comparison to the other two locations, since the site boasts numerous significant buildings that are still in use, while the other two locations have 1 or 2 building with major significance, but the remainder of them are not recognized as historically significant. In turn, economic viability considers the projected costs of renovation and potential for future capital generation. While the Industrial zone of Novi Sad and the Czech warehouse both have great potential to become capital generators (such as event centers, shopping zones etc.), the costs associated with their renovation are potentially much greater that those of the Jevrejksa-Futoška streets. Community sentiment in this grading system mostly revolves around verbal testimonies of the locals. In this context the first two sites have gained much sympathy in the last years, while the Industrial zone is still not recognized as a heritage site by the broader community. This kind of comparison can be useful in the early stages of a project and can include a much wider range of potential locations, as well as more than 3 criteria.

After careful consideration of the potential locations and choosing one that is the most suitable for the development of the project it is sound to formulate a general project structure, outlining the potential phases of the project. One such formulation of the process of adaptive reuse has been researched and developed for the purpose of this paper, particularly in consideration of Novi Sad’s linear heritage districts.

2.4. **Project structure**

In this part we will discuss the proposed project phases which could be taken into consideration when implementing an adaptive reuse project. The authors have created the structure through studying of the literature and through research conducted both in the field and within case studies. The phases are sorted chronologically and are not determining, meaning they can differ depending on the nature of the project itself. These phases are:

1. Research and analysis phase – the first phase of a project should always be the research phase. Through different processes the authors can better understand the building and its context, the opportunities and threats that are present and gain a clearer path for the further development of the project itself. Besides architectural and historical research it is important to conduct in this phase more thorough research of the physical state of the building, to gain an overall understanding of the building's structural integrity and potential costs and dangers. The undertaken and planned research methods for the case of Futoška-Jevrejska streets are: photography, video, historical and archive documentation, taking measurements, aerial survey, and so on.

2. Evaluation phase – during the evaluation phase one can consider the previously conducted research and reflect upon the potential opportunities and threats that the project brings. Furthermore, it is useful to consider external factors during the evaluation: funding opportunities, government support, community sentiment etc. This phase is also adequate for considering the basic preservation and adaption principles which can later translate into the architectural concept. The evaluation phase is most often conducted simultaneously with the research and concept phases. During the evaluation of the research site, authors have concluded that a great number of significant heritage sites are present at the location, but several potentially unwanted aspects have been observed as well, such as new apartment buildings or high traffic and noise pollution.

3. The concept phase – essentially the concept phase is the bridge between the idea of the project and its realization. It is crucial to consider the concept of adaptive reuse seriously, as we are dealing with a pre-existing condition which usually has a genius-loci of its own, thus blunt and generic architectural solutions are never a good option. Some of the methods that can help us develop a valid adaptive reuse concept are interviewing locals, case studies analysis, storytelling etc. Regarding the research area of the Futoška-Jevrejska streets, concept development has mainly been focused towards creating a new socio-cultural model, regarded as 'Linear heritage district', which aims to create new value for the community.

4. Project development phase – during this phase the project is, broadly speaking, defined into more detail and its more practical and technical aspects are determined – preservation techniques, materials, structural systems, zoning regulations, budgeting etc. Thus, careful planning and correspondence of different specialists is crucial here. Furthermore, this is the phase in which technical drawings and 3D models of both the existing structure and the proposed adaptation are developed and produced, which form the basis not only for the realization of the project but for its future use and management as well.

5. Construction phase – the realization or construction phase is the physical realization of the envisioned adaptive-reuse concept. It involves meticulous coordination of construction activities, adherence to design plans and specifications, and procurement of skilled contractors and craftsmen. It is paramount that the architects of the projects undertake regular site surveys and ensure the highest quality of construction drawings. The construction phase requires diligent project management to ensure efficient resource allocation, maintain quality standards, and address unforeseen challenges that may arise during the renovation process. Authors have considered multiple local contractors and craftsmen, from different areas of expertise, although any potential construction in the Futoška-Jevrejska area is long down the road.

6. Post-production phase – It is crucial that the architects involve themselves in the after-phase of an adaptive reuse project, to ensure proper use of the building and its prolonged life. This phase includes building management and maintenance planning, and potentially the analysis of the realization of the project. The post-project steps are discussed later in the paper.

Considering all these phases prior to starting actual work on the project can give us a functional framework for the project's development and organization. Strategy and organization play a crucial role during all the phases. As ODASA states in their 2014 *Design Guidance Note "Quality of process comes through the design of the strategy used in the project..."* [5], further citing the Office of the Victorian Government Architect: *"Good design does not just happen: it is purposefully and* *carefully undertaken by skilled practitioners, valued by the client, and needs to be protected through delivery of the project."* [6]

3. RESULTS AND MANAGEMENT

3.1. Heritage management

To ensure the wellbeing of a building after it has undergone the process of adaptive reuse it is essential to formulate a clear vision of its future. This can be done through a management plan which can be created in communication between architects, stake holders and the community. In this aspect of adaptive reuse, the paper draws on ideas and thoughts explained by Barile and Saviano [7]. There are several key aspects to consider when formulating such a plan:

1. Vision creation and storytelling – The first key aspect can essentially be formulated even during the early phases of the project and such practice is even encouraged. During the project architects and other actors tend to create a story around it, especially when the project is dealing with a building or site with rich culture and history. Such a narrative helps establish the building's identity and purpose and fosters a connection with the community. Careful consideration of this aspect of the project can serve as a guiding principle for the management process and can contribute to the building's long-term success and sustainability. In the context of Jevrejska-Futoška street, a deep and complex narrative could potentially be formulated, given that the buildings in the area are attributed to different periods of history and different national and cultural identities.

2. Regular maintenance and preservation – A fundamental aspect of managing an adaptively reused building is implementing a proactive maintenance program. This could include routine inspections, timely repairs, documentation of buildings exploitation etc. Implementing such a plan could ensure the building's prolonged life and preservation of its functionality, visual appeal and cultural value.

3. Sustainable practices – Including sustainable practices into the management plan of a building can ensure its long-term viability. Sustainability in adaptive reuse can be understood through technological, ecological, political or social activities. The linear heritage districts of Novi Sad, especially the Jevrejska-Futoška area, bear a great opportunity for creating a sustainable environment, particularly through cultivation of linear green zones and education of the local community in how to maintain sustainable behaviors.

4. Monitoring and evaluation – Monitoring and evaluating adaptive reuse projects after their competition holds significant importance in ensuring the long-term success. Through systematic assessments, architects and stakeholders could document the performance of the site, its impact on the community and the achievement of set goals. Careful monitoring allows for timely adjustments to the building and its management in a timely manner

and can allow project managers to identify areas for improvement, weak spots and possible emerging issues. Furthermore, evaluation provides valuable insights for future projects and their success.

Coherence of this and other management aspects can ensure the building's proper usage, longevity and sustainability. Failing to create and implement an optimal management plan can lead to short-term problems and long-term failure of a project. Architecture, especially in the world of adaptive reuse, is never a finished product, but an ongoing process and as such needs proper care and attention to ensure its success, all in the function of fulfilling the needs of the people.

In the context of Novi Sad, due to lack of proper managing bodies, it is possible to consider a formation of a civic non-profit organization that could possibly undertake the duties of maintaining adaptively reused heritage buildings, alongside the building's in-house management team.

3.2. **Funding opportunities and difficulties**

There can be no adaptive reuse without proper funding. Adaptive reuse projects are either privately funded or need public funding to ensure their success. In Vojvodina and Serbia in general these opportunities are limited, and the lack of funding greatly contributes to the current state of emergency that most of the built heritage is in. However, due to Serbia's status as a candidate country for EU membership, many more funding opportunities have been made accessible in the previous years, making adaptive reuse projects more realistic. Furthermore, the national and local governments of Serbia have seemingly realized the importance of the built heritage in general and wider support to projects has been possible lately. This can be seen in recent successful projects such as the Fetislam fortress or Svilara culture station. This recent rise of interest in built heritage protection creates a more friendly atmosphere for new adaptive reuse projects.

During the research and project development, the authors have considered numerous funding options, amongst which some of them are:

1. Government grants and programs – Although limited, governmental programs present the most viable option for adaptive reuse project funding. Serbia at a national level has only recently seen a rise of interest in adaptive reuse as an approach to safeguarding of the built heritage, hence funding options are still limited. There are certain programs that have been considered as possible funding options for the development of adaptive reuse projects in Novi Sad, which are granted by bodies such as The Ministry of Culture and Information or the Provincial Secretariat for Culture

2. European Union funding – Possibly the best funding options for adaptive reuse projects, in terms of value and support, are EU funding programs. Options for applying in Serbia are limited, given that the country is not a member of the Union, but many funds have been opening their doors to non-EU countries in the past years and even programs specific for non-member states have been created. Some of the programs include: European

Regional Development Fund (ERDF), Creative Europe, Horizon etc. Furthermore, certain organizations based in the EU have started operating more in the region and have shown interest in supporting local projects, which could be of great value to projects proposed in this paper. One such organization is EuropaNostra.

3. International organizations – Certain international organizations, foundations and institutions offer funding opportunities which can be applicable to adaptive reuse projects. Among others some of the organizations that hold such programs are: UNESCO, the World Monuments Fund, Getty Foundation...International funds usually see great influx of project applicants and can be harder to get, hence these weren't considered as important as the first two categories in this paper. However, funding from these types of organizations can be extensive and should be considered in general.

3.3. Research results

Conducting research on the topic of adaptive reuse in the context of Vojvodina is a possibly endless process, as it could be in any culturally diverse region, and so far, authors of this paper have recognized more than 50 potential project locations in the greater Novi Sad region alone, including: the Jevrejska-Futoška streets, Industrial Zone north, the Agraria building, The Czech Warehouse, The House of Army etc. Archiving, analyzing and categorizing buildings has been the main focus of the research so far. In the future authors plan to create a cohesive database consisting of the researched locations.

4. DISCUSSION

Adaptive reuse as a discipline is still under development, and could benefit from project structures, databases and criteria lists, such as the ones described in the paper. Having a clear vision of the project process can help ensure the best possible outcome of adaptive reuse. Location plays a paramount role in the adaptive reuse process, and addressing aspects such as historical context, structural integrity, economic viability and community sentiment could help choose the optimal location for the proposed project.

Adaptive reuse as an approach to built heritage protection can bring great benefits to the region of Vojvodina and the city of Novi Sad in particular. However, it is crucial that the method gets recognized by both the local and national government to secure the feasibility of potential projects. As for the case of Novi Sad, it plays to the support of the adaptive reuse approach that numerous projects have already been realized in the city, such as: Svilara culture station, The Creative District, KC Lab and so on. We should state here that not only historical buildings have potential for adaptive reuse, but structure from the modern era as well (such as SPENS or The Railway Station in Novi Sad), a theory which is vastly explored in the Docomomo 14th conference paper by Tostoes and Ferreira. Hence, our perspectives as architects don't need to be fixated at only one body of heritage buildings. At the time of writing of this paper authors have undertaken several steps in the development of an adaptive reuse project for the Futoška-Jevrejska streets. Next steps would include formulating a more concrete concept and searching for funding, both local and international. We look forward to developing the project, but also to exploring different locations in the city.

5. CONCLUSION

In conclusion, this paper has explored the potential of choosing adaptive reuse as an approach to preserving built heritage in the Province of Vojvodina and its capital city of Novi Sad, presenting the opportunities and threats it faces in addressing challenges in the region. The complex research methodology, combining top-down and bottom-up approaches, numerous location-choosing criteria and different processes has provided valuable insights into the possible benefits adaptive reuse projects could bring. Furthermore, the study highlights the importance of community involvement, funding opportunities and management possibilities. The topics discussed are addressed in general terms, but also through specific research location in Novi Sad, which the authors have chosen for their own project development. The two proposed theoretical frameworks (location criteria and project structure) could bring value to the development of adaptive reuse as a discipline. The paper finishes with plans for the research and project development, highlighting the possibilities that this approach can offer.

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POSSIBILITIES FOR IMPROVING LIVING ENVIRONMENT IN HIGH-RISE HOUSING AREAS FROM POST-SOCIALIST PERIOD THROUGH URBAN GREEN SPACES: CASE STUDY OF NIŠ, SERBIA

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Abstract

The significance of urban green spaces (UGS) in high-rise housing areas (HRHA) has been recognized in various studies due to their multifunctional benefits for the quality of the living environment. In the current conditions, the increase in pollution and climate changes pose serious threats to HRHA, thus the importance of UGS is increasing more than ever. Despite this, UGS in HRHA built in the post-socialist period are often very modest or they are lacking. The aim of the paper is to evaluate the quality of the living environment in HRHA built-in post-socialist period and to explore possibilities for its improvement through UGS introduction. The study was conducted on HRHA in Romanijska street in the neighborhood KriviVir in the city of Niš built in post socialist period which represents typical mode of UGS lacking. Namely, this particular HRHA was chosen because although it is conceived as a luxury residential area built on previously vacant space with enough spatial possibilities for UGS planning, they are almost gradually missing. The study reveals that the absence of UGS in this HRHA has a negative impact on the quality of the living environment in this HRHA and provides possible types of UGS that could be of great importance for the improvement of residents' quality of life. The paper recommends the application of various types of UGS, such as private gardens, courtyards, green roofs, community gardens, rooftop gardens, and green walls, to improve living conditions in the selected HRHA. The results of this research may be important for improving the quality of the living environment through UGS in HRHA built-in post-socialist period as well as for proposing recommendations for possible UGS types in newly planned HRHA in order to create better living conditions.

Key words: *high-rise housing areas, urban green spaces, quality of life*

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1. INTRODUCTION

During the different phases of urbanization, the presence and importance of planning and construction of urban green spaces (UGS) have been rapidly increasing. In current conditions UGS are gaining the greatest significance as never before. Namely, today almost 50% of the world's population lives in cities, with a tendency to increase to 70% by 2050. Hyper urbanization worldwide is expected to have major negative implications for the life, health and well-being of citizens. Apart from hyper-urbanization, overcrowding and the ever-increasing growth of densely built-up cities in presence, as well as negative consequences of climate changes, and above all air pollution and rising global temperatures pose serious threats to cities around the world. In this context, the UGS is gaining more and more importance as a suitable planning instrument for mitigating aforementioned problems, creating favorable conditions for a healthier lifestyle and the sustainability of urban agglomerations. The significance of UGS in high-rise housing areas (HRHA) has been recognized in various studies due to their multifunctional benefits for the quality of the living environment [1], [2], [3] such as health, environmental, social, educational and visual-aesthetic.

As in other post-socialist countries, uncontrolled processes of transition and turbulent changes in the economic, social and planning frameworks left various negative consequences in Serbian cities in the last two decades. One of the main consequences of those changes was transition to the market system, as well as radical shift in housing policy, in actors in the housing construction process and institutions responsible for planning and maintenance of residential buildings. New housing policy is marked by the complete withdrawal of the public sector from high rise housing construction. Apart from other differences from HRHA development in the socialist period, one of the key ones is the treatment of UGS in HRHA. Unlike generously designed broad UGS in HRHA built in socialist period, many UGS in HRHA built in the post-socialist period in Serbia, as well as in other surrounding countries are often very modest or lacking [4]. Bearing in mind mentioned multiple benefits of UGS, their absence in new developed HRHA has negative implications for the quality of living environment and residents' well-being. The goal of this paper is to examine the quality of the living environment in HRHA built-in the post-socialist period, using the case study of HGHA in the city of Niš and to explore possibilities for its improvement through the UGS introduction.

2. METHODOLOGY

The methodology used in this study is based on the empirical method, analysis, synthesis, and case study. The theoretical basis of the research consists of the analysis of the literature related to the benefits of UGS as components of open spaces, as well as possible favorable types of UGS for the higher quality of the living environment. The method of analysis is used to provide an insight into UGS in HRHA built in post-socialist period in Serbia. Considering that UGS in HRHA built in post-socialist period are marginalized, despite their multifunctional benefits, it can be claimed that Niš is a representative example for a current analysis of presence and state of UGS within HRHA. For the purposes of the research, the typical HRHA built in post-socialist in the city of Niš is chosen. Namely, although this particular HRHA is conceived as a luxury residential area built on previously vacant space with enough spatial possibilities for UGS planning, they are almost completely missing. Thus, this area is an appropriate example for studying the treatment of UGS in post-socialist HRHA and its influence on the quality of the living environment.

The case study analysis consists of: 1. analyses of development of the chosen housing area trough description based on internet sources; 2. on-site observations and evaluation of quality of living environment. The on-site observations has been conducted with an objective to evaluate the presence and current condition of UGS identified in the theoretical part of the study in the chosen HRHA in the city of Nis. The quality of living environment was estimated based on assessing environmental, social, functional and visual and aesthetical problems in the chosen HRHA caused by UGS lacking. After establishing the quality of living environment, the physical and functional characteristics of the selected HRHA and its physical capacity for the UGS application were considered using relevant map and by on-site assessment. The results of this research may be important for improving the quality of the living environment through UGS implementation in HRHA built in the post-socialist period as well as for proposing recommendations for possible UGS types in newly planned HRHA towards increasing the well-being of residents.

3. BENEFITS AND POSSIBLE UGS TYPES FOR THE QUALITY OF LIVING ENVIRONMENT IN HRHA

Based on various studies UGS have multiple benefits for the quality of living environment in HRHA. Ecological benefits include several aspects: UGS improve the chemical composition of the air, reduce air pollution, contribute to the reduction of air temperature, protect asphalt surfaces from overheating and also absorb part of noise from different sources and provide protection from wind blows [5]. Thereby they contribute to the provision of favorable outdoor thermal comfort, which, in addition to providing opportunities for active and passive recreation, positively contributes to the mental and physical health of HRHC residents. In particular, the importance of UGS as a modern instrument for draining rainwater using the concept of Water Sensitive Urban Design should be highlighted [6]. This, at the same time, affects the reduction of costs related to investing in the remediation of problems caused by climate change (floods, etc.). The social significance of the UGS is reflected in the fact that various joint activities of the residents can take place on them, contributing to the sense of community, the sense of belonging and territoriality and the development of good neighbor relations. In the context of meetings, gatherings, the organization of residents' activities, urban agriculture in common residential gardens as elements of UGS, is especially important [3]. Besides, adequately planned and maintained UGS contribute to the prevention of antisocial behavior in HGRH. UGS have an educational significance, for children to get acquainted with nature, as well as for adults to get acquainted with urban agriculture, i.e. acquiring new skills [3]. Except for the above UGS have a crucial importance in creating the visual identity and ambient values of the living environment. UGS colorfully enliven the space, create contrasts with built structures, and the choice of vegetation affects the creation of a more humane residential environment. This affects the strengthening of the feeling of belonging to the residential environment and the responsibility for its maintenance [7].

In order to achieve the mentioned benefits, it is important to introduce the most diverse types of UGS, which with their integrated effect can contribute to the quality of the living environment and residents' wellbeing. Possible UGS types which differ by ownership type, usage and benefits for residents' wellbeing are presented in table 1. Beside benefits given in the table 1, all UGG types also have visual and aesthetical benefits for HRHA residents, which is significant reason for their application in the greatest possible quantity.

Table 1. Possible urban green spaces types in high rise housing areas

TYPES		*BENEFITS*
private gardens for flats on the ground floor		*functional, environmental,*
common residential spaces		*functional, environmental*
inner courtyards		*functional, social, functional*
green roofs	private for flats on the last floor	environmental
	common green roofs	environmental, social
urban gardens	on balconies/terraces	environmental
	for the flats on the ground floor	functional, environmental
	community gardens on the ground	functional, social, environmental
	roof top gardens for flats on the top floor	functional, environmental,
	common rooftop gardens	functional, social, environmental
green walls		environmental
greening along the streets		ecological
greening along riverside		functional, social, environmental

Source: Author, adapted from [3], [5], [8]

Despite all the mentioned benefits of the various types of UGS, in the HRHA built in the post-socialist period in Serbia, green and open areas are very modest. One of the reasons is the problem of the functional solution of parking, which is often organized at the expense of green and open areas. The key reason is that investing in their development is unprofitable for private investors, which unfortunately has a huge negative consequence on the well-being of the residents.

4. UGS TREATEMENT IN POST SOCIALIST HRHA AND POSSIBILITIES FOR UGS IMPLEMENTATION - CASE STUDY

The city of Niš with 254,723 inhabitants in 2020 is the third largest city in Serbia and represents a typical post-industrial city in Serbia. During the socialist era, the typical East European housing model was represented in the City of Niš. HRHA were state-owned and constructed at the outskirts of the cities. In most of them several problems appeared producing low level of quality of life. Beside problems, one of the main characteristics of HRHA are generously built and well organized open and green areas with appropriate facilities for residents' activities [9].

After 1990, the collapse of socialist regime occurred and the process of transition began, resulting in socio-economic and institutional changes and a transition to a market orientation without planning. The consequences of the transition manifested themselves through changes in the urban structure of cities, as well as the disintegration of the Eastern European housing model [10]. It is characteristic of the withdrawal of state-owned construction and the beginning of construction with private capital through the following characteristic models: 1) reconstruction of the city core; 2) infill development, 3) construction of larger scale on brownfield sites, including urban transformation and densification of inherited LHE from the socialist past, and 4) new construction on greenfield sites on the outskirts of the city [11] Unlike HRHA built in socialist period, the quantitative and qualitative reduction of public open spaces and an extremely low degree of UGS is represented in HRHA constructed in post socialist period.

4.1. **Study area**

The study area is the HRHA in Romanijska street in the Krivi vir area in the city of Niš. Krivi vir is part of Bulevar Nemanjića residential zone. It was built on the outskirts of the city in the early 1980s of the 20th century. The analyzed HRHA is surrounded by Romanijska street and the bank of the Gabrovačka River and developed by private investors. Romanijska street HRHA was constructed on previously almost vacant land that was was partly owned by the city and partly privately owned (Fig. 1a). The development began in 2007 and was finished in 2010 (Fig. 1b). It consists of 2 residential buildings having basement, ground level and 8 floors with flats intended for sale. Within this complex there are 320 flats, office spaces on the ground floor, two underground garages and a small parking space on the ground floor (Figure 1c). The office spaces on the ground floor are oriented towards the streets, while on the ground floor, towards the inner part of the complex, and Gabrovačka River there are flats. Those flats do not have private gardens, which is very unfavorable for their residents. Within the complex, there are two commercial buildings, which occupy approximately third of the open space which was planned for residents in the original design.

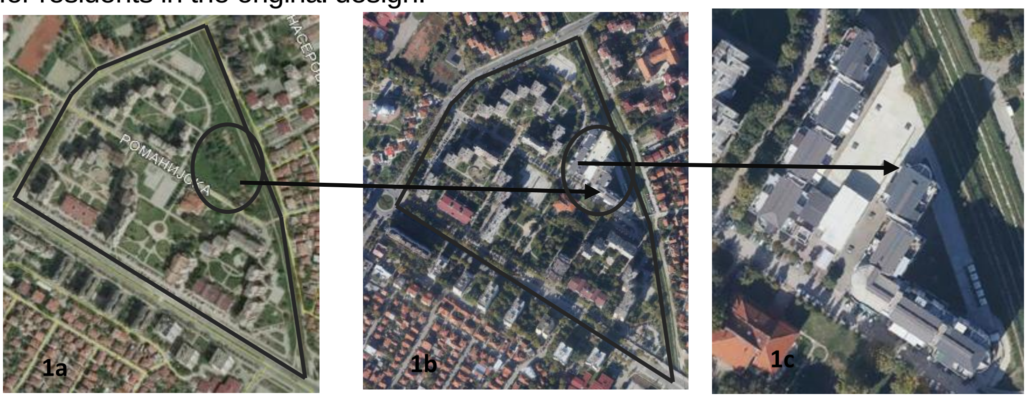

Figure 1. HRHA in Romanijska street 1a. Location in Krivi vir housing area in 2006; 1b. Location in Krivi vir housing area in 2023; 1c. Detailed view of the study area, source: https://gis.ni.rs/smartPortal/gunisPublic

Despite the fascinating ideas of the architects, that in the courtyard between the buildings there would be a common open space with urban facilities for all residential age categories, playground, gathering area for residents and greening especially towards the Gabrovačka River, nothing of that has so far been built. After the first commercial building was built, at the end of 2010, the second building was constructed. The consequences of these activities are the reduction of the public open space (Fig.2). Also a smaller green area was removed, and in current conditions, the amount of greenery in the complex can be assessed as extremely scarce. It is represented by the planter box and the perimeter of HRHA towards the parking area along the street, one small planter box on the entrance to the garage in the Gabrovačka River and one small green area in the north-east part of the area (Fig. 2b, 2f). The paved surfaces are dominant in the whole open spaces of this HRHA, while UGS are almost lacking (Fig. 2, Fig. a,b,d,f,g). Apart from all the above, the obligation of the investor was also to arrange the area along the coast of Gabrovačka River, which the table was also never built (Fig. 2c).

The analysis of the studied HRHA reveals a lot of disadvantages and negative trends in the quality of the living environment. One of the problems is that flats on the ground floor do not have gardens, which adversely affects the privacy and quality of life of the apartment (Fig 2a). The crucial negative consequence of all of aforementioned facts revealed in analysis is extremely unfavorable environmental comfort. It is manifested during in the summer as overheating of the paving surfaces, and creation of effect of thermal islands. In addition, between residential buildings dominant winds are very often presented, creating unfavorable comfort during winter, autumn and spring. The problem of air pollution is present as for the whole city of Niš. The HRHA is particularly at risk due to the emission of greenhouse gases produced by heating of individual housing units on the eastern side. Apart from the negative implications of environmental comfort, the lack of well-organized open space and the absence of greenery have an extremely unfavorable influence on the residents' wellbeing (Fig. a,d,f,g) In particular, it should be noted that most of the flats have an unfavorable inner comfort during summer, as well as that the flats on the top floor are prone to overheating due to the flat roofs. This analyses shows that quantity of green spaces is very poor, as well open spaces arrangement, thus the quality of the residential environment can be assessed as very low.

Figure 2: Map, Source: https://gis.ni.rs; Figures 2a-2g, source: private archive

4.2. Possibilities for UGS implementation

Besides all aforementioned, this research also reveals that in the analyzed HRHA there is a physical capacity of the space such as in inner courtyard, on balconies and terraces, on walls and pitched roofs etc. for the implementation of new contents, including different types of UGS and for open spaces design.

Table 2. Possible types of urban green spaces in high rise housing areas

Possible types of UGS in HRHA		
1. private gardens for flats on the ground floor	2. common residential spaces	*3. inner courtyards*
		
4. green walls	5. green roofs on the top of buildings	6. green roofs on the top of commercial buildings
		
7. urban gardens		
7a. on the top of underground garage	*7b. on balconies/terraces*	7c. for the flats on the ground floor
		
7. urban gardens		
7d. community gardens on the ground	*7e. roof top gardens for flats on the last floor*	7f. common rooftop gardens
		
Sources: 1. https://designbuildexpo.com.au/landscape-urban/10-up-high-australias-best-green-roofs/; 2., 3., 7., 8., 9. https://zinco-greenroof.com 4. https://www.biotecture.uk.com/portfolio/student-accommodation-tower-bridge/; 5. https://www.dicalite.com/2020/07/lightweight-growing-solutions-for-your-roof-garden/; 6. https://www.greenroofs.com/projects/herrity-building-parking-garage-demonstration-garden/; 10. https://www.nparks.gov.sg/gardening/allotment-gardens; 11. https://www.melbourne.vic.gov.au/community/greening-the-city/urban-forest-fund/funded-projects/ Pages/melbourne-skyfarm.aspx; 12.http://www.greenroofs.com/2020/01/18/urban-farming-a-budding-investment-opportunity-in-real-estate/;		

From the standpoint of this research, the research reveals the possibility of applying the following types of UGS in this HRHA (Table 2): 1.private gardens for flats on the ground floor (Fig. 2a); 2. common residential spaces (Fig. 2d, 2g); 3. inner courtyards (Fig. 2d); 4. green walls on the south-west oriented facades of buildings (Fig. 2e); 5. green roofs on the top of buildings (Fig. 2e); 6. green roofs on the top of commercial objects (Fig. 2b); 7. urban gardens: 7a on the top of underground garage (Fig. 2d); 7b urban gardens on balconies/terraces (Fig. 2e, 2f); 7c urban gardens for the flats on the ground floor (Fig. 2a, 2c) 7d community gardens on the ground (Fig. 2a, 2f); 7e roof top gardens for flats on the last floor (Fig. 2e*); 7f common rooftop gardens (Fig. 2e**).

The assumption is that, the application of the mentioned types of UGS could contribute to the improvement of the living environment in the studied HRHA in the following ways: reduction of air pollution and overheating and open spaces and apartments in the complex, e.g. improvement of the ecological comfort and rather the microclimate; protection of inner courtyard and buildings from dominant winds; encouraging good neighborly relations and strengthening of residents community, enabling the cultivation of healthy food in the buildings' surrounding, the inclusion of children and youth and bringing them closer to the organized UGS, reducing antisocial behavior, as well as creating physical and aesthetic integrity and connecting the built environment with the surrounding river bank.

5. CONCLUSION

Theoretical discussion of this paper confirms that urban green spaces have great potentials for improvement of living environment in high rise housing areas. The study reveals that the absence of UGS in HRHA built in post-socialist period has a negative impact on the quality of the living environment in this HRHA and provides possible types of UGS that could be of great importance for the improvement of residents' quality of life. The case study showed that in the analyzed post socialist HRHA the quantitative level of UGS is very low but there are adequate spatial capacities for introduction of various types of UGS towards realization of multiple benefits of UGS related to residents' wellbeing. The recommendation of this research is that certain basic types of UGS should be obligatory in planning documents for future HRHA construction and the most important the investors must be obliged to develop them according to plans. The results of this initial research may be important for improving the quality of the living environment through UGS application in HRHA built-in the post-socialist period as well as for proposing recommendations for possible UGS types in newly planned HRHA in order to create better living conditions in the city of Niš and other cities in Serbia. A more detailed qualitative and quantitative study of the state of UGS in HRHA built in the post-socialist period is needed in order to determine the specific possible types of UGS that can be implemented, which goes beyond the scope of this paper and may be the subject of further research. The conducted research also opens the possibility for further examination of institutional, organizational, planning and financial potentials for UGS introduction in HRHA built in the post socialist cities that could be of great importance for improving the quality of life.

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IDENTIFYING THE INFLUENCE OF DEMOGRAPHIC COMPONENTS ON URBAN SHRINKAGE OF SMALL TOWNS IN SERBIA

Milica Ljubenović [1], Ivana Bogdanović-Protić [2], Jelena Đekić[3], Mihailo Mitković[4]

Abstract

Shrinking cities are a widespread phenomenon, which have received increasing scholarly attention during last decades. Population loss is recognized as a defining feature of shrinkage, but it is a complex process that involves multiple interconnected dimensions. Economic decline influenced by global economic changes within national and local context is considered the key driver of shrinkage. However, the self-reinforcing demographic trends as low fertility rates and ageing will probably drive further shrinkage. In Serbia, a large number of small towns have suffered population and economic decline since the beginning of this century. Considering the persistent of negative demographic trends they are highly likely to continue. However, small towns represent heterogeneous group and urban shrinkage differs in them. For this reason it is important to determine the main demographic factors that contribute to urban shrinkage of small towns in Serbia. This paper examines demographic components of small shrinking towns in Serbia. The goal is to analyse and compare current demographic trends in them and to identify the main influencing factors of their shrinkage. The results from this analysis are significant for future urban and spatial planning of small towns in Serbia.

Key words: *small shrinking towns, Serbia, population decline, migration, natural decrease*

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1. INTRODUCTION

Urban shrinkage is a common phenomenon for many cities in the world and it is expected to continue in the future. It is a complex process characterized mainly by population loss caused by various economic, demographic and spatial changes from global to local context. Over the last decades, the phenomenon of shrinking cities has gained large academic and policy attention. However, most of the studies on this topic focus on larger urban area. On the other hand, the largest number of shrinking cities in Europe belongs to small and medium-sized towns [1]. They also register a more intense population decline than larger ones [2]. In Serbia, small towns are the most numerous group of urban settlements, and population loss is the most pronounced in them.

Researches have used different indicators and methods to characterize and measure urban shrinkage. Since the population loss is an initial sign of this process, it is the most commonly used for mapping temporal dynamics and spatial distribution of shrinking cities [3, 4, 5]. However, the urban shrinkage involves also other factors and aspects, and in various analyses the population decline is usually supplemented with additional demographic and economic indicators [6, 7]. Economic indicators are used less often and are less consistent in research. On the other hand, demographic indicators are more clearly defined and directly related to the causes of urban shrinkage and the characteristics of the second demographic transition.

Urban shrinkage is very pronounced in Serbia. In the period 2002-2011, more than 60% of settlements with over 5,000 inhabitants lost population, with the decline being particularly pronounced in small towns [8]. According to the first results of the Census in 2022, the decline has continued and intensified. The aim of this paper is to identify current demographic trends of small shrinking towns in Serbia and to determine demographic causes of population loss. Small towns represent a heterogeneous group and the causes and trajectories of urban shrinkage differ in them. For this reason, it is important to distinguish the most influential indicators of their shrinkage, which could help in the development of future policies. Focusing on the last intercensal period this research also tends to draw attention to the fact that the shrinkage of small towns has intensified and it is unlikely to stop.

2. THE THEORETICAL FRAMEWORK: DEMOGRAPHIC FACTORS OF URBAN SHRINKAGE

Although there is no consensus in defining the shrinking cities, they generally present urban areas that experience population decline combined with economic transformation. The causes and consequences of the urban shrinkage have been extensively researched [9, 10, 11] and demographic factors play a significant role in this process. The negative natural increase and emigration of the population are the key drivers of population decline, but at the same time they are the consequence of economic, social and cultural changes. According to Olsen [12], it is useful to analyse the population decline through the fertility and migration components, because both can lead in different directions and have very different implications for the labour market. Low fertility may be a long-term problem, but in the short-term, the migration balance is more important because of the greater effect on the working population.

The negative natural increase is a consequence of low fertility rate, which is the main feature of the second demographic transition, present in Europe since 1965 [13]. In most Western European countries, the second demographic transition was mainly offset by immigration [9]. In the Central and Eastern European countries, population decline as a result of low birth rates has become a primary factor since the end of the 1980s, and the process was further accelerated by emigration [10]. The sharp decline in fertility in these countries is described as a "demographic shock" caused by post-socialist transition [14].

Migration is an important factor that has a direct impact on the growth and decline of the population. The emigration of well-educated and talented residents in search of better employment opportunities, i.e. "brain drain", weakens the intellectual and innovation capacity of cities, which makes their recovery difficult. This can be a part of chain reaction [10]: if the most talented and skilled people leave a shrinking city because they expect better future opportunities elsewhere, the city can become less attractive to companies and investors, which can encourage even more people to leave. Such migrations lead to increasing polarization between growing and shrinking areas.

Mortality and fertility trends, as well as emigration of certain age groups, can affect the composition of the rest of the population and lead to aging. An aging population requires increased demand for services, which puts financial pressure on declining cities with declining incomes [1].

3. THE CONTEXT AND DEVELOPMENT TRENDS OF SMALL TOWNS IN SERBIA

In the second half of the 20th century, significant spatial and demographic changes took place on the territory of Serbia, which were primarily the result of the process of urbanization, i.e. intense internal migrations. During the period of accelerated industrialization, the most intense were local rural-urban migrations, then regional migrations from smaller to larger urban settlements, and finally population migrations to large regional centres [15]. Such migration flows have led to the creation of a spatial and demographic imbalance in the network of settlements in Serbia, as well as a significant mismatch in the concentration of residents and the level of socio-economic development [16].

Until the 1980s, the increase in the urban population was dominated by the migration component, participating with 70% [17]. Since then its participation began to decrease, and in the last decade of the 20th century, urban settlements grew exclusively under the influence of natural growth, which is also rapidly decreasing. The characteristics of the second demographic transition in the form of declining natural increase and aging became visible at the end of the 20th century.

Small urban settlements grew intensively in the period 1953–1981 by attracting the population from rural areas, thereby strengthening their central functions. The demographic growth of small towns was influenced by natural increase and migration. After the decline of rural demographic resources, migrations are directed to larger cities and small towns have become places of emigration [18].

Demographic processes during the 90s were affected by difficult socio-economic conditions, changing the network of settlements and creating a demographic imbalance. Large parts of the country are being abandoned (eastern, southern and, to a lesser extent, western) and the inhabitants are moving abroad or to the big cities [19]. Small towns have become places of depopulation. In the period 1991–2002, a negative population trend was recorded in 31 settlements out of 81 small towns, so that in the following intercensal period, that number would rise to 61.

4. DATA AND METHODS

The work is methodologically set up as a statistical analysis of trends in demographic indicators of small towns in Serbia. The last intercensal period 2011–2022 was covered, and the previous intercensal period 2002–2011 was partially used to compare population trends. Official national statistical data from the Statistical office of the Republic of Serbia were used for the analysis [20].

Since the research focuses on small towns, it was necessary to define them. Various definitions and thresholds have been used by researches to define small towns, depending on the context of the study and national criteria. In Serbia, settlements are divided into urban and other according to administrative-legal criteria. The researches in Serbia have adopted various rankings of urban settlements according to population size. Small towns usually were classified as urban settlements with less than 20,000 inhabitants [15, 21], but in some cases the upper threshold of 30,000 was defined [22]. In ESPON's project TOWN small towns have a population between 5,000 and 25,000 [23]. This limit is applied to this research, whereby settlements that are statistically classified as urban were considered.

The research deals with the role of demographic components in the urban shrinkage of small towns in Serbia and accordingly analyses migration and natural increase as key factors of population decline, highly connected to other social, economic and built environment variables. A minor issue in analysis represented the availability and consistency of data. Data on migration and natural increase are recorded only at the municipal level, which does not give a fully picture of these impacts at the level of the urban settlement. Municipalities in Serbia differ in size and the share of the urban in the total population of the municipality varies. Regardless, these indicators can serve as indicators of trends in the municipality, which are certainly reflected in urban settlements.

5. RESULTS AND DISCUSSION

Based on the set criteria, 78[5] urban settlements were singled out, which had 5,000-25,000 inhabitants in 2022. The results of the 2022 census show that in the period 2011-2022, the decline in the population of small towns is more intense than in the previous intercensal period (Table 1). Only 8 small towns recorded growth, and 6 of them never experienced shrinkage - Surčin, Petrovaradin, Sremska Kamenica, Šid, Temerin, Tutin and Ub. In addition to the prevalence, the severity of shrinkage in the period 2011-2022 is greater, with more than half of the cities losing 10-20% of their inhabitants.

[5] Preševo and Bujanovac were excluded from the analysis due to incomplete data from the 2011 census.

Table 1. Prevalence and intensity of shrinking small towns in Serbia in the periods 2002-2011 and 2011-2022

Period	*Number of shrinking towns*	*Population decline*			
		0-5%	*5-10%*	*10-20%*	*> 20%*
2002-2011	*61*	*27*	*26*	*7*	*1*
2011-2022	*70*	*9*	*17*	*40*	*3*

If we look at the regional affiliation (Table 2), it can be seen that the most intensive decline is in the Vojvodina Region (-11.2%), which has the largest number of small towns. This partially explains the growth of Novi Sad and its suburbs. On the other hand, the shrinkage of small towns in the Region of Southern and Eastern Serbia is of a similar intensity, but Niš, as the largest city in this region, has also stagnated. As a result, the entire region is demographically threatened. Unlike the previous census, when small towns in the Belgrade region recorded growth (10.9%), in the latest census they are stagnating.

Table 2. The intensity of shrinking small towns in Serbia in the period 2011-2022 by regions

				Population decline			
Region	*Total number*	*Total growth /decline*	*Number of shrinking towns*	*0-5%*	*5-10%*	*10-20%*	*> 20%*
Belgrade	*4*	*0.1%*	*3*	*1*	*2*	*0*	*0*
Vojvodina	*32*	*-11.2%*	*29*	*2*	*3*	*21*	*3*
Šumadija and Western Serbia	*22*	*-7.0%*	*19*	*5*	*6*	*8*	*0*
Southern and Eastern Serbia	*20*	*-10.8%*	*20*	*1*	*8*	*11*	*0*

Further analysis relates to the natural and mechanical components of decline. Figure 1 shows the share of migration and natural increase in the shrinkage of small town municipalities. It should be noted that the decline of municipalities continued, but with a reduced intensity compared to previous periods, which is a consequence of their long-term shrinkage. Due to the mismatch of data for certain municipalities, where according to the migration balance and natural increase, the decline was much higher compared to the data from the census, these municipalities were excluded from the analysis (total of 7 cities). Towns that are part of larger cities (e.g. Novi Sad, Pančevo) were also left out, because their population is a small part of that city's population and indicators at the municipal level would not be realistic.

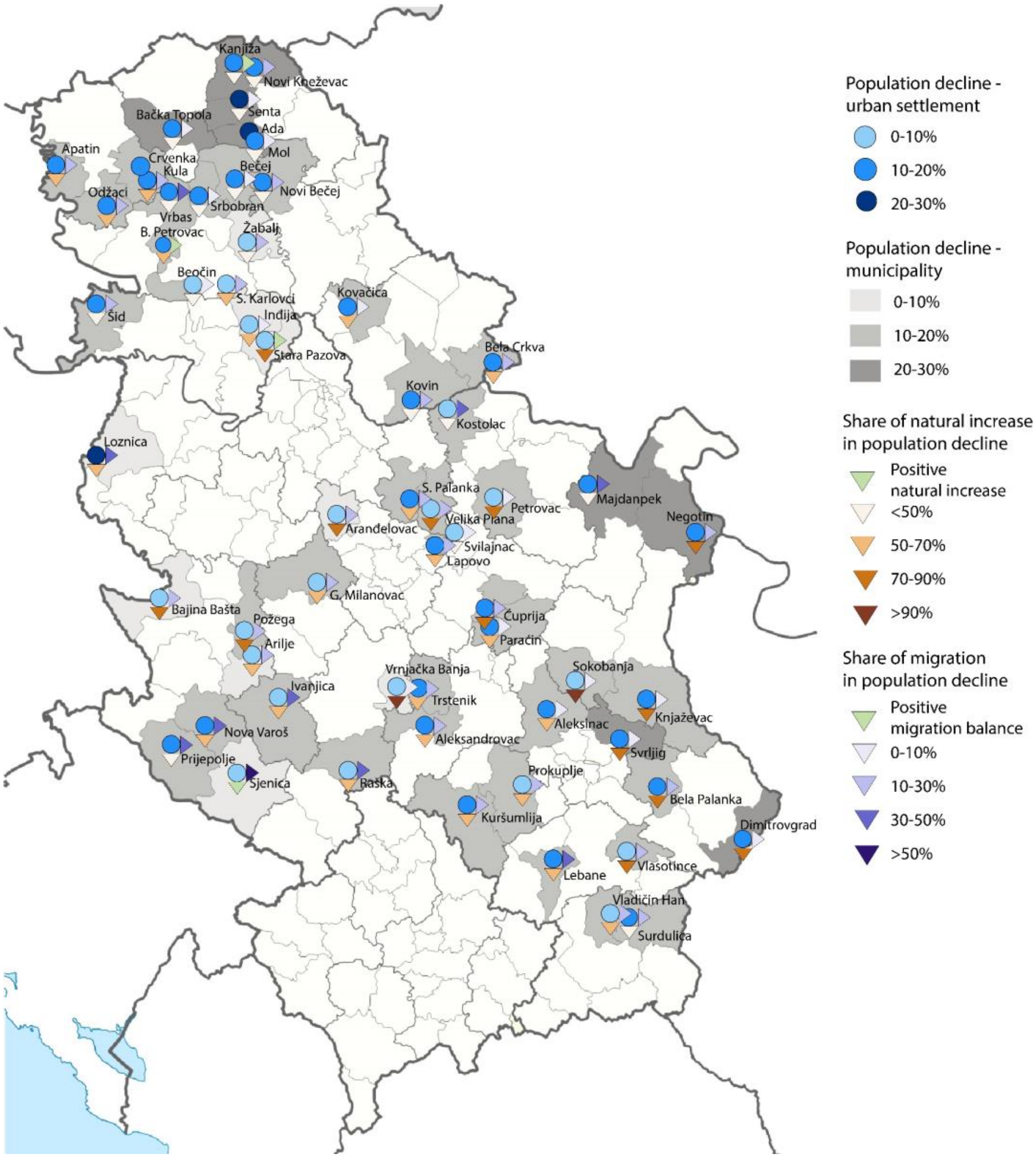

Figure 1.The share of migration and natural increase in the shrinkage of municipalities of small towns

The results of the analysis show that natural increase is the main component of the urban shrinkage of small towns. Sjenica is the only small town where the natural increase was positive, so the population decline in that town is solely the result of emigration. Prijepolje and Kostolac also recorded a smaller impact of negative natural increase, while in all other municipalities its share was over 40%. Two extreme cases are Sokobanja and Vrnjačka Banja, in which the share of negative natural increase in shrinkage was over 90%. The impact of negative natural growth is generally more pronounced in Central Serbia, while it is less pronounced in Vojvodina.

Migrations have a smaller impact on urban shrinkage, although it should be noticed that only internal migrations are recorded. Only three municipalities have a positive migration balance - Bački Petrovac, Kanjiža and Stara Pazova, and their shrinkage is influenced only by negative natural increase. On the other hand, Sjenica is the municipality with the most pronounced emigration. Territorially, emigration is less pronounced in Vojvodina, while it is most pronounced in southwestern Serbia. Large values of negative natural increase influenced the more intensive aging process in the urban settlements of those municipalities. Dimitrovgrad and Svrljig have the largest share of people over the age of 65 in the total population (27%).

By comparing different factors – the intensity of population decline, the share of migration and natural increase, the territorial context, it can be concluded that it is not possible to establish a unique pattern. It is noted that emigration is less pronounced in towns near the growth poles – Novi Sad and Belgrade, although this is not a universal pattern. Different impacts also occur in border areas. These results indicate that it is not recommended to develop a single spatial policy for the development of shrinking small towns, but an individual approach is necessary. It is possible to form a typology with groups of cities in which similar impacts are expressed and to develop appropriate packages of program measures accordingly.

6. CONCLUSION

Demographic factors are very important for the analysis of the urban shrinkage because they directly lead to the population growth or decline. Based on the observed previous trends and the current demographic indicators of small towns in Serbia, it is expected that their shrinkage will continue in the future. This is particularly contributed by the negative natural increase which is largely present in almost all small towns and which cannot be easily reversed, especially when the low fertility rate is a consequence of living standards and attitudes. Despite some measures already taken and the financial support of the state, radical changes cannot be expected in the near future. Therefore, it is necessary to consider the accelerated aging, as a consequence of these trends, and implement strategies and planning measures to adapt the environment to aging.

Additionally, it is necessary to pay more attention to migration patterns, as a dynamic factor that leads to the depopulation of some areas and the growth of the others. To that end, it is first of all necessary to develop a better migration monitoring system. In order to determine the real dynamics, it is necessary to monitor migration at the settlement level, as well as to monitor the direction of migration. This could determine the connection between the dynamics of the urban shrinkage of small towns and the dynamics of urban changes in the surrounding areas. It is necessary to establish the factors that push and pull the population in order to prevent further emigration and to consider the possibility of eventual immigration. This wold include job supply, labour demand, level of income, quality of services and environment.

The results of the research indicate the key demographic components of the urban shrinkage of small towns. Their analysis leads to the conclusion that the causes of shrinkage of small towns are different and it is necessary to undertake different case studies in order to deepen the aspects and factors of this process. This research provides a basis for further analyses of shrinking small towns in Serbia, complemented with other factors of shrinkage (economic, social and spatial). This would help define additional measures towards planning for improving the development of Serbian small towns.

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PRESERVING THE ARCHITECTURAL HERITAGE OF THE CITY OF NIS IN THE 21ST CENTURY: CHALLENGES AND OPPORTUNITIES (OBILIĆEV VENAC CASE STUDY)

Ivana Cvetković[1], Đorđe Stošić[2], Ana Momćilović Petronijeviić[3], Sonja Stanković[4]

Abstract

The current situation in the urban core of Nis imposes the urgency of preserving and valorizing the architectural heritage of the city. This means that the architectural heritage must be given a defined role through a process that should take place simultaneously with the current urbanization of the city. So far, individual successful examples and results have mainly been focused on individual immovable cultural assets for using their spaces for the needs of cultural institutions, city offices and premises, museums, galleries, and similar institutions. It is notable that the architectural heritage, which is crucial to the city's future, has been largely neglected, in contrast to the accelerated modern construction that knows only the interests of investors.

This paper analyzes and examines the areas covered by the General Urban Plan of Nis in the context of architectural heritage. Through graphic analysis, significant spatial areas with layers of cultural heritage that need to be treated differently from the rest of the urban territory have been identified in the planning documentation. When planning the future development of the city, it is crucial to bear in mind the values of cultural and historical heritage, as well as the fact that immovable cultural heritage represents an irreplaceable resource, following legal regulations and ratified world and European charters and conventions. In addition to that, further in the paper, the case study of an old city block - Obilicev Venac is given, containing a historical analysis, the current condition, and an architectural proposal for its urban regeneration.

Keywords: *Built heritage, Management, Niš, heritage mapping, sustainable development*

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1. INTRODUCTION

Through careful research, in order to study and evaluate, as well as active preservation of cultural heritage, we can contribute to the conservation and emphasize the identity of a neighborhood, or city, as well as a broader landscape or region. Architecture serves as a significant component of the identity of a space, rooted in both tangible and intangible heritage and the surrounding environment [1].

The central area of the City of Niš encompasses a continuous display of historical existence and urban development, characterized by a complex fabric of spontaneous and layered creation spanning centuries. The imprint of prehistoric, Roman, Byzantine, Ottoman, and modern European civilizations, including the socialist era, has left profound traces in the overall material culture, wherein urbanism and architecture hold prominent positions. New urban and architectural interventions need to be planned in a manner that accentuates and conserves the architectural heritage. Regrettably, the historic city of Niš and its historic urban core (varoš) have not received the necessary attention from architects, planners, and urbanists, thereby hindering the logical progression of further urban planning.

Although (on the international level it is supported) the international level strongly supports the renovation, preservation, and revitalization of urban heritage, and the Republic of Serbia formally incorporates these principles into its legal framework, practical solutions at the national level have been lacking. The integration of heritage preservation and promotion into spatial and urban planning has not become a common practice, and the mechanisms for practical implementation have not been adequately developed. The Law on Planning and Construction [2], outlines that spatial planning, development, and utilization should be based on sustainable development principles. Holistic planning should encourage the rational use of non-renewable resources, and promote urban and rural renewal and its protection (including the sustainable use of immovable cultural heritage). However, these goals often fall short, even with well-defined legal norms. Progress has been made in legal regulations with the adoption of the Law on Cultural Heritage [3] the development of a Strategy for Sustainable Urban Development [4] and the National Architectural Strategy [1]. By emphasizing architectural heritage, the Strategy for Sustainable Urban Development aims to address the inadequate representation of cultural heritage in spatial and urban planning practices. The strategy acknowledges that architectural heritage, along with other elements of urban structure, extends beyond immovable cultural assets and plays a valuable role in shaping the character and identity of the city. Unfortunately, over the past three decades in the Republic of Serbia, uncritical interventions in the urban space have prevailed, leading to the deterioration of cities' urban identities. Examples of inappropriate horizontal and vertical regulations regarding architectural design are common, disrupting the balance between old and new structures. While heritage preservation is recognized as a general objective, including clear recommendations for expanding the scope of protection to encompass buildings and architectural ensembles that are not currently recognized as immovable cultural assets, the practical implementation of these guidelines has been lacking, and urban planning documents do not acknowledge the term "architectural heritage."

2. THE CITY OF NIŠ - CULTURAL HERITAGE

The city of Niš abounds with immovable cultural heritage and preserved micro-ambient spaces that have not been adequately treated in terms of protecting spatial cultural-historical entities. Considering the complex historical circumstances, a certain number of smaller urban entities, sequences of buildings, and interesting examples of urban architecture from the late 19th and early 20th centuries have remained preserved in the central urban area of Niš. This collection encompasses a rich building tradition that must not be neglected in the dynamic development of the contemporary urban fabric. The necessity and urgency of processing and valorizing the old urban core of Niš are of crucial importance at a moment of spontaneous urbanization in attractive locations and central zones, driven by capital interests, leading to a reduction in the quality of urban space, that contributes to a decrease in the quality of life for residents, loss of identity in urban settlements, and degradation of the urban and cultural landscape as a whole.

The actual situation of today's urban core of Niš imposes the necessity of valuing architectural heritage, specifically, the remaining historical urban entities, for the architectural legacy to obtain its defined role in the contemporary development of material and spiritual culture. The valorization of these cultural features is a process that should co-occur with urbanization, and their high-quality presentation and integration into contemporary trends can elevate them to dominant positions within the ambient.

We can observe that the previous individual successful examples in the city have largely focused on utilizing specific cultural monuments by reshaping them for the needs of cultural institutions, urban areas, museums, galleries, and similar establishments. It is noticeable that the remaining architectural heritage, which represents a precious asset of the city, has been largely neglected. We must incorporate it into contemporary forms of active living.

In the central urban core, within the area of Niš town, measured by contemporary preservation principles, a much larger number of buildings and entities should have been preserved compared to the current state. Due to both wartime events and aggressive urban policies, a considerable number of important structures (or entire blocks) have been demolished, which would have represented the city's cultural heritage today. The previous urban planning has largely distanced itself from heritage and the existing framework by focusing on constructing large-scale structures and forming new city centers. As a result, the urban core does not represent a balanced environment like the former Niš town used to.

The application of digitization, mapping, and graphical analysis of cultural, architectural, and urban heritage (immovable cultural assets such as cultural monuments, spatial cultural-historical entities, iconic sites, and archaeological sites, as well as assets under previous protection and those enjoying the status of previous protection) has served as an effective method for spatially comprehending the inherited values of Niš. Its purpose is to achieve a holistic understanding and clear definition of locations and areas with the highest concentration of cultural heritage.

Through graphical analysis, spatial areas with significant concentrations of architectural heritage have been identified, and need to be treated differently from the rest of the urban territory. These areas are enriched with layers of cultural heritage and thus require specific treatment through urban planning documentation.

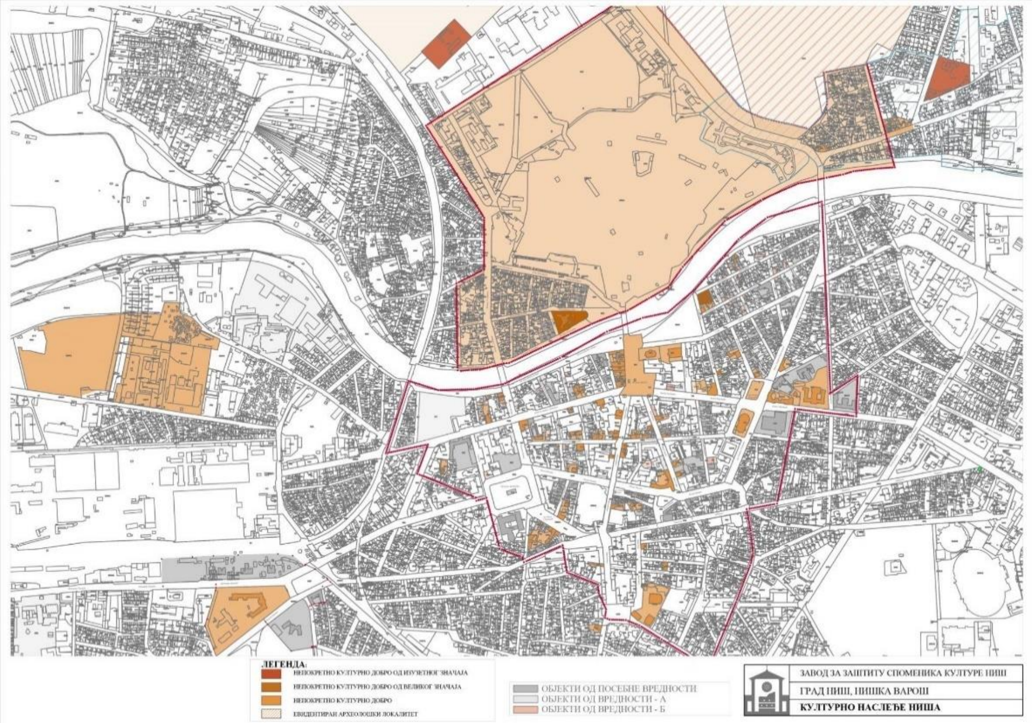

Figure 1. Overview of the cultural heritage of the city of Nis, ICHP Nis, I. Cvetkovic, 2023.

The most significant cultural-historical entities and spatial areas, individual buildings presumed to have cultural value, or layered heritage from different periods, are presented through the following categorization:

I - The archaeological site of Naissus, with remains of an ancient, Byzantine, and medieval city, heritage from the Ottoman Empire era, and contemporary buildings. Within this complex, the following areas stand out: Niš Fortress, The City Field area, Knez Mihailo Barracks, Konjičko cemetery archaeological site, Late Antique and Early Byzantine Necropolis in Jagodin Mala quarter, and the Beogradska Mala area. The aforementioned describes the different components and areas within the archaeological site of Naissus, encompassing various historical periods and architectural features.

II - Niš city core - the Niška Varoš, with the remains of its urban layout, represents a slightly later phase of development, which emerged through spontaneous settlement formation and building construction, followed by the implementation of regulatory plans for modernization. [5] It consists of a spatial, cultural-historical, and urbanistic complex on the right bank of the Nišava River, known as Beograd Mala, a series of buildings along the Jagodin Mala, and an urban agglomeration on the left bank of the Nišava River. The mentioned urban districts constitute the old historical core, known as the old Niška Varoš, and together they form the identity of the city.

2.1. Obilićev Venac - a case study

The old city block "Obilićev Venac" is located in the central area of Niš, close to Obrenovićeva Street, and it's part of the city's historic core. It encompasses the space between Obilićev Venac Street, Jug Bogdanova Street, and Pavla Stojkovića Square. The block of old houses on Obilićev Venac represents a historic urban complex and is prominently featured in the first plan of Niš's regulation (Winter's plan). It is significant because it has preserved its urban layout and, to a large extent, the architectural appearance from the late 19th and early 20th centuries.

2.1.1. Historical Data

Most of the buildings on Obilićev Venac were built as a result of the construction of the Belgrade-Niš railway line in 1884. Buildings facing Obilićev Venac Street reflect strong influences of Western European architectural trends, which rapidly developed in this region after the liberation from the Turks. [6] The part of the block facing Trg Pavla Stojkovića still incorporates mostly single-story buildings of older traditional architecture, with small shops. On Jug Bogdanova Street, there is a peaceful atmosphere with single-story houses, interrupted by the Catholic Church bell tower.

Obilićev Venac quarter is dominated by single-story old buildings with richly decorated facades, numerous ornaments, carved decorations on windows, doors, and portals, iron fences and gates, and intricately designed balconies.

Figure 2. Block from Obilićev Venac Street, view towards the west, the third decade of the 20th century, old postcards (left), present condition, I. Cvetkovic, 2023 (right)

The buildings facing Obilićev Venac Street are more lavish and of higher quality compared to those on Trg Pavla Stojkovića. The structures located on Obilićev Venac Street, numbers 2 to 10, were built in the last decade of the 19th century, as well as the buildings at numbers 20, 22, and 24. These buildings are characterized by a serene silhouette, prominently designed and beautifully profiled cornices, shallow relief facade decorations, and a variety of treatments for wooden windows and portals [7]. The most valuable buildings in this complex were constructed in the early 20th century, where the former building of the

Južnomoravska Banka (South Morava Bank), built in 1920, stands out in particular [6].
Ground-floor shops facing Pavle Stojković Square were built at the end of the 19th century. Most of the houses are modest, single-story buildings with a simple rectangular layout. They are characterized by prominent under-roof cornices and shallow façade decorations, as well as large-sized windows made of solid wood, carefully profiled and decorated.

Figure 3. Pavle Stojković Square, appearance before 1920 (left), Catholic Church early 20th century (right) - old postcards

Some of the houses, such as the Delja family house at number 10, were constructed as elongated buildings with a spacious courtyard accessed through a vaulted passage enclosed by large semicircular gates. The house was built in 1882 as the Leatherworking Shop of Panajot J. Delja and Others. The other part of the house, number 10a, with a tavern, belonged to Panajot's wife, Evdokija Delja. It housed the tavern "Carigrad" one of the oldest taverns in Niš, which has retained its name since its founding in 1885 [6].
The Catholic Church in Niš stands out with its religious architecture, distinguishing it from the few Catholic churches in southern Serbia. The Catholic residents of Niš, who were predominantly involved in the construction of the Belgrade – Thessaloniki, and Niš – Istanbul railway lines, rented a private house on October 7, 1884, where they temporarily established a chapel [8]. The construction of the Church of the Most Sacred Heart of Jesus began in 1887, along with the parish residence. The church was renovated and expanded in 1925, and a tower with three bells was built alongside. Later, in 1934, an additional floor was added, and the extension project was designed by architect Julian Djupon [9].

2.1.2. **Current condition and improvement proposals**

The Obilićev Venac in Niš preserved its original appearance, building arrangement, horizontal and vertical regulation, and dimensions, to some extent. The original function of the buildings has also been relatively preserved, which is another characteristic of the ensemble. This block represents one of the main views of the city center, contributing to the visual and social aspects of the city.

Significant interventions within the block have occurred in the context of the architectural treatment of facades. The interventions on the facades were not following the principles and rules of the conservation profession, which led to the devastation of the aesthetics of the entire block. All individual elements of decorative facade treatment (except for the former South Morava Bank at Obilićev Venac Street No. 18) are in poor condition due to numerous unprofessional works, thereby jeopardizing the original architectural and ambient characteristics of the ensemble.

Figure 4. Site plan of the Obilićev Venac, significant buildings, ICHP Niš, I. Cvetković, S. Stanković, 2023.

In terms of function, the buildings on Obilićev Venac Street are following the former bazaar character of the area. There are two buildings of significant cultural value, several two-story buildings that have residential spaces on the first floor and/or attic, as well as several service and retail shops. The single-story buildings with artisanal and commercial content at numbers 4, 4a, 6, 8v, and 10 are more degraded compared to the rest of the block, as they have undergone certain modifications in terms of dimensions, structural composition, and architectural treatment of facade planes. The two-story building at number 2 has been demolished and replaced with a single-story building of inappropriate appearance.

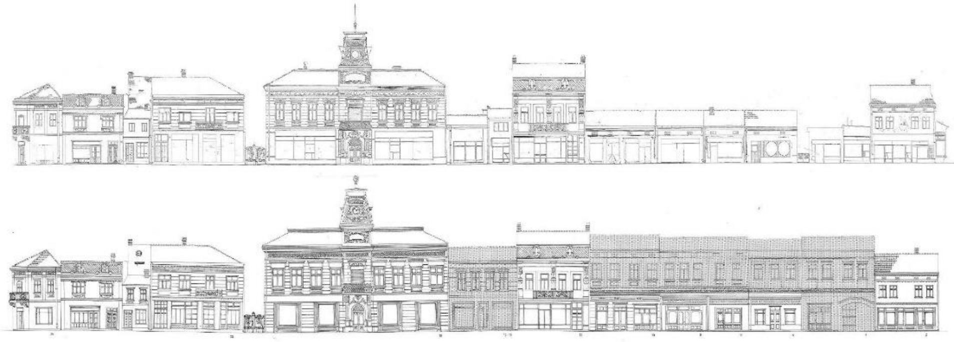

Figure 5. Obilićev Venac Street, condition of buildings in 1987 and restoration proposal, ICHP Nis, D. Janić, 1987.

The current condition of the block in terms of style and architecture is extremely poor. The aesthetic value has been diminished in most buildings due to partial changes caused by the unprofessional treatment of facades. An exception to this is the building of the former South Morava Bank at No. 18, the building at No. 20, and the building with a bookstore on the ground floor at No. 22. Two of these mentioned buildings have been the subject of recent adaptive reuse projects, serving as examples of good practice in that regard. The first adaptation of the South Morava Bank building was carried out in 1934 according to the project prepared by the Niš architect Dragoljub Milićević [10]. The second revitalization and repurposing were implemented during 1979 and 1980, according to the project of the Institute for Cultural Heritage Preservation Niš, designed by architect Danica Janić. More recently, in 2019, revitalization was carried out, during which the building was adapted into a restaurant [11].

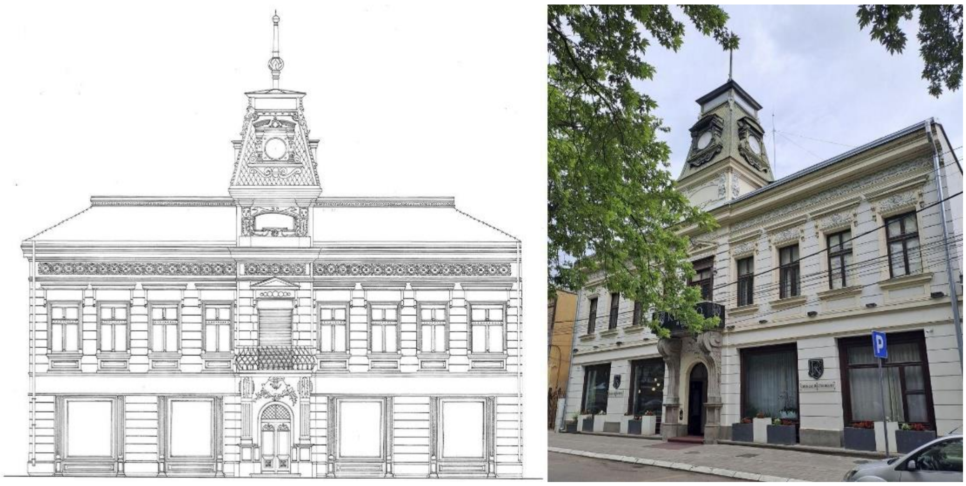

Figure 6. Južnomoravska Banka (South Morava Bank) at No. 18 Obilićev Venac Street, documentation of the ICHP Nis, D. Janić, 1980 (left), I.Cvetković, 2023 (right)

The street front facing Trg Pavla Stojkovića has largely preserved its original appearance in terms of dimensions, and horizontal and vertical regulations (except for the building at Trg Pavla Stojkovića no. 14a, which has been remodeled), but the quality of the final architectural design of the facades is lacking. The current use of the buildings in this row deviates significantly from their former commercial character, and several of them are not in use.

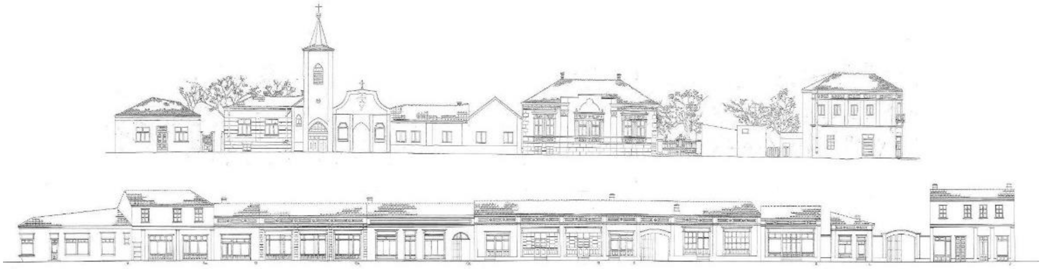

Figure 7. Square Pavle Stojkovic and Jug Bogdanova Street, restoration proposal, documentation by the ICHP Nis, D. Janic, 1987.

Considering the architectural design, most of the buildings possess prominent stylistic characteristics that indicate the historical significance of the area. Their monument values have been significantly diminished due to inappropriate (partial) interventions, the way advertising panels are displayed, and added elements. The moderate devastation of the area requires "minor effort" to renovate individual buildings and bring them back to life.

Given its location in the city center and its significant impact on the visual identity of the city, the renovation and regeneration of the subject area emerge as a priority. It is necessary to take urgent measures to prevent further deterioration of historic buildings. Figure 8 displays a conceptual proposal for the revitalization of the Obilićev Venac block that reflects a group of measures that would potentially improve its current condition and merge it life of the city. This architectural solution, at the present moment, has no legal impact and represents an architectural proposal that contains a new traffic solution as well as building restoration and reconstruction which is under Institute for cultural heritage preservation practice. However, in the next stages (optionally), it is advised to incorporate a community participation strategy to achieve sustainable design.

Figure 8. Situational plan Obilićoev Venac, proposed improvement solution, by S. Stanković and I. Cvetković, 2023.

The urban area of the square has the potential for spatial integration with the pedestrian zone of the city and active engagement in the social life of the local community. By returning to the original character and uses, the revitalization of the entire block would be initiated. Professional restoration of individual building facades is proposed, aiming to restore their original appearance where justified, while stylistic integration with preserved buildings in terms of complementary color and form is envisioned for the remaining structures. Advertising panels need to be visually aligned and limited to the smallest possible area. The goal is to achieve an aesthetically coherent and functional area.

It is desirable to functionally and visually integrate the street front on Pavle Stojković Square with the nearby public urban greenery. The full potential of this area would be achieved by introducing green design, compensating for the lack of (functional) greenery in the city center. In this way, appropriate scenery would be achieved, and the city would be enriched with a new place for socializing. In addition to the redesign of Pavle Stojković Square, the immediate surroundings south of the Obilićev Venac block offer the possibility of creating a significant green area, and by introducing integrated streets along Obilićev Venac and Jug Bogdanova Street, traffic would be calmed and the character of the whole area improved.

Figure 9. Proposal for the development of a pedestrian zone in the current area of Pavle Stojković Square, S. Stanković, 2023.

To efficiently integrate the subject area into the social life of the city, positioning it as a new, vibrant, and attractive social hub, urban planning and traffic minimization are proposed. The pedestrian areas in front of the mentioned buildings are narrow and currently used as taxi stand. In line with the proposed content changes, it is necessary to provide corresponding public spaces for a series of buildings on Pavle Stojković Square, connecting them with the existing public greenery within the square. This would allow the establishment of a restaurant and cafe and their outdoor seating areas. This can be achieved by creating a promenade directly alongside the line of buildings. This approach would facilitate desired pedestrian flow and retention.

The buildings on the street front (located at Pavle Stojković Square, No. 10, 10a, and 10b, which are publicly owned by the City of Niš) have a spacious inner courtyard connected by a passage to Pavle Stojković Square. The courtyard predominantly features single-story residential buildings. Through urban planning and the implementation of the mentioned or suitable facilities (restaurants, commerce, culture, etc.), it is possible to establish a functional connection between the inner courtyard and the rest of the block. This would contribute to the efficient integration with the city center.

Figure 10. Open space within the block, proposed design, S. Stanković, 2023.

3. CONCLUSION

A paradox can be observed when it comes to representing and promoting Niš as a city with a rich history and valuable cultural heritage, with the actual attitude towards that heritage. The city of Niš possesses significant architectural heritage that is an integral part of its building tradition, which should not be neglected in the expansive development of the modern urban core. One notable example is the "Obilićev Venac" area. Unfortunately, many architectural structures within this area have suffered damage due to unprofessional interventions, resulting in the loss of their historic and architectural characteristics and endangering their inherent ambient value.

Furthermore, there is a significant threat to the preservation of the continuity of architectural and artistic development. Inappropriate renovations, the incorporation of new modern elements using contemporary materials, and the removal of original details from facades and interiors have all contributed to this challenge. Consequently, a specific task emerges - the need for a comprehensive and detailed plan to address the urban location of the central urban complex known as "Obilićev Venac." The content of this plan must be aligned with the study dedicated to preserving the architectural heritage of this block.

Preserving the block and its noteworthy buildings can be attained through urban planning and subsequently transformed through reconstruction and revitalization. These aspirations will transform the area into vibrant and contemporary urban spaces, thereby creating opportunities for meaningful interaction between the old urban core and an architecture that harmonizes with the human scale and embraces modern life.

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INTEGRATING SUSTAINABILITY ASSESSMENT INTO ARCHITECTURAL EDUCATION. CASE STUDY FOR THE 5TH YEAR STUDENTS, FACULTY OF ARCHITECTURE, BUCHAREST, ROMANIA

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Abstract

SCOPE: Our work aims to identify relevant information concerning sustainable architectural design to 5th year architecture students at „Ion Mincu" University of Architecture and Urban Planning, Bucharest, Romania (UAUIM).

METHODOLOGY: This study focuses on the quantitative analysis of 173 projects delivered in the first semester, for the academic year 2021-2022, at the mandatory discipline ST-23 Architectural Technology Design Studio (4), UAUIM.

The specialized project ST-23 proposes an interdisciplinary approach to the building design process during 6 weeks with the Architectural Design Studio, by evaluating the degree of sustainability achieved through 24 criteria, grouped into 7 categories: Energy, Health & Comfort, Transport, Water, Materials, Waste and Pollution.

A series of tools were offered to facilitate students' study: general data template, written report template, information, conditions, spreadsheets and examples for each criterion, presentations for free software packages.

RESULTS AND DISCUSSION: Fulfilling each specific requirement allowed obtaining a certain number of points, which placed the building in one assessment category, from unsatisfactory to exceptional. Almost half of the analyzed projects (45%) were rated with grades between 8 and 10, 40% were rated between 6 and 7,95, 11% between 5 and 5,88 and 4% failed the subject. The diversity of the architectural programs (biodiversity center, business tower center, exhibition complex and Olympic swimming pool) allowed a wide area of sustainable principles and the integration of new or current technologies.

CONCLUSIONS: The statistical analysis presents diverse ways of distribution for 24 sustainable criteria addressed by 173 integrated design projects. Students had the freedom to approach different fields on their own knowledge and interests and integrate bioclimatic concepts, materials, constructive systems, and equipment with low environmental impact, depending on site characteristics and architectural program.

Key words: *Architectural Education, Sustainable Technologies, Integrated Projects, Interdisciplinary Architectural Design*

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1. INTRODUCTION

Sustainable architectural design is a key topic in the current context of climate change and environmental challenges. Global warming effects are becoming more evident and extreme weather phenomena are occurring more and more often. European Union and Romanian national regulations only partially address the problem [1], by imposing the nZEB (nearly Zero Energy Buildings) design and execution after December 31, 2020, dealing mainly with energy efficiency [2].

The constructive complexity, the different profile of the users, the different functions of the buildings, the specific local conditions are all factors that lead to different sustainable building certification schemes: BREEAM [3], LEED [4], LBC [5], WEEL [6], EDGE [7], DGNB [8] etc. These are complex systems for evaluating the overall performance of buildings, can be used on a voluntarily basis and carry out a certification by an independent body. Despite the shared fundamental similarities, the certification systems bring to light different facets of their sustainable building model. This fact is mainly due to their independent development, following parallel research, undertaken in each national climate studied. All systems evaluate the qualities and capacity of the building to have a mitigated impact on the environment, in a holistic approach that analyses the building's entire life cycle. In other words, they address all the stages involved, from the management of the entire process, then design in all its phases, execution, operation and up to post-use.

In this paper, we present a case study of a mandatory discipline at „Ion Mincu" University of Architecture and Urban Planning, Bucharest, Romania (UAUIM), that aims to introduce 5th year architecture students to sustainable architectural design through an integrated project.

For the assessment of the overall sustainability of the building and the feasibility of the structural concept in our examined project *ST-23 Architectural Technology Design Studio (4)* (head of discipline: Assoc. Prof. Arch. Radu Pană, Vice Dean of the Faculty of Architecture, UAUIM) [9], the analysis was limited to the students' (i.e., architects) intervention possibilities. Keeping all the principles established by the certification systems, the evaluation focused on those criteria and actions that are under the control of the architectural designer.

Our team studied the outcomes of 173 projects delivered in the first semester of the academic year 2021-2022 and evaluated the degree of sustainability of the designed buildings through 24 criteria, grouped into 7 categories.

Considering the general theme of the architectural design studio long project for the 5th Year – *Special Structures* – it was necessary for the students to define a viable structural system, which would be properly illustrated in the architectural drawings. To allow design flexibility for each building according to the most suitable principles, no set of common requirements were defined, and the structure of the building was solved following individual discussions on each project, with adequate pre-dimensioning of the main elements.

An interdisciplinary approach for teaching and learning sustainable architectural design involves interrelated criteria that need to be integrated in the design process. Therefore, it is important to continuously explore how architectural education can foster the development of sustainable design skills and competencies among students. This research paper discusses the challenges and opportunities of this academic approach, as well as its implications for future research and practice.

2. METHODOLOGY

The sustainability of the designed buildings was evaluated through a total number of 24 criteria, grouped into 7 categories: *Energy* (EN), *Health and Comfort* (SC), *Transport* (TR), *Water* (AP), *Materials* (MT), *Waste* (DS) and *Pollution* (PL).

Fulfilling the specific requirements of each criterion allowed obtaining a certain number of points (credits), which, added up, lead to the building being rated in one of the following six classifications: *Unsatisfactory* (below 35 points), *Satisfactory* (35 – 49 points), Good (50 – 59 points), *Very good* (60 – 69 points), *Excellent* (70 – 84 points) and up to *Exceptional* (more than 85 points). Certain criteria allowed for a higher number of points depending on the performance of the building.

All criteria were optional, with no mandatory pre-requisites, but the general condition for passing was the accumulation of at least 40 points. Each student had the freedom to analyze the most suitable topics, depending both on the characteristics of the site and the designed building, but also on the knowledge and interests of each student / team of two students.

To facilitate the study, a series of tools were provided, some general (information, conditions, specifications, etc.), others specific to each criterion (spreadsheets, software, etc.), available on the online digital platform of UAUIM. The score could be carried out by students in the calculation table provided (Excel format), by entering relevant information in the page related to each criterion. Calculation of the total score and the final classification in the sustainability category was carried out automatically. A template for the written documentation was also provided, which allowed the description of the measures and solutions adopted to demonstrate the fulfilment of the sustainability criteria selected for each project.

2.1. **Energy**

EN01 Energy for heating refers to reducing the energy required for heating. It is required to reach at least the normed values for the global insulation coefficient G1, depending on the type of building. The G1 value, together with the minimum standardized one, G1ref, is obtained using an Excel calculation spreadsheet. Students had to insert different layers compositions for the building's heated envelope: walls, floors, roof. Points from 8 to 15 are given according to the degree of improvement for the G1ref / G1 ratio (from 101% to 220%).

EN02 Energy for cooling asks for reducing the energy required for cooling, by providing solar protection elements at least on the facades with S and W exposure. For a maximum score of 10 points, it is required to demonstrate, through a solar study (solar diagram, shadow mask or other methods), that the effectiveness of the sun protection is at least 50% during the sunny period in the warm months (May – September).

EN03 Renewable energy quantifies the use of renewable energy sources (photovoltaic panels, wind turbines, biogas plants, heat pumps, etc.), to reduce energy consumption from fossil fuels. A maximum of 6 points is given for using up to three renewable energy sources in the designed building. For each source, students should specify the estimated installed power and the estimate of a covered percentage of the total energy required.

EN04 Bioclimatic design refers to the following seven components: climatic data (temperature, humidity, wind regime, precipitation, etc.); site location;

cardinal orientation; spatial configuration of functions in relation to orientation; comfort analysis (psychrometric chart); defining strategies / operation scenarios from a bioclimatic point of view (thermal mass, building occupancy, natural lighting strategy, ventilation strategy, passive solar input, etc.); climate change adaptation measures. The score of maximum 5 points can be obtained through graphs and schemes for fully illustrating the implemented design solutions. The free use of the software Climate Consultant 6.0 [10] is recommended for climate data analysis and the weather data file for Bucharest is provided.

EN05 Free cooling requires the analysis of one or more of the following technologies, for one point (in total): cooling at night; cooling through an air-ground heat exchanger; displacement ventilation; deep water cooling; surface water cooling; direct or indirect evaporative cooling; cooling by dehumidification and evaporation, using waste heat.

2.2. **Health & comfort**

SC01 Natural lighting is an important component which refers to ensuring adequate natural lighting in all spaces of the designed building. Students could choose from two different strategies:

1. An accurate natural light study using simulation software to provide daylight factor values (maximum 14 points). It is recommended to use the DIALux simulation software [11];
2. A simplified determination of the level of natural lighting, based on the ratio Window Area / Room Floor Area for at least 5 rooms of the building with different functions / sizes (maximum 4 points).

SC02 Visual comfort – views to the outside requires to demonstrate that 95% of the surface of spaces where users carry out their activities falls within a certain distance range from a window. The value depends on the Window Area / Wall Area ratio. It is not required to verify this criterion of 2 points in spaces such as conference rooms, theatres, gyms, laboratories, media centers or other spaces where reducing / controlling the natural light is a functional requirement.

SC03 Visual comfort – glare control asks for glare reduction systems which do not reduce natural light on cloudy days (blinds, shutters etc.). Mobile systems mounted inside or between glass sheets, which can be controlled by users or by sensors, are preferred. In general, external solar control systems (sunshades, louvres, cantilevers, etc.) cannot cover this requirement throughout the day (especially in the cold season), as they would be too obtrusive and reduce the lighting too much on cloudy days. There may be exceptions, but they must be justified. By reaching this criterion, 1 point can be obtained.

SC04 Air quality – VOCs must demonstrate the use of materials and finishes with low emissions of volatile organic compounds (VOC) with a Total Volatile Organic Compounds (TVOC) of a maximum 1.0 mg / m^3. For obtaining 1 point, materials that do not inherently contain VOC (brick, natural stone, concrete, ceramic tiles, glass, metal surfaces) and are left exposed without the use of organic films, adhesives or sealants are considered compliant. A bonus point can be awarded for using materials that trap VOCs in the air, thereby reducing the total concentration. It is necessary to choose materials from at least 3 of the following categories: paints and interior covering materials; wood-based products; materials for floors (including screeds, resins, etc.); materials for heat insulation and sound insulation; adhesives and sealing for interior.

SC05 Air quality – natural ventilation verifies that the building ventilation strategy is flexible and adaptable to the needs of potential building users and climate scenarios (maximum of 1 point). The occupied spaces of the building must be designed so that they can be fully naturally ventilated. The window opening area in each occupied space in the building is equivalent to 5% of the usable area. For rooms with a depth between 7 to 15 m, windows that open must be located on opposite sides and evenly distributed over the entire surface of the room. The following spaces can be excluded from the natural ventilation analysis: annex spaces such as bathrooms, corridors, staircases, storage spaces, technical spaces; small kitchenettes for employees; changing rooms; laboratories or other spaces where environmental control is needed.

SC06 Acoustic comfort – interior noise level quantifies in the first place the degree of providing necessary airborne noise insulation for the building envelope (2 points). Secondly, for 1 point it is required to ensure that all indoor technical equipment (ventilation-conditioning, heating, etc.) have a noise level at least 5 dB(A) lower than the limit value allowed in that specific room.

SC07 Acoustic comfort – noise insulation analyzes the partition walls for a total score of 4 points:

Airborne noise insulation (R'_w index) is checked for walls and floors. The spaces for which acoustic protection is required and the spaces producing noise are identified. Depending on the noise level values, the optimum partition elements can be chosen (2 points).

Impact sound insulation ($L'_{n,w}$ index) for floors is checked. Depending on the vertical overlap of the spaces, the $L'_{n,w}$ index is determined for the structural floor – flooring assembly (2 points).

SC08 Acoustic comfort – reverberation time aims to determine the recommended reverberation time for the main space with acoustic destination in the project, depending on the volume and the type of sound production. A specific chart is provided in the documentation package. The calculated values for each frequency must fall within the accepted limits (± 20%) compared to the recommended values. The Excel spreadsheet will be used (maximum 10 points).

SC09 Accessibility - safe access requires for the following elements to be clearly indicated in the site plan and / or floor plan: pedestrian walkways from the public sidewalk to the building’s access areas; streets; bicycle paths, along the entire studied site. One point can be obtained by clearly illustrating in the drawings that pedestrian routes do not intersect with the auto or bike routes. Adequate covered / protected bicycle parking spaces should also be provided.

SC10 Accessibility - inclusive design highlights the facilities offered to people with various (dis)abilities. For a maximum of 2 points, students should explain in their plans and sections the solutions for access ramps, widths required for the movement of wheelchairs, appropriately sized doors, sanitary facilities, etc.

2.3. **Transport**

TR01 Public transport accessibility refers to the recognition of a project with easy access to public transport and reduced pollution and congestion generated by individual car travel. One specific criterion is the distance between the building's main entrance and a public transport stop, which must check one of the following conditions: maximum 500 m from the entrance to a metro station; maximum 300 m from a surface public transport station (bus, trolleybus, tram). For the score of 1 point, it is necessary to indicate on the site plan the position of the public transport stations and the distance from the main entrance to the building. The distance must be measured along a footpath, not in a straight line.

TR02 Accessibility of services requires the recognition of a project with easy access to common public services that are expected to be needed by future users. The building must be at a maximum distance of 500 m from a minimum number of services, according to the main function of the building. For scoring 1 point, it is necessary to indicate on the situation plan the position of the services and the distance from the main entrance to the building (measured along a walking path, not in a straight line). Some of the necessary services can be included in the designed building. Certain services can be found within others (for example a shop in a gas station, ATM or pharmacy in a supermarket, etc.).

TR03 Alternative modes of transport quantifies for 1 point the ensured facilities that encourage low-carbon transport: parking spaces for bicycles in the minimum required number depending on the type of building, as well as facilities for staff traveling by bicycle (changing rooms, storage spaces). The necessary facilities include changing rooms sized according to the number of people (according to the number of parking spaces), showers, storage spaces etc. If the score for criterion *TR01* is achieved, the number of spaces required can be reduced by 50%. For large buildings, the required spaces can also be reduced, as follows:

- number of users between 200 and 300: 33% reduction;
- number of users between 300 and 400: 50% reduction;
- number of users over 400: 60% reduction.

The reduction can be applied successively, i.e. for the first 200 users nothing is reduced, for the next 100 the 33% reduction is applied, for the next 100 it is reduced by 50% and for the remaining users the required number is reduced by 60%. A bicycle parking space requires the allocation of a space of 2.00 x 0.60 m; the free circulation space for access between 2 rows is at least 1.80 m.

2.4. **Water**

AP01 Water consumption asks for reducing water consumption by collecting rainwater and using it for sanitary facilities, irrigation, etc. A system for rainwater collection, storage, filtration, and reuse as "grey water" is provided for supplying sanitary facilities, irrigating green spaces and other purposes. One point is given for indicating in plans and sections the tank for rainwater, as well as indicating in the written documentation the proposed use for the collected water.

AP02 Efficient equipment refers to water-efficient equipment and solutions: sensor-based, zoned irrigation systems or the provision of plants that do not require irrigation. The need for water consumption other than for drinking and domestic use (for example for swimming pools, car washing, irrigation, etc.) can also be identified. Examples of efficient water consumption systems: drip irrigation systems, which incorporate moisture sensors in the soil; the control system is zoned, allowing different settings for areas with different plants; use of green areas that rely exclusively on precipitation to ensure the annual water requirement; the choice of plant species that develop naturally without irrigation.

If no water consumption other than for drinking and domestic activities is identified, the total credit of 1 point cannot be obtained.

2.5. Materials

MT01 Life cycle analysis means reducing the building's impact on the environment through an overall assessment of building elements throughout their life cycle. From 10 to 15 points are awarded for this study, applying the free software *Athena Impact Estimator for Buildings* (IE4B) [12]. A life cycle analysis can be generated, by comparison, between the designed building and the reference building (a building whose geometry is identical to the optimized one, but which uses common compositions and materials for all component subassemblies). It is required to reduce the impact on the environment, over the entire life of the building, by at least 10% (to obtain the minimum score), for at least two of the LCA parameters. A discount of more than 50% brings the maximum score. With the help of the free program, the reference building will be defined by its sub-assemblies (foundations, columns and beams, floors, walls, roof), with the actual dimensions of the designed building and with usual compositions and materials. The final building is obtained by copying the reference building and optimizing the composition of some components, replacing some materials or improving their characteristics.

The LCA evaluated parameters are: *Global Warming Potential; Acidification Potential; Ozone Depletion Potential; Photochemical Smog Potential; Eutrophication Potential; Fossil Fuel Consumption* [13].

The LCA software can only account for energy use by the building functioning (and thus compare different variations of the insulation layers) if a value calculated elsewhere is provided. For this purpose, a special spreadsheet allows the simplified calculation of annual energy need for the heating of the building, based on the heat losses (G1 coefficient) and heat gains (internal and solar).

MT02 Environmental Product Declarations (EPD) refers to choosing materials for which EPD are available. One point can be obtained for providing at least 5 different products from the following categories: *wood or wood-based products; concrete or cement-based materials; metal; stone or aggregates; clay-based products; gypsum; glass; plastic, polymers, resins, paints, bituminous; animal fibers, skins, cellulosic fibers; other categories*.

2.6. Waste

DS01 Functional adaptability measures the degree of allowing subsequent changes in the use of the building during its lifetime. One point can be obtained by illustrating solutions that allow an adaptation of the building's future scenarios of functioning: mechanical assembly systems for facades; easy loading partitioning systems; raised floors that allow the reconfiguration of building equipment's routes; defining a modular system, with standardized dimensions; finishing systems for walls, ceilings and floors that allow easy replacement.

2.7. Pollution

PL01 Noise pollution refers to measures taken to reduce the noise emitted in the environment by interior or exterior technical equipment. The noise level emitted outside must not exceed the background noise level in the area within acceptable limits. Equipment located on the building's terrace or on the building site must be protected by shielding. Acoustic screens must be made of solid panels (not meshes) with a minimum mass of 15 kg / m^2, having a minimum height equal to that of the equipment it screens. If there is no exterior technical equipment provided, 1 point can also be awarded by mentioning this fact in the written documentation.

3. RESULTS

Our results are based on the analysis of *ST-23 Architectural Technology Design Studio (4)*, an integrated specialized project for 5th year students in the Faculty of Architecture, completed in the academic year 2021-2022. The quantitative analysis refers to a total number of 173 projects (63 projects in teams of two students and 110 individual architectural design projects).

3.1. Addressed criteria

The students' selection of the 7 categories comprising 24 sustainable design criteria within the 173 projects studied is illustrated in Figure 1.

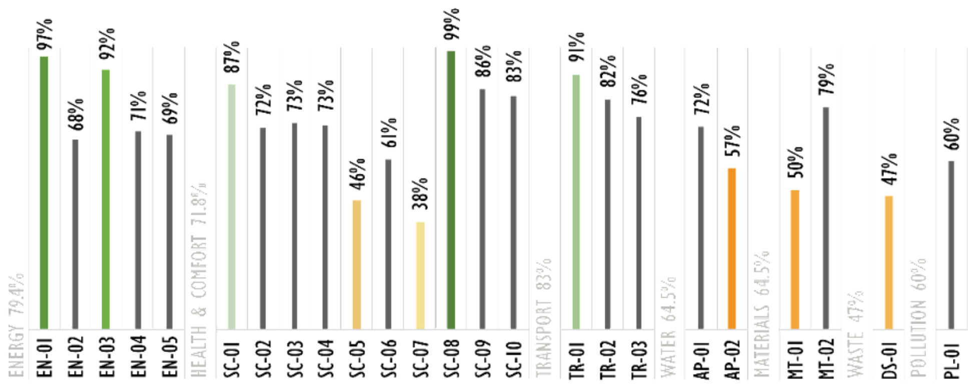

Figure 1. Percents of the 24 sustainable criteria studied within the students' projects

The 5 most addressed criteria by the students illustrated in Figure 2 were SC-08 *Acoustic comfort – reverberation time* (171 out of 173 projects, 99%), EN-01 *Energy for heating* (168 out of 173 projects, 97%), EN-03 *Renewable energy* (160 projects, 92%), TR-01 *Public transport accessibility* (157 projects, 91%) and SC-01 *Natural lighting* (151 projects, 87%).

Figure 2. Top 5 most addressed and least addressed criteria

Figure 2 also shows the least addressed 5 criteria in the 5th year architectural design projects: SC-07 *Acoustic comfort – noise insulation* (66 projects, 38%), SC-05 *Air quality – natural ventilation* (79 projects, 46%), DS-01 *Functional adaptability* (82 projects, 47%), MT-01 *Life cycle analysis* (86 projects, 50%) and AP-02 *Efficient equipment* (99 projects, 57%).

3.2. **Grades**

Assessment criteria included the quality of the sustainable approach in the students' projects and was based on the overall score obtained for the designed building, the quality of the technical and constructive solutions and the clarity and expressiveness of the project. The statistical analysis explained in Table 1 below highlighted the following data: 78 projects rated between grades 8 and 10 (45%); 69 projects rated between grades 6 and 7.95 (40%); 20 projects (11%) rated between 5 and 5.88 and 7 projects rated below grade 5 (4%).

Table 1. Distribution of the 173 projects analyzed according to their grades

No. of projects	Final Grades Interval	Minimum Score	Maximum Score
40	9.00 – 10.00	50	92
38	8.00 – 8.90	53	91
23	7.50 – 7.90	50	92
19	7.00 – 7.25	46	81
20	6.50 – 6.90	42	88
7	6.00 – 6.25	50	90
12	5.50 – 5.88	42	88
8	5.00 – 5.25	42	67
7	3.50 – 4.50	29	46

Almost half of the projects (45%) achieved a high degree of sustainability, while only 4% failed the subject. Even if most of the students were able to meet the requirements, there is also a lot of space for improvement and further development of the students' work, as 40% of the projects achieved only a moderate degree of sustainability, and 11% achieved a low degree of sustainability.

Figure 2 illustrates a more detailed image of the grades obtained for the 173 studied projects:

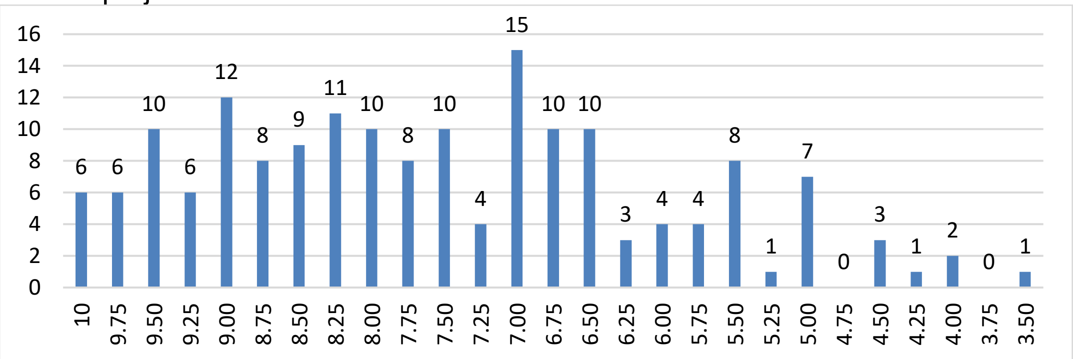

Figure 2. Percents of final grades, ST-23 Architectural Technology Design Studio (4)

4. DISCUSSIONS

The academic approach of *ST-23 Architectural Technology Design Studio (4)* at UAUIM allowed 5th year architecture students to explore various aspects of building performance and environmental impact, and to apply their knowledge and skills in a complex design problem.

Table 2 below conclusively describes the promotor factors, barriers and possible solutions for future integrated projects related to sustainable architectural design education at UAUIM. Our research resumes 5 positive aspects that support the students' learning and development of sustainable design skills. It also reveals 5 negative facets that hinder the students' learning and development of sustainable design competencies. The table also suggests 5 possible solutions for future integrated projects that could enhance the learning and teaching experiences.

The diversity of architectural programs and site characteristics enabled students to address different challenges for sustainable design and to integrate new or current technologies that can enhance their conceptual projects.

However, this discipline confronted with some difficulties and limitations, such as the short duration of the project, the large number of criteria and tools to be used, the large amount of information for the students, and the assessment and feedback methods. These challenges may affect the quality and consistency of the students' work, as well as their motivation and satisfaction. Therefore, some improvements and adjustments are needed to overcome these issues and to further enhance the learning outcomes and experiences of the students.

Table 2. Promotor factors, barriers and possible solutions for efficient integrating the sustainability criteria into the 5th year architectural design studio projects

	5 aspects to consider
Promotor Factors	○ the variety of resources provided: generic data template; written report template; specific conditions for each criterion; spreadsheets; norms, standards, and regulations; examples and particular information for every component; presentations of free software; ○ the interest, curiosity, and enthusiasm of a few students for particular topics and sustainable facets; ○ applied discussions (for the whole group) about the documentation that some students have brought; ○ certain students improved their solutions and sustainable design became an added-value to their projects; ○ continuous training on the topic of sustainability in the last two years of more than half of the faculty project team.
Barriers	● a large majority of students did not read the explanatory documentation offered and they relied exclusively on the tutors' guidance; furthermore, students did not attend every discussion session; arguments invoked: "we have nothing to show"; "our solution will change anyway"; ● most students have shown difficulties in searching solutions for current sustainable technologies suited to their studied architectural program: biodiversity center / business tower center / exhibition complex /

	Olympic swimming pool. Instead, they brought general diagrams or examples of building equipment for individual dwellings; ● the difficulty to advance with some criteria (for example, a lot of students postponed their EN01 study since their heated volume was in a process of transforming from one week to another and difficult to define). ● the pitfall of approaching the project with a checklist mentality leading to a lack of coherence between drawings and the written pieces. ● students' discussions with tutors from the 5th year in the Architectural Design Studio are not based, in general, on a sustainable approach, but rather on the aesthetics, functional and volumetric features.
Possible solutions for future integrated projects	➢ giving students the opportunity to choose a maximum of 3 categories to focus, out of the total of 7: *Energy, Health & Comfort, Transport, Water, Materials, Waste, Pollution*. ➢ organizing joint presentations with participants from both the team of tutors from the technical project and the team of teachers from the architectural design studio ➢ deepening the discussions with students regarding keywords, search engines, databases ➢ creating new online didactic support materials for the discipline ➢ enhancing the provided tools to allow a better illustration of the solutions.

5. CONCLUSIONS

Sustainable architecture is more than a sum of technical solutions. In its core, it is a holistic approach aiming to improve people's quality of life and reduce the anthropic environmental impact.

The case study of *ST-23 Architectural Technology Design Studio (4)* at UAUIM shows that sustainable architectural design can be taught and learned through an integrated project that involves an interdisciplinary approach. Our analysis reveals that students succeeded in achieving various degrees of sustainability in their designs, depending on site characteristics, architectural program and their specific knowledge and interests. Detailed techniques were embedded into the projects, allowing students to explore renewable energies, sustainable materials, smart use of space, and bioclimatic design.

This research paper contributes to the literature on architectural education by providing evidence and insights from a large-scale integrated project. It also suggests some directions for further research and practice related to sustainable architectural design: improving the clarity of the complex set of criteria and tools, incorporating more user feedback, and comparing different approaches, teaching and learning experiences and future outcomes.

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FUNCTIONAL ORGANIZATION OF MEDIUM-SIZED APARTMENTS IN NEW CONSTRUCTION IN SERBIA

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Abstract

The paper deals with the analysis of the functional organization of medium-sized (about 55 m²) newly built apartments in the Republic of Serbia. The research was conducted through a comparative analysis of 8 selected examples of apartments from the territory of the City of Nis, one of the largest cities in Serbia. Analyzed apartments are chosen based on the criteria of total net area, as well as the diversity of the organizational scheme. The aim of the research is to review the current situation in the field of residential architecture in Serbia and to find out whether newly built apartments meet all the needs of their users. The scientific methods applied in the work are analysis, synthesis, comparison, observation, modeling method and survey. The research came to the conclusions that in the design of medium-sized apartments it is aimed the maximum use of space, that the degree of flexibility of the apartments is low and that a large number of medium-sized apartments offered on the market often do not meet all the criteria prescribed by the current regulations. Based on the conclusions, at the end of the paper were given some proposals for regulation amendment and suggestions on the necessity of greater involvement of competent authorities in the control of market apartments.

Key words: *medium sized apartments, functional organization, newly built apartments in Serbia*

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1. INTRODUCTION

The topic of the paper are *medium-sized apartments* (a term introduced for research purposes that refers to apartments with an area between 45 m^2 and 65 m^2, that is, with an average area of around 55 m^2), the most popular in housing construction and apartment sales in the current situation of the City of Nis and the Republic of Serbia. The research deals with the analysis of the functional organization of such apartments, the degree of their flexibility, as well as the possibility of adaptability to the current needs of the users. The aim of the research is to review the current situation in the field of residential architecture in Serbia, as well as to find out whether newly built apartments meet all the needs of their users. The research was carried out on the territory of the City of Nis, which, as one of the largest cities in Serbia, was selected as a representative sample, whose circumstances can be mirrored to a greater extent on the circumstances of the entire country.

Based on the number of currently active construction sites (Figure 1), the offer of newly built apartments and apartments under construction that can be found by searching real estate sales websites and investor websites, as well as the empirical experience of problems related to housing construction in Serbia, it can be concluded that the demand for apartments on the territory of the city of Nis in recent years has been in expansion. The reason for this can be found in the constant migration of the population from the countryside to the city, the development of Nis as a leading center of the IT industry in the region, the opening of several factories, the role of Nis as the university city, increased investment in real estate due to the global economic crisis after the COVID pandemic and increased inflation.

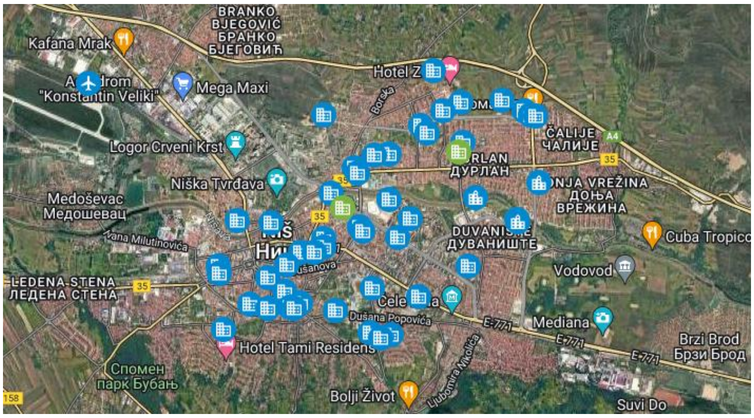

Figure 1. The map of active construction sites in the City of Nis, source: [https://www.gradnja.rs/mapa/,](https://www.gradnja.rs/mapa/) *(accessed: 20.6.2023.)*

According to the data of the *Statistical Office of the Republic of Serbia (RZS)* [1], the average area of sold newly built apartments in 2022 on the territory of the Republic of Serbia was 57 m^2. Based on the data published on the *RZS* website, the average area of newly built apartments sold in 2022 on the territory of the Belgrade municipalities of Vozdovac, Zvezdara, Palilula and Rakovica was, respectively: 56 m^2, 52 m^2, 55 m^2 and 54 m^2. The situation is similar in other major cities of the country: in Novi Sad - 55 m^2, Kragujevac - 54 m^2, in the municipalities of Pantelej and Medijana in Nis - 55 m^2. In Nis, the users of the largest number of newly built *medium-sized apartments* are young married couples with or without children, or couples who are in the initial phase of starting a family (for example, in a survey conducted for research purposes in one of the parts of the residential buildings in Vojvodjanska Street in Nis, constructed in 2018, out of 8 apartments, as many as there are, only one apartment is occupied by elderly users, while the users of the other apartments are primarily couples with small or school-aged children).

1.1. Apartment as one of the basic prerequisites for a normal life

According to G. Knezevic [2], the issue of meeting the needs and the right to housing worthy of a human being is the most significant after the issue of hunger. B. Nestorovic [3] points out that in a series of complex social problems, human housing occupies one of the most important places. Dealing with the issue of housing in post-war socialist Yugoslavia, he talks about how the life of the family, both in terms of health and social aspects, depends primarily on housing conditions, adding that these conditions indirectly extend to the spiritual development of the family and the whole society. Taking into account that housing takes up 70-75% of a person's life, and is expressed in various manifestations that are conditioned by the physiological, sociological and psychological needs of a person, he underlines that, from a sociological point of view, it cannot be considered that the problem of housing is solved only by the existence of sufficient number of apartments, i.e. rooms for living, but also by the fact that those apartments really have conditions for living, because: "it is not the same whether a family lives, eats and sleeps in one same space, or in several spaces, which have their own specific purposes". According to him, in modern society, an apartment cannot be understood only as a "roof over the head", but as the possibility of housing under modern social conditions, which, on the one hand, are in accordance with the technical progress of our time, and on the other hand, with the rights of a free man. Also, as he says, housing is the result of the general social culture and economic progress of the people, and it has a direct impact on the development of man, family and the entire social community.

Dealing with the analysis of the apartment as a whole, M. Baylon [4] highlights some elements that have an impact on the quality of the apartment: 1) the communication between basic groups of rooms (group of the living room, group of rooms for sleeping and hygiene, group of rooms for the household, which also includes the kitchen) has to take place as smoothly as possible, without large distances and without many intersections; 2) the connection between individual rooms in one group has to be as short and simple as possible, without unnecessary corners (in communication), and without passing through other rooms; 3) the usability of certain rooms for a specific purpose has to be quantitatively and qualitatively good (maximum) considering the size of the room.

2. RESEARCH

The research is based on the analysis of functional organization of selected examples of newly built apartments in Nis, whose area varies between 50 m^2 and 60 m^2. For the purposes of the research were selected 8 apartments, which fit into the given square footage, and whose organization schemes vary among themselves (Figure 2). The floor plan drawings of the apartments were found on the websites of the investors, where they were displayed in the catalog of apartments for sale, or were made based on the recordings. The apartments were chosen based on the diversity of the organizational scheme and the diversity of the structure.

Apartment number 1, with an approximate net area of 53 m^2, is designed as a two-room apartment (typology of apartments according to the current Rulebook in the Republic of Serbia based on the apartment's structure [5] [5]). The living room, dining room and kitchen are combined into one unit (open space concept of living area) from which the open area is accessed. The bedroom is designed as a double room and has the possibility of creating a mini work corner on the side of the window. Access to the bedroom, bathroom and living area is possible through the entrance part of the apartment, which reduces the area of communications in the apartment to a minimum. All square footage prescribed by the Rulebook have been met.

Apartment number 2, with an approximate net area of 53 m^2, is also designed as a two-room apartment. The living room, dining room and kitchen are also combined into one unit. Although in this example the living area, bedroom and bathroom are accessed through a common entrance hall, the night area of the apartment is formed in a better way compared to the previous example, because it is separated from the living area. The path from the entrance to the apartment to the living room is straight and direct, so that, with the elongated geometry of the corridor, it was possible to differentiate the basic zones in the apartment. The open area is connected to the living room. The dimensions of the kitchen and bedroom are debatable, as they are slightly below the minimum prescribed by the Rulebook. For the given structure, the minimum prescribed width of the living room is 340 cm, and we can take this condition as satisfied in the given apartment, only if we take into account the area belonging to the dining area, as communication around the table.

Apartment number 3, with an approximate net area of 50 m^2, is designed as a two-and-a-half-room apartment, although according to the Rulebook, the minimum area of an apartment of that structure should be 56 m^2. The living room, dining room and kitchen are also here united into one common space, but their total area does not meet the minimum required by the Regulations. What can be ascertain as unfavorable in the functional organization is the peripheral position of the entrance to the apartment, which affects the lack of zoning of the apartment into day and night parts. The path to the living area is long, and in order to get there one has to go pass by every room. The entrance to the bathroom is positioned right in front of the front door, which spoils the first impression after stepping into the interior of the apartment. Also in this case, the open area is connected to the living area. The width of the kitchen is almost 30 cm below the prescribed minimum, which is half of the modular measure.

[5] According to the current Rulebook, an apartment, based on its structure, can be:
1) studio apartment (entrance, multipurpose room with space for food preparation (kitchenette) and bathroom);
2) one-room apartment (entrance, food preparation area (kitchen), multipurpose room with dining area and bathroom);
3) one-and-a-half-room apartment (entrance, food preparation area (kitchen), living room, dining area, room for one person and bathroom);
4) two-room apartment (entrance, food preparation area (kitchen), living room, dining area, bedroom and bathroom);
5) two-and-a-half-room apartment and larger (entrance, food preparation area (kitchen), living room, dining area, bedrooms, bathroom and toilet).

Figure 2. Floor plans of the analyzed apartments, source: drawings are authors' interpretation

Apartment number 4, with an approximate net area of 50 m^2, is also designed as a two-and-a-half-room apartment, with the total net area below the one required for such a structure. The central position of the entrance creates the conditions for an adequate division of the space into day and night zones. The living room, dining room and kitchen, arranged within the same space, do not meet the minimum required area. The width of the living room and kitchen are below the minimum dimensions. The room designed as a parent's room does not meet the required minimum area, as well as the prescribed dimensions. It is impossible to fit a wardrobe in it. Although the adjacent room in the drawing of the floor plan is shown as a cloakroom, it is evident that in practice it will be used as a children's room, for which it is suitable both in terms of square footage and dimensions. The open area is positioned between the day and night zones, and is only accessible through the living room.

Apartment number 5, 60 m^2 in basis, is designed as a two-and-a-half-room apartment. Its advantage is three-sided orientation, which enables cross ventilation and the fact that it has two balconies, which is rare for this type of structure and apartment's net area. The entrance part is placed centrally, and in relation to it, the apartment is divided into two zones. An elongated hallway divides the apartment space into day and night spaces, at the same time serving as a storage space or an additional wardrobe. The problem arises because the entrance part is not separated, but occupies a part of the mentioned corridor, which is imposed as the main line of communication through the apartment. One must pass through it on the way to a certain room, which causes the crossbreeding of clean and dirty paths. In Serbian culture, the habit of tenants taking off their shoes after entering the apartment is widely presented, primarily for hygiene reasons. After entering apartment, the users take off their shoes and put on the home shoes. In this way, the entrance area is considered a dirty area of the apartment, because it is accessed in shoes that were previously used outside.

Apartment number 6, with an approximate net area of 54 m^2, is designed as a two-and-a-half-room apartment, although according to the Rulebook, the minimum required area for an apartment of that structure is slightly larger - 56 m^2. The day area is clearly separated from the night area and unites the living room, dining and kitchen in a common area. It is accessed directly from the entrance. The night zone, although not separated by a door, is clearly divided from the living room in the spatial organization of the apartment. It consists of two bedrooms and a bathroom. Due to the absence of an additional toilet, the bathroom is also used from the living area, which overlaps the domains of the day and night areas. A balcony is inserted between the day and night zones and can be accessed from all the main rooms. Although the good position of the entrance part impacted adequate zoning in the apartment, the fact that it is not clearly secluded (it is an integral part of the corridor from which is the access to individual contents) affects, as in the previous example, the intersection of frequency communication lines and the mixing of dirty and clean paths. In this example, we can see a deviation from the prescribed minimum areas in the part of the living room, kitchen and dining room, as well as in the parents' bedroom, which also lacks adequate width. The children's room is intended for one person, although due to its width, with a slight increase in length, it can grow into a room where there would be a space for two children.

Apartment number 7, with an approximate net area of 56 m^2, is designed as a two-and-a-half-room apartment. The living room and dining room are combined into one space, connected to the kitchen. The wall between the kitchen and the living room, besides allowing the living room to complement the contents, creates an interesting circular connection of these rooms with the entrance area. The entrance is slightly pushed out in relation to the longitudinal axis of the apartment, which makes it possible to separate the dirty from the clean area to some extent. Although the day zone, due to its position in the apartment, is clearly separated, the night zone is not formed as a separate one, but the bedrooms are accessed directly from the entrance. Also here, the bathroom is the only sanitary room. Deviations in the area occur in the living room and dining room, and in the width of the room in the parents' bedroom.

Apartment number 8, with an approximate net area of 57 m^2, is designed as a two-and-a-half-room apartment. The living room, dining room and kitchen, linearly strung together, are united within the same space, which is followed by an open area, the length of which follows the width of the mentioned contents. Also here, there is no clear zoning in the part of the bedrooms, so there is no distinctly formed night zone, although it is separated from the day contents. The entrance hall is part of the corridor that leads to the bedrooms. It is not physically emphasized, so it is a place that is often passed when moving through the apartment. The position of the bathroom, right across the dining room, creates a bad visual connection, where the dining table and the bathroom door are in direct visual contact, which should be avoided. Although the kitchen and dining room are in the same space and their areas for communication are united and overlap, it is still clear that the width of the communication area in the kitchen is far below adequate. We can see the debatable dimensions of the space in the living room and the parents' bedroom.

Table 1. Tabular overview of analyzed parameters in apartments

	AP. 01	AP. 02	AP. 03	AP. 04	AP. 05	AP. 06	AP. 07	AP. 08
approximate net area (m^2)	53 m^2	53 m^2	50 m^2	50 m^2	60 m^2	54 m^2	56 m^2	57 m^2
apartment's structure	two-room	two-room	two-and-a-half-room	two-and-a-half-room	two-and-a-half-room	two-and-a-half-room	two-and-a-half-room	two-and-a-half-room
minimum required area of the certain apartment's structure according to the regulations (m^2)	48	48	56	56	56	56	56	56
number of bedrooms	1	1	2	2*	2	2	2	2
number of bathrooms	1	1	1	1	1	1	1	1
number of toilets	0	0	0	0	0	0	0	0
number of balconies	1	1	1	1	2	1	1	1
living room + dining room approximate net area / minimum required area according to the regulations (m^2)	22.89 / 16+4	21.77 / 16+4	16.49 / 16+4	17.20 / 16+4	21.10 / 16+4	17.93 / 16+4	18.18 / 16+4	19.50 / 16+4
kitchen approximate net area / minimum required area according to the regulations (m^2)	5.10 / 4	4.85 / 4	3.67 / 4	3.25 / 4	4.16 / 4	3.75 / 4	4.57 / 4	4.65 / 4
bathroom approximate net area / minimum required area according to the regulations (m^2)	4.90 / 3	4.79 / 3	3.56 / 3	3.45 / 3	4.28 / 3	4.15 / 3	4.74 / 3	4.86 / 3
parents' bedroom approximate net area / minimum required area for two persons bedroom according to the regulations (m^2)	11.65 / 11	12.16 / 11	11.16 / 11	8.12 / 11	10.40 / 11	10.65 / 11	12.58 / 11	12.13 / 11
children's bedroom approximate net area / minimum required area for one person bedroom according to the regulations (m^2)	/	/	7.16 / 7	9* / 7	8.16 / 7	9.05 / 7	7.31 / 7	7.48 / 7
entrance + corridor approximate net area (m^2)	5.23	5.47	6.77	6.20	6.85	6.35	6.71	4.59
balcony approximate net area (m^2)	4.03	4.46	1.70	2.56	2.83 + 2.32	2.97	2.61	4.47
parents' bedroom width / minimum required width according to the regulations (cm)	330 / 280	275 / 280	284 / 280	268 / 280	273 / 280	270 / 280	273 / 280	270 / 280
children's bedroom width / minimum required according to the regulations (cm)	/	/	210 / 210	210 / 210	217 / 210	260 / 210	210 / 210	260 / 210
living room width / minimum required according to the regulations (cm)	365 / 340	280 / 340	340 / 340	270 / 340	310 / 340	360 / 340	339 / 340	275 / 340
kitchen width / minimum required according to the regulations (cm)	220 / 170	167 / 170	143 / 170	155 / 170	165 / 170	140 / 170	170 / 170	120 / 170

3. SURVEY

For the purposes of the research, a survey was conducted in one of the parts of the residential buildings where the analyzed apartment number 5 is located. This building, completed in 2018, was selected for the survey because one of its parts contains apartments of approximately the same area and similar organization, which was convenient to create a picture of how different users experience spaces with a similar functional organization. Building part consists of 4 residential floors, with two apartments each (of net area ranging from 46m^2 to 60m^2). Out of a total of 8 apartments, 6 were surveyed (the first floor was omitted, since its functional organization deviates from the functional organization of other floors). Figure 4 shows the plan of one building's floors. The apartments on one floor are mostly designed according to the principle of mirroring the scheme in relation to the longitudinal axis, with slight variations.

The users of the apartments belong to the younger and middle-aged population (up to 55 years of age), and are mostly married couples with and without children. The questions that were asked through the survey are as follows:

1. Does the functional organization of the apartment meet the needs of all users in the apartment?
2. Are you satisfied with the size of the apartment in relation to its current number of users?
3. Are you satisfied with the design of the entrance part in the apartment?
4. Are you satisfied with the size of the living room and dining room in the apartment?
5. Are you satisfied with the size of the kitchen in the apartment?
6. Are you satisfied with the size of the bathroom in the apartment?
7. Are you satisfied with the size of the bedroom/bedrooms in the apartment?
8. Are you satisfied with the size of the open area/open areas in the apartment?
9. Do you think that the absence of additional toilet in the apartments is justified?
10. If your apartment does not have a separate workroom, do you think that within some area of the apartment (bedroom, living room...), it is possible to organize a "work corner" that suits you?
11. Do you think that the day (living room and dining room) and night areas of the apartment (bedrooms) are adequately separated?
12. Do you think that your apartment is flexible enough to adapt to the future needs of users?

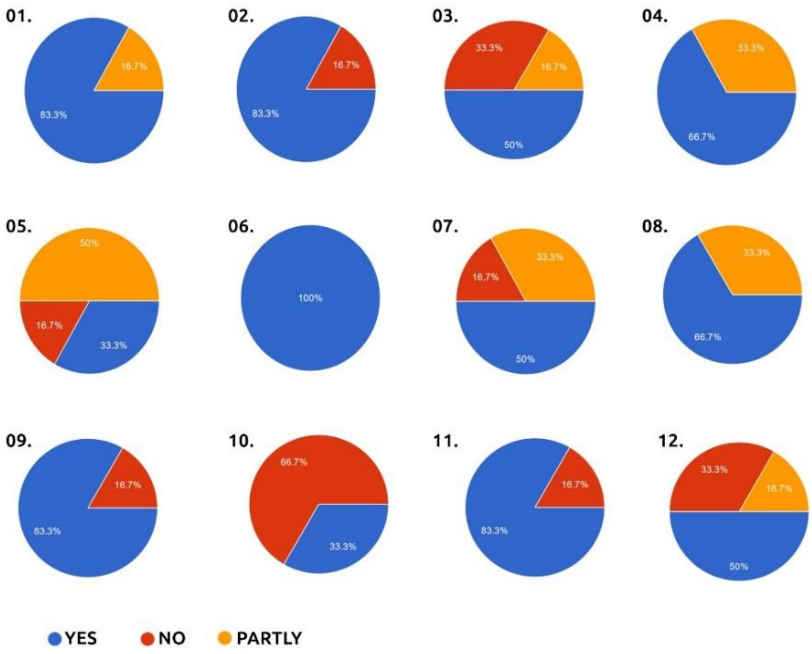

Figure 3. The results of the survey shown in graphics - answers to questions 1-12*, source: authors*

The following results emerged from the survey (Figure 3): About 80% of respondents estimate that the functional organization of the apartment meets the needs of all users in the apartment. 20% deem that the functional organization partly meets the needs of all users, and the small area of the children's room is cited as one of the reasons. Compared to the current number of users, over 80% of respondents are satisfied with the size of the apartment. When it comes to individual parts of the apartment, 50% of the respondents consider the entrance part not being designed according to their needs. As an explanation for this answer, they state: "problem in hygiene", due to the overlapping of the paths, as well as the fact that it is not clearly separated. 1/3 of respondents are not completely satisfied with the size of the living room and think that it is small when there are also guests staying in the apartment. Only 1/3 is satisfied with the size of the kitchen in the apartment, while the rest of the respondents believe that the kitchen is small and that there is a lack of work space in it. The size of the bathroom was assessed by all respondents as satisfactory. Half of the respondents said that the bedrooms are small and not enough functional. 2/3 of users rate the size of the open areas in the apartment as adequate, but cite comments such as: "it would be nice if the loggia was larger" and "if open spaces were bigger, they would be more functional". More than 80% of respondents do not think that the lack of a toilet, in addition to a bathroom, is unjustified. They agree that it is better to increase the area of other facilities at the expense of the omitted toilet. 2/3 of respondents states that there is no place in the apartment to insert an adequate work corner, 83.3% say that they are satisfied with the zoning of the apartment, and 50% are of the opinion that the apartment is not flexible or is partially flexible to adapt to the future needs of users: "The apartment is ideal for a family of four while the children are younger and can share a children's room"; "due to the minimal dimensions, it is difficult to add any content".

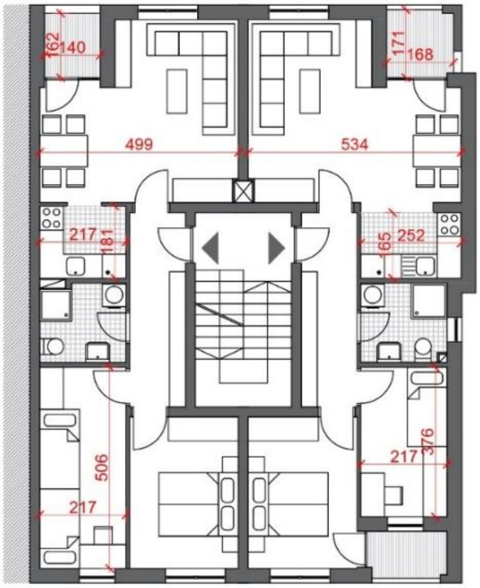

Figure 4. Apartment number 5 within the floor assembly, source: drawing is authors' interpretation

4. DISCUSSION

The analyzed apartments were taken as a representative of the currently most demanded apartments in terms of net area on the market. Their structures are such that they correspond to the number of users from 2 to 4, which would mean that they correspond to the needs of those who most often buy them, namely young married couples at the beginning of family formation. By comparing the total net area of the apartment and the contents placed in it, it can be concluded that the degree of utilization of the space of the apartment is maximal, but, in that regard, the question can also be raised as to whether this affects the quality of the living space. Based on the previous analysis, we can look for an answer to that question.

In the largest number of analyzed apartments, it is noticeable that the surfaces of daily contents are below the minimum, while in the rest of the examples they are on the border with the minimum. This is also logical, given that the emphasis in all design solutions was placed on the formation of as many bedrooms as possible, so the surfaces of the daily contents had to be reduced. In all examples, an open space variant of the organization of daily contents is observed, that is, the unification of the kitchen, dining room and living room into one unit. This also affects the more rational use of surfaces, because the communications within the given spaces overlap and compress each other. According to G. Jovanovic [6], the number of seats at the table in the dining room, as well as the number of seats in the living room is determined by increasing the number of household members by two. However, in many examples, in the dining area, there is no possibility to extend the table for two additional places for guests. In 5 out of 8 analyzed apartment designs (Figure 6), the widths of the living rooms are below the minimum (in apartment number 4 the deviation is as much as 70 cm), which cannot be justified in any way, having in mind the importance of these contents in the functioning of an apartment - the living room and the dining room are gathering places for all family members, and sometimes guests too. Deviation in the prescribed dimensions of the bedrooms, especially double parental bedrooms, is evident in 6 out of 8 analyzed examples (Figure 5), which affects the non-functionality of the spaces themselves, that is, results in tight communications and inadequate working dimensions of the usable spaces. According to the Rulebook [5], in two-and-a-half-room and larger apartments, it is necessary to design at least one room for two people with a minimum width of 280 cm. Also, 6 out of 8 analyzed examples have a problem with the inadequate width of the kitchen, which disables adequate work in the kitchen, and which, due to the minimal area, barely manages to accommodate the most basic kitchen elements. The dysfunctionality of the kitchen was also shown by the results of the survey, in which users highlighted the lack of a work surface as the main comment. Slight increasement in dimensions in the kitchen could significantly improve its functionality, without particularly affecting the final area of the apartment. If we look at the sketch of the two neighboring apartments in Figure 4, we will see how a slight overhang in the part of the apartment number 5, of only about 30 cm, in the part of the dining room and kitchen, made for the reasons of architectural shaping of the building, significantly influenced the improvement of the functionality of the mentioned spaces. The kitchen was provided with a larger work surface, which, when it comes to spaces on the border of minimal dimensions, is significant, even though it was only half of the modular size.

In all cases, children's rooms are designed as rooms for one person, which is justified considering the total net area of the apartments. However, in certain examples, in which the rooms are not reduced, but their width enables the formation of two-bed organizations, with minor interventions in their length, there is a possibility of creating children's rooms in which two children could fit. Again, the question of the durability of such a solution arises here, because children should be separated after a certain age. According to D. Ilic [7]: "It can be considered optimal that a child after the third year should have his own room, which first of all represents a bio-physiological need, but it partly satisfies the needs of other natures, and at the latest with the sixth year, because over that age, the parents objectively perceive the child's stay in the parents' room as a disturbance, with all the negative consequences that such a feeling can cause. With the birth of the second child, the need for a separate room for the first child is immediately actualized, regardless of age. Children of different genders should be in separate rooms from the beginning, and at the latest when the older child reaches the teenage age (10 years). In the teenage years, there is an intense need for independence, which is why children of the same genders should have their own separate rooms (at the age of 12-14 at the latest).

As a positive comment on the analyzed designs, it can be singled out that all apartments are designed with an open area, despite the fact that the Rulebook does not set any condition for this. If we take into account that apartments, unlike houses, do not have yards, the open area is an element that plays an important role in the apartment, as a basic connection with the outside environment. However, what is debatable are the dimensions of the designed open areas, which to a large extent, inadequate sizes, can reduce the functional value of open spaces.

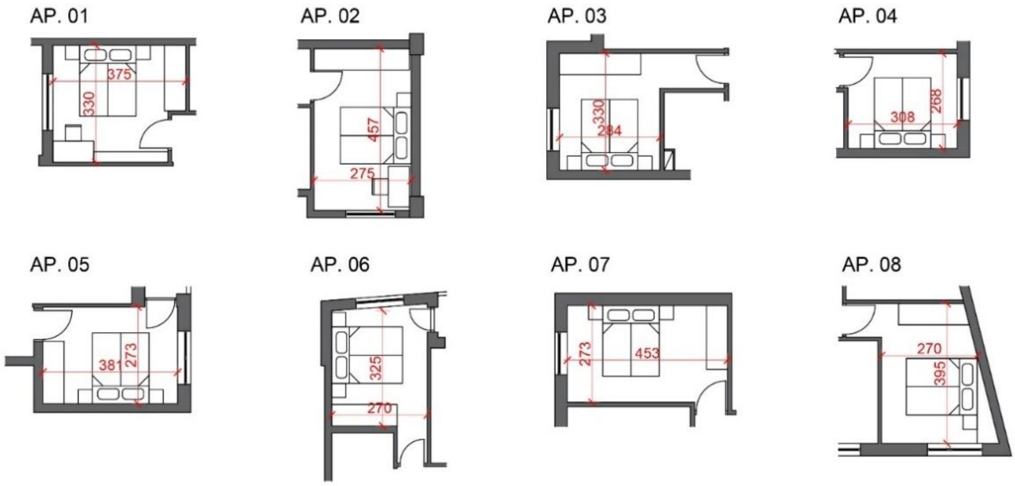

Figure 5. Analysis of the dimensions of the parents' bedroom in apartments*, source: drawings are authors' interpretation*

Figure 6. Analysis of living room, dining room and kitchen dimensions in apartments*, source: drawings are authors' interpretation*

What is noticeable in all the examples is the problematic design solution of the entrance part. Again, due to the tendency to reduce the total area of the apartment, the entrance part is usually merged with the corridor, which is the main communication through the apartment. From the entrance door, one enters the apartment directly, there is no vestibule that would serve as a buffer zone between the inner private space of the apartment and the common communications in the building. In the survey, there are also comments that dirty and clean paths in the apartment intersect at the entrance, which affects the hygiene of the apartment (Figure 7a).

Figure 7. a) The entrance as a place where communications are intersected*;*
b) Potential modifications within the daily zone; *c)* Potential place to form a work corner*, source: drawings are authors' interpretation*

When it comes to the flexibility and adaptability of the space to new needs of the users, it can be said that its degree is very low, and the reason for this is found in the minimal areas of each individual room. However, some smaller changes can be made, which could affect the improvement of the original design solution. An example is given for the apartment number 5 (Figures 7b and 7c). By inserting a counter between the kitchen and the dining room, it is possible to increase the working surface of the kitchen, as well as the storage space that would be found under the counter. In this way, the kitchen gets another lane to work on, which relieves its initial workload. By combining the living room and the dining room as a whole, it was possible to compress the communication spaces in these rooms, leaving enough space to add two more seats to the dining table. By rotating the direction of door opening towards the living room, in addition to better views when entering, the space on the left side of the entrance to the living room becomes more functional, and if necessary, it can also be used to create a work corner. (Figure 7b) It is possible to create a mini work corner in the bedroom, on the side of the window, by throwing out the bedside table, using a bed with a smaller width (140 cm) and moving it as far as possible towards the closet. (Figure 7c)

5. CONCLUSIONS

Regardless of diversity of the design solutions, it can be concluded that the functional schemes of *medium-sized apartments* are essentially very similar:

- The daily zone is separated and designed according to the principles of the open space concept, combining cooking, dining and living area. These 3 contents are usually linearly connected to each other, so that the dining room is located between the living room and the kitchen and has indirect lighting. A more favorable variant, in terms of natural lighting and ventilation, is the one where the living room and dining room are lined up so that they both lie on the façade plane.
- The rooms in the apartment are most often accessed through the same corridor. The central position of the entrance divides the corridor into two

zones that form the day and night part of the apartment. If the position of the entrance is moved peripherally, the zoning is broken.

- *Medium-sized apartments* are the most comfortable if they contain only one bedroom. As the tendency in practice is to gain the maximum number of bedrooms for the same net area, apartments generally have two bedrooms, one of which is at least 210 cm wide, the so-called reduced room. This certainly affects the reduction of the area of other content in the apartment.
- The toilet is often left out of the design solution, even though its necessity in certain apartment's structures is prescribed by the regulations.
- An open area occurs next to the living area, and can often be additionally accessed from bedrooms.

In practice, it has been shown that when designing two-room and larger apartments, toilets are often omitted. User experience shows that in apartments with two bedrooms, there is no need for an additional toilet. At the expense of the toilet, the areas of other contents can be increased, which can be considered justified when designing medium-sized apartments. In this regard, as one of the conclusions of this research, stands out the proposal to omit the requirement that two-and-a-half-room apartments must have a toilet in addition to a bathroom from the Rulebook. Also, due to the importance of the existence of open areas in the apartment, what was especially imposed as important during the lockdown situation caused by recent global COVID pandemic, the proposal is to introduce to the Rulebook an obligation to design open areas within the apartment, and to define their minimum dimensions, in order to make them be functional. The problems encountered at the entrance to the apartment indicate that during the design process, special care should be taken to give greater importance to this part of the apartment, because it is the first contact with the apartment and the place of transition from one environment to another.

In a large number of medium-sized newly built apartments, there is noticeable a deviation in terms of area and dimensions from the minimum values prescribed by the Regulations, that is, the apartments do not meet the minimum conditions prescribed by the Regulations. In this regard, as a general conclusion of the research, it is stated the necessity of engaging professionals, which would carry out a detailed control of the facilities before granting the use permit.

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21ST CENTURY ARCHITECTURE TRENDS - NEW CLOCKWORK ORANGE CHALLANGE

Dejan Vlaškalić[1]

Abstract

In his book Cities for a small planet, Richard Rogers emphasizes that he is "wild about technology but not about technology run wild". The development of technology at the end of the 20th century also contributed to the 21st century appearing earlier. Today, technology enables the realization of projects that even in the recent past seemed utopian (unbuildable). However, it would be better if some projects remained unbuilt, on the paper or on the screen whatsoever. In the absence of true revolutions, it seems that the only one on the market is the Mass-timber revolution. With absence of self-criticism it looks like it will eat its own children as most of revolutions do. Mass Tiber myths show that it is not all black or white, good or bad, more or less sustainable. More efforts should be made to improve human environment, not in the flourishing greenery on 3D renders of contemporary designed buildings. All these emerging questions are excellant for making corrections on the paths for finding the right answers. But they also often blur the trends of architecture deconstruction: from earthquakes that reveal reckless construction to war conflicts that can only reveal senselessness. Artificial intelligence suggest us in 21st century, as protagonsts "immersed in this hyper-connected world", to change Clockwork Orange title to Digital Dystopia. However, before this possibly happens, architecture must find the new paths, the new technologies and the new value system. Even the new title.

Key words: *Technology, Mass Timber, Skyscrapers, Dystopia, Clockwork Orange*

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1. INTRODUCTION

“What’s going to be then, eh?” [1]

… the question is now. In fact, it's one of the few eternal questions that we always get an answer to. We would like to know it right away, but it comes exactly after the period of time the question is asked for. Anthony Burges in his novel *A Clockwork Orange* (1962) sets it up in the very first sentence of the book. However, that question was asked for the near future, which the reader experiences as extremely violent, apparently as Stanley Kubrick does, the director of the movie with the same title (1971).

In order to assure us what it would look like architecturally, the *mise-en-scène* suited him the best, was the brutalist South Thamesmead housing estate in south-east London, which had just been completed at the time of shooting. In 60s it has been thought that this kind of urbanism and that architecture style would only experience its glory in the days to come. But in the coming years, brutalism experienced its decline in architectural trends and prevailing styles, even its collapse in public opinion, although in the last few years it has been rediscovered almost as a beauty.

Skybreak House, one of the first Team 4 (Sue Brumwell, Wendy Cheeseman, Norman Foster and Richard Rogers, 1966) projects, served as the scene of brutal rape and beating in Clockwork Orange movie. In contrast of that scenes, the interior is very reduced, refined and as such it looked futuristic at the time. The *Retreat pod* completed this image by design, at the same time providing a place to escape from everything, i.e. the world itself. We should not forget that Kubrick made this movie after the iconic 2001: Space Odyssey (1968), also trying to persuade us what kind of a future awaits us. The above mentioned Richard Rogers and Norman Foster are also the luminaries of hi-tech architecture, a style they developed each in their own way during long time careers. A style that even at the beginning of its creation already had a SciFiction aura. The most exposed example which actually has opened the game was certainly the Pompidou Center in Paris, by Rogers and Piano (1977).

However, Rogers writes: „The history of architecture should be seen as a history of social and technical invention and not of styles and forms”. [2] And furthermore: “The buildings of all epochs have celebrated the technology of which they were built. The steel framework of the Pompidour Center gives order and flexibility of use. The double-span flying buttresses of Notre Dame enable the Gothic cathedral to reach up to God.”

In his book *Cities for a small planet* [3], Rogers emphasizes: “I am wild about technology but not about technology run wild”. And to end with quoting this British architect, who has been engaged in deep thoughts about architecture and not only its future all his life, stating what is his approach to sustainability: “mobilizing creative thinking and technology to secure humanity’s future on this small planet of the finite resources”.

2. TECHNOLOGY

The development of technology at the end of the 20th century also contributed to the 21st century appearing earlier. Today, technology (construction, materials...) enables the realization of projects that even in the recent past seemed utopian (unbuildable). So the question is for example how far is Superstudio conceptual Continuous Monument: An Architectural Model for Total Urbanization (1969), from 170 km long linear city known as The Line, already started to be built, including some famous architects contributed on the project. They say it will be the city of the future, without cars, without streets, with zero net carbon emissions… *Chepooka*, let us use the word for "nonsense" from the Nadsat language invented for the Clockwork Orange novel. This leads only to the following logical question: would it be better if some projects remained utopian, on the paper or on the screen whatsoever.

This is also reflected in the construction of skyscrapers, and we will find confirmation, for example, in the research made by architecture web magazine Deezen on 9/11 2021 [4], exactly two decades after the collapse of the Twin Towers. Similar to the yachting industry, the terms super-tall (buildings above 300m) and mega-tall (buildings above 600m) are now appearing in architecture as well. The 1 km height of the building, which is a goal for itself (take a look at the Saudi Arabia's Jeddah Tower destiny, and there is talk of 2-kilometer skyscraper in Riyadh) is *bezoomnny* („mad" on Nadsat language).

Moreover, most skyscrapers have glazed facades – „That's how the light gets in" but require high levels of air conditioning, so they are very energy inefficient („There is a crack, a crack in everything", just to reverse Leonard Cohen lyrics).

The terms skinny skyscrapers (minimum width-to-height ratio of 1:10) were also introduced, and there is no surprise when we face super-skinny (1200 Bay Street tower in Toronto, Herzog & de Meuron) and other fashion terms in the world of architecture. The statistics is telling us that before 9/11/2001 the number of buildings over 200 meters was 285 and after that the number of 1.480 on this *prêt-à-porter* list speaks for itself. And the fact that 84% of the skyscrapers standing today have been built in the past 20 years.

One of the better analyzes of this „race to the sky" can be found in Charles Jencks article about „iconic buildings" [5]: „Monuments have lost their power to persuade, and enshrine permanent memories, but society has hardly lost its appetite for grand structures. Quite the opposite: the self-important building characterizes our time, partly because the size of commissions becomes ever larger under late-capitalizm and partly because architects and their commercial products must compete for attention." For Jencks „this is a cause for considerable irony, and a little analysis". We will do the same with some of 21st century trends: carbon neutrality, mass timber, greenery…

3. TRENDS

In the absence of true revolutions, it seems that the only one on the market is the Mass-timber revolution, and with absence of self-criticism it looks like it will eat its own children as most of revolutions do. We will highlight only one of the more objective views of this wooden trend. It is a series of essays by Laver Architecture together with Atelier Ten [6] that analyze Mass Tiber myths: *Mass timber buildings are carbon neutral* (important, but there are other critical factors), *Wood is always more sustainable than concrete* (solely utilizing wood products does not automatically make buildings more sustainable), *Mass timber buildings absorb carbon emissions* (Timber buildings hold carbon absorbed by trees, but timber buildings do not actively absorb carbon), *All wood is good wood* (Wood products are only as “good” as the forestry practices associated with those products).

The facts they listed for each myth are so logical that they almost don't even need to be explained. Despite this, in the architectural global community, projects with the suffix "biggest” (or similar *bolshy* term on Nadsat language) mass timber object still stands out. One of the examples could be Stockholm Wood City (Scandinavian studios Henning Larsen and White Arkitekter) - „the world's largest mass-timber development“ [7]. Or, Ascent tower in Milwaukee (USA) by Korb + Associates Architects, the world's tallest mass-timber building at the moment. Architects claim that "they're not trophy hunters", but the project of the 19-storey building by providing additional parking spaces has changed to 25 floors and with the current height of 86.6 meters it surpasses the previous tallest mass-timber building, Mjøstårnet in Norway, by a whole meter [8].

Another example of a detour in architecture is the hasty, uncritical response to the recent pandemic. One of the few who saw the crisis differently (it will turn out to be right) and through the historical context of civilization (so we are talking about experience) was Norman Foster. One of his paradigmatic articles was from the year 2020 entitled „The pandemic will accelerate the evolution of our cities“ [9]. „In the period since the start of the pandemic it might seem as if everything is different, but in the long term, I would suggest that rather than changing anything, it has merely hastened and magnified trends that were already apparent before the virus struck.“ And it was sublimated into one sentence on his Future of cities illustration, exhibited at the Royal Academy of Arts in London in October the same year: „Covid 19 will hasten existing trends, will not create new trends“.

Is the 15-Minute City (project created by Dan Luscher) trend? Is it new idea that "Everyone living in a city should have access to essential urban services within a 15 minute walk or bike" [10]? We would say not. If we are talking about "small towns", the explanation seems more clear. When we are talking about cities with million plus inhabitans, equal development of city municipalities also could achieve that. This applies, for example, to Belgrade in the 20th century, in which even *sinny* („cinemas“ on Nadsat language) were accessible to the local population "on foot".

“Big city is no longer modern”, Frank Lloyd Wright writes in the book „The Disappearing City” [11]. However, when he describes new scale of measurement, he also states that “the man seated in his motor car with its powers being the unit of that standard rather than the man standing on his legs”. So, what is a trend or perhaps an utopia today, was a vision or an anti-utopia yesterday. Or other way around.

One of trends nowadays is literally throwing as much greenery into 3D renders of contemporary designed buildings as your eyes can get. It looks nice, it is ecological, it is almost a sacred thing that cannot be questioned. But even if we exclude applicability in different climatic zones, let's not forget at least about its "maintenance". And a visualization of how those buildings and projects would look like if abandoned due to lack of will, money or because of global warming. If the greenery would be the verb, the definiton shuld be: existing concrete and asphalt surfaces handing over to future grass and trees city areas.

4. CONCLUSION

All these emerging questions are excellant for making corrections on our paths for finding the right answers. But they also often blur the trends of architecture deconstruction: from earthquakes that reveal reckless construction to war conflicts that can only reveal senselessness. So, if we accept the theory that the 20th century was the shortest century so far (from 1918 to 1989, from war to revolution), 21st threatens to be even shorter (from revolution, through pandemic to… dystopia).

So, the architecture is, and we are all, in 21st century more than 30 years now, very very deeply, although we still refuse to face it. Century which adorse everything short and quick, and specially new abbreviations, including AI. When you try to use an artificial intelligence tool for writing an essay (ChatGPT for example) with the title "Architecture in 21st century", the result could be impressive for the moment. Including very optimistic AI conclusion: „The future of architecture is undoubtedly intertwined with the advancements in technology, and the possibilities are truly limitless." If you try to do the same with title „21st Century Clockwork Orange", first of all AI would suggested the new title for the book: „Digital Dystopia", and the new setting: „The story takes place in a near-future metropolis, where advanced technology and social media dominate every aspect of society. The city is filled with augmented reality overlays, surveillance drones, and virtual reality experiences. The protagonist, Alex, is a troubled young man immersed in this hyper-connected world."

However, before this digital dystopia conquare Alex and the mankind, architecture, as we said, must find the new paths, the new technologies and the new value system. Even the new title.

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PROGRAM ACTIVITIES FOR SUSTAINABLE RURAL DEVELOPMENT: CASE STUDY, VILLAGE VUKMANOVO, NIŠ

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Abstract

This paper deals with the analysis, proposals, and development of program actions and measures aiming at a sustainable development of the village of Vukmanovo. During the case study analysis, survey analysis, general data about the village and its development characteristics were collected. The main shortcomings of the village are the constant migration of the inhabitants of the village to cities and thus the decrease of the total number of inhabitants in the village, the absence of institutions of extreme importance for the life and functioning of the villagers such as a clinic, post office, kindergarten, institutions for higher education, roads are in bad condition, etc. Also, in addition to the mentioned shortcomings, there is insufficient activity and insufficient interest of the local population in improving the conditions in the village. Using SWOT analysis, development problems and potentials are shown. The paper defines the strategic directions of sustainable development, general and specific goals, as well as program actions and measures.

Key words: *Vukmanovo***,** *village, sustainable development, measures, rural development, rural architecture*

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1. INTRODUCTION

Rural region represents a territorial unit with one ormore small/middle-sized towns surrounded by a large area of open space, with a relatively low population density and regional economic structure, which reflects the situation of a certain labour market [1]. Rural development is an ongoing process aimed at creating sustainable, prosperous and active rural communities. The basic goal of sustainable rural development is to improve the quality of life of the rural population, first of all, through income growth and the integration of rural areas into the wider system through health, educational, cultural and other institutions [2]. On the territory of the Republic of Serbia, in mountainous and border areas, approximately 85% of the territory is undeveloped and therefore the most endangered area [3]. The space of southeast Serbia, also the city of Niš, has many specifics resulting from their geographic position, spatial arrangement, historical or inherited factors, tradition, economic development and human resources [4]. Villages are characterized by a small number of inhabitants, their constant migration to cities due to better living conditions and employment opportunities, as well as poorly developed external functions. The infrastructural equipment of the village is at a weak level, the roads are in bad condition, they are not asphalted, most of the villages have only one store, no post office, no clinic, and some villages do not even have a primary school. It is necessary to determine the development goals of the village and to identify the shortcomings that exist and the conditions that need to be improved for the development of the village with the help of strategic initiatives, strategic documents of development programs, measures and activities, the most important of which are the Rural Development Policy and the Rural Development Program that resulted from it. In recent decades, the mentioned programs have been implemented over a period of six years. The current program period is 2021-2027. in which four development directions are recognized. The main development directions are represented by: economic development, territorial development and environmental protection, social development and management [5]. Also, after defining the problems and shortcomings of the village that are analyzed, it is necessary to determine and specify the development measures that will contribute to its improvement. The village of Vukmanovo, located near the city of Niš, was chosen for the case study in this paper. The aim of the paper is to show, through the analysis of the selected village, the possibility of implementing mechanisms and measures in accordance with the valid strategic document at the local level of the city of Niš.

2. METHODOLOGY

The methods defined in the paper are: description, observation, SWOT analysis, survey and case study method. The analysis method was applied for the basic development and strategic determinants of rural development. The analysis method was applied when describing the functional structure and utility equipment. Locals used polls to indicate the current situation in the village and the shortcomings or weaknesses in the village. Using the SWOT analysis, the strengths, weaknesses, opportunities and threats for the possible development of the village of Vukmanovo are shown. The observation method, the mentioned survey and the case study method were chosen to define the mechanisms, measures and examine the possibilities for village development.

3. RURAL DEVELOPMENT – SETTING THE CONTEXT

From a planning and geographical perspective, rural is defined as a spatial category described by size features, settlement structure, or socio-economic features [6]. In the EU, rural areas represent an ideal place for a healthy life where people concentrate on strengthening the economy, producing healthy organic food, i.e. domestic products. The population on their own chooses the village as a place to live. The EU Rural Development Policy (RDP) plays a key role in the realization of the development process of rural areas which is based on three strategic objectives: 1. encouraging the competitiveness of agriculture; 2. ensuring sustainable management of natural resources and climate change; 3. achieving balanced territorial development of rural economies and communities, including creating opportunities for increased employment [7].

In Serbia, one of the problems of rural areas is stagnation, i.e. lagging in development that has been going on for decades. In the aforementioned villages in the EU, in Serbia, there is a marked demographic emptying of villages and strong depopulation, the economy is poorly developed and a low level of physical and social infrastructure is noticeable.In Serbia, rural population accounts for 43.60% of the total population, while about 85% of the national territory consists of rural areas [8].

Rural development can be defined as the process of improving the quality of life in relatively isolated and sparsely populated areas and, at the same time, the process of improving the lives of people living in those areas. Three basic development areas are important for the development of rural areas: 1. economic development; 2. arrangement of space and settlement; 3. social and cultural development [9].

4. CASE STUDY: VUKMANOVO VILLAGE, NIŠ

The paper investigates the village of Vukmanovo, its geographical position and the structure of the village. In addition to the aforementioned, an analysis of the demographic, morphological, urban and functional structure, as well as an analysis of the communal equipment of the village, is carried out.

4.1. General Information about the village

Geographical position

Vukmanovo is a populated place located about 10 km from the city of Niš and belongs to the municipality of Palilula (Fig. 1a). It belongs to the Nišava district and is located on the southern edge of the Nišava basin. Besides the village of Vukmanovo, there are two other villages, Gabrovac and Berbatovo.

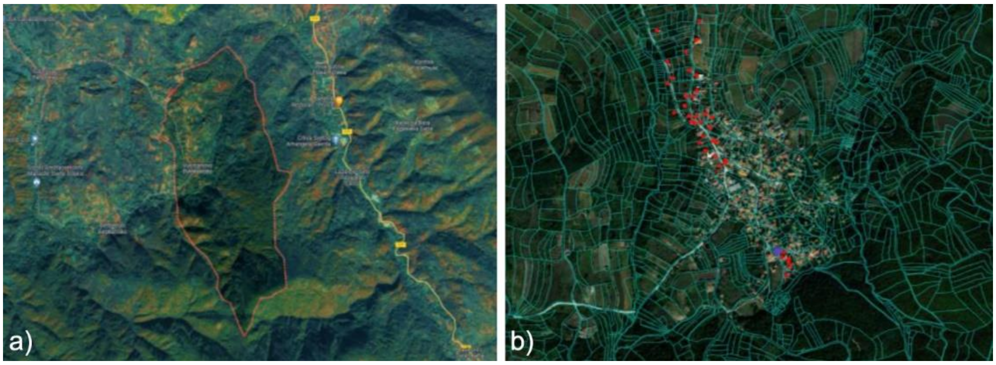


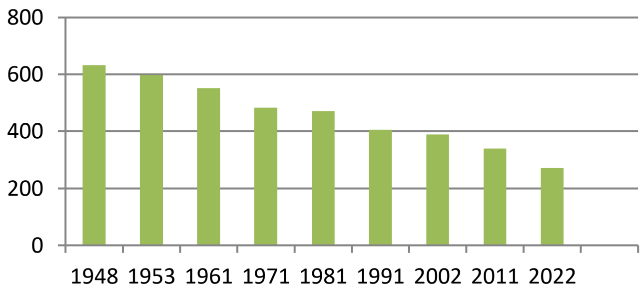
Figure 1. a) View of the village Vukmanovo, https://a3.geosrbija.rs/ ; b) *layout drawing of the compact type of village and the radial structure and appearance the blocks within the village, https://a3.geosrbija.rs/*

Urban-morphological structure

Vukmanovo is an example of a compact village that was built without planning. Judging by the shape of the village, it can be concluded that the structure of the village is radial, the streets are arranged radially. The mountainous relief is reflected when looking at the blocks that are of irregular shape and the placement of buildings that are placed next to each other (Fig. 1b). Buildings, mostly individual houses occupy a larger part of the plots, while yards occupy a smaller part. The main square of the village is located in the central part where there is a primary school with a field as well as the only shop in the village. If you look at the approach from Gabrovac, before the square itself there is a main fork in the streets. Buildings and arable land are positioned along the main streets and access paths.

Population

According to the 2022 census of the Republic of Serbia, the village of Vukmanovo had 272 inhabitants, which is less than 1% of the total population in Serbia. Given the number of inhabitants, which is less than 400 inhabitants, the village of Vukmanovo belongs to the group of small villages. The largest number of inhabitants in the village was recorded in 1948, when the number of inhabitants was 633, while the smallest number of inhabitants was recorded in 2022 at the last population census. Between 1948 and 2022, the number of inhabitants decreased from 633 to 272 (Graph 1).



Graph 1. Population of Vukmanovo village during the period 1948-2022

Out of a total of 272 inhabitants, 161 are male while 111 are female. The largest number of inhabitants, 27 people are between 65-69 years old, 26 of them are people between 50-54 years old. The smallest population is made up of locals aged 15-19. The average age index is 51.02. The adult population consists of 241 inhabitants.

Functional structure and communal equipment

The village has only one educational institution - the advanced department of the "Branko Radičević" Elementary School (Fig. 2a). As part of the school, there is an asphalted field where the younger population of the village often gathers (Fig. 2b). In addition to the field, the school also has adequate furniture for children to play. The school is old but not in a visibly bad condition. There are children in the village who attend the mentioned school. There are no kindergartens or other educational facilities in the village. There is no clinic or any other health facility. The former memorial home in Vukmanovo is closed (Fig. 2c). There is no social protection institution, no cultural facility, and no post office in the village. If necessary, the inhabitants of the village go to the post office located in the village of Gabrovac.

Figure 2. a) Primary school “Branko Radičević”, b) school playground, c) closed memorial home, source: personal archive, May 2023

Vukmanovo has one religious building - the Church (Fig. 3a). There is a cemetery near the church (Fig. 3b). The main meeting point in the village is the area from where the streets "branch" to the other sides of the village. Within that space, there is the only service facility – the retail store "Zoki i Boki" (Fig. 3c). Across the road from the drag store, there is the already mentioned Primary School. Among other things, it also serves as a place where the population of the village most often gathers. In order to make a larger purchase, the inhabitants of the village go to the city of Niš.

Figure 3. (a) Village church, (b) village cemetery, (c) only shop in the village, source: personal archive, May 2023

Old and dilapidated houses predominate in the village (Figure 4a). In addition to the old houses that predominate, new houses are often found that are built right next to the old ones (Figure 4b). Most of the facades are dilapidated. There are several houses that are under construction (Figure 4c).

Figure 4. a) Old and abandoned village house, b) an example of a new house next to the old one, c) new house under construction, source: personal archive, May 2023

The village of Vukmanovo does not have special landfills for garbage, but only uses existing containers when it comes to municipal waste, and in most cases they dump the waste into the village river. The biggest problem in the village is the lack of water for daily use and drinking. As for the waste water drainage, it is also drained into the river. Public suburban traffic is circular - 23K: Niš - Vukmanovo - Berbatovo - Niš and is well organized - the bus runs every weekday as well as on weekends. The condition of the roads in the village is not at a satisfactory level. The road is of poor quality, unsuccessfully "patched" (Figure 5a), and parts of the roads leading to certain households and cemeteries are unpaved (Figure 5b). Also, the safety of the locals is not at an adequate level because the street lighting is also weak. Adequate signage has been placed along the streets everywhere (Figure 5c). At the entrance to the village there is a board with the inscription "Vukmanovo" (Figure 5d).

Figure 5. a, b) Roads in the village, c, d)sign and Vukmanovo sign at the village entrance, source: personal archive, May 2023

4.2. Development problems and potentials - SWOT analysis

In addition to the analysis of available statistical data and development documents, a SWOT analysis was also used to assess the development problems and potential of the village. The results of the SWOT analysis are shown in Table 1.

Table 1. SWOT analysis of development potentials and problems of Vukmanovo settlement

Strengths	*Weaknesses*
- favorable geographical location - connectivity and accessibility - good infrastructural connection between the village and the city - available land resources for agricultural production and fertile land - natural resource for the development of a unique offer of services and products/rural tourism, plant and livestock production and processing - various natural attractions and biodiversity, mountains, clean air - the existence of a church and a cemetery in the village - the existence of the outlying part of Elementary School "Branko Radičević" - existence of grounds for recreation	- population depopulation and unfavorable age structure in rural areas - poorly accessible communal infrastructure in the villages as well as facilities of the standard of living (institutions, education, healthcare, cultural center, internet) - rural tourism is not recognized as a development potential, inadequate knowledge in the field of agrotourism - inadequate support for tourism, trade and hospitality - lack of tourist offers for tourists to stay for more than two days - lack of adequate space for depositing waste - lack of production capacity, purchase stations or any other production plant that would motivate residents to start production not only for their own needs - insufficient commitment of the population to contribute to the general development of the village - insufficient encouragement and investment by the state
Opportunities	*Threats*
- sources of funding for investments in agriculture and rural development/LGU fund, Ministry of Agriculture, Forestry and Water Management, Ministry of Rural Care, foreign organizations, etc. Programs of the Republic to support young people in the countryside - announcements by the state for large investments in infrastructure in the countryside in order to retain young people - marked mountain hiking trails for mass tourism, not just for mountaineers	- quick withdrawal of agricultural producers due to the disappointed expected profit - lack of motivation among young people to engage in agriculture - present poverty, indebtedness and slow economic development - limited purchasing and processing capacities and long trade chains - lack of quality standards in the provision of tourist services

4.3. Defining strategic directions of sustainable development, general and priority goals, program actions and measures

In order to adequately develop the village, i.e. to implement the appropriate directions for its development, it was first of all necessary to look at its positive and negative aspects and to pay attention to the existing shortcomings using a SWOT analysis. After the problems of the village were established, it was necessary to devise ideas and measures for solving them, in in which direction the further development and growth of the village should be oriented, as well as the fact which investments are necessary for the selected location.

Based on the conducted analyzes and surveys of the residents of the village of Vukmanovo, it was established that the first development direction of the development of the village was Development direction I: Economic development.

The priority goal for Development Direction 1 is:

1.3. Competitive agriculture and dignified quality of life in rural areas.

The specific action and measure for achieving priority goal 1.3 is:

1.3.6. Organizational strengthening of agricultural production - in the village, each household produces food separately, whether it is agriculture or animal husbandry. There is no village market or any other place where residents can sell their products. It is necessary to support the village population and give them the opportunity to develop their production of healthy (organic) food.

Table 2. Program action I – Economic development

Goals		*Measures*
Direction 1	*No.*	*Direction: Territory, infrastructure and environment*
Priority goal 1.3.	*1.3.6*	*Organizational strengthening of agricultural production*

The second chosen strategic direction for the improvement of the village is Development Direction III, which is devoted to social development.

The goal for Development Direction III is a balanced and comprehensive improvement of life in the city of Niš.

The priority goal of Development Direction III are 3.2 and 3.3:

3.2. – Creation of conditions for the development of modern, quality and accessible education for all.

Concrete action and measure to achieve the priority goal 3.2. is:

3.2.7*. Adaptation of educational programs to the needs of the economy* - in the village, each household produces food separately, whether it is agriculture or animal husbandry. There is no village market or any other place where residents can sell their products, no one is engaged in food export. It is necessary to support the young inhabitants of the village and give them the opportunity to get an education, focus on economic programs and later develop their business into the production of healthy (organic) food.

3.3. – Ensuring a healthy life, social equality and inclusion for all people of all generations.

Concrete action and measure to achieve the priority goal 3.3. is:

3.3.18. *Revitalization, reconstruction and adaptation of existing sports, recreational and tourist facilities and terrain for sports, recreation and extreme sports* - the terrain of the village of Vukmanovo is suitable for the development of mountain biking. It is possible to organize races that would be held during spring and summer.In addition of cycling, the terrain of the village is also suitable for hiking and running.

Table 3. Program action III – Social development

Goals		*Measures*
Direction 3	*No.*	*Direction: Development of the economy and business*
Priority goal 3.2.	*3.2.7*	Adaptation of educational programs to the needs of the economy
Priority goal 3.3.	*3.3.18.*	Revitalization, reconstruction and adaptation of existing sports, recreational and tourist facilities and grounds for sports, recreation and extreme sports

5. DISCUSSION

Rural areas face a constant decline in the number of inhabitants and their migrations. It is estimated that in the coming years, villages with less than 100 inhabitants will disappear, and most of such villages are located in eastern, southeastern and southern Serbia. Specifically, in the period between the previous population census in 2011 and the new one in 2022, the number of inhabitants in the village of Vukmanovo decreased by 68. The main problem is the death of the old population and the migration of the young population to the cities. Another problem is the insufficient education of rural residents and the only orientation of young residents to the city for higher education and employment. The village also faces a lack of water, which is the source of life.The essential problems of the current state of the village also include infrastructural and institutional equipment.

In order to survive, the village must overcome the mentioned main problems and work on the development of the village itself in all fields including economic development, social and cultural development and spatial planning. It is also mandatory to strengthen agricultural production in the village and encourage the establishment of small businesses in the village. It is necessary to increase the number of facilities in the village, create better and healthier living conditions and create new opportunities for work. It would also be of great importance to introduce reforms in basic education, the curriculum, that is, to direct the content taught in school more towards the importance of agriculture and rural goods, thus raising awareness among young people about the existence of conditions for growth and development in the village. Also, it is possible to revitalize and create fields for sports, including forest bike paths, and get people, especially young people, interested in mountain biking and races that would be held in the village during the spring and summer period.

6. CONCLUSION

The development of the village is hampered by many problems, most of which are listed in the paper. It is necessary to determine what the disadvantages and threats are as well as what the advantages and strengths are, the measures that can affect the development of the village. It is necessary to design national and regional programs for the revival of sustainable villages in order to, among other things, attract investors who could invest and employ people who have remained unemployed in the cities, eager to move to the countryside or people, above all, who were born and they want to stay and start their own business in the countryside. Jobs in the countryside would primarily be based on agriculture, animal husbandry or some craft such as embroidery, gold embroidery, creating souvenirs, etc. There is also the possibility of creating your own brands and exporting organic healthy fruits and vegetables, winter crops, medicinal herbs, etc. The development of tourism and mountain sports is also possible, given the fact that the relief and nature of the village are suitable for this. The main thing is to encourage residents to stay in the village and to introduce new facilities that the village would have to offer both to the residents of the village and to tourists visiting the village.

After conducting analyses, observations, surveys, and case study methods, the conclusion was reached that the best approach for the development of rural areas, in this case specifically the village of Vukmanovo, 10km away from the city of Niš, is the introduction of strategic support for development in the form of a strategic document that defines appropriate measures in work – Development Plan of the City of Niš 2021-2027 [5].

One of the shortcomings in the Development Plan of the City of Niš 2021-2027. [5] represents the absence of actions or measures related to communal infrastructure, specifically for the water supply network. In the previous Action Plan of the city of Niš 2015-2020. [10] the direction "Territory/infrastructure/ environment" was clearly defined, in which the specific goal 1.2 was defined. and concrete action 1.2.2. "Ensuring the necessary quantities of quality drinking water - development of an integral system of water supply in urban and rural areas". The village of Vukmanovo is certainly not the only populated place in the vicinity of Niš that faces this problem, and the Plan does not consider an adequate solution at all, even though the issue is extremely important. It is necessary to find a measure or a priority goal related to the lack of a water infrastructure network in the Development Plan of the city. The proposal of a priority goal for which the mentioned measure would be adequate is priority goal 1.3. "Competitive agriculture and dignified quality of life in rural areas" considering that the existence of adequate communal equipment directly affects the quality of life and health of people and has an impact on environmental pollution.

It is possible to work on the development of the village, all the measures from the plan that are listed in the work are realistic and achievable. For the inhabitants of the village it is necessary to get involved in the creation of ideas, in the discussion and to participate in making decisions for the sake of a better life in the village.

ACKNOWLEDGMENTS

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BIOCLIMATIC ARCHITECTURE: A REVIEW OF ARCHITECTURAL PRACTICE DURING THE PERIOD OF MODERNISM

Sonja Stanković[1]

Abstract

At the time of prolonged climate crisis that threatens to change life as we know it, a certain thoughtful and considerate way of treating natural environment has become a moral obligation of every architect. However, less than a century ago, this kind of approach was not a matter of ethics. Instead, architects and experts in natural sciences sought to gain insight into the correlation between social patterns and the ecological system. When applying the acquired knowledge, the objective was to optimize this relationship, towards the efficient coexistence of man and the natural environment. This narrative shaped the course of architectural modernism. The work of these architects, as well as experts in other fields, directly influenced the conceptualization of bioclimatic architecture, providing the basis for each of its aspects. Today, bioclimatic methodology, advanced by technological achievements, represents a tool which is of key importance for achieving energy-efficient and ecologically sustainable architecture.

This paper brings the research of suppressed creative movements during the period of modernism, often initiated by prominent architects, with the aim of illuminating their neglected ideas, projects and experiments. Taking into account social and political conditions of that time, an overview of fruitful ideas and relevant projects is given. The purpose of this paper is to generate a new way of thinking and designing through getting to know the once common but later forgotten architectural practice - one that considers man and his habitat as an inseparable part of the planetary ecosystem.

Key words: *bioclimatic architecture, architectural modernism, olgyay, sustainability, le corbusier, richard neutra*

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1. INTRODUCTION

Architecture in the era of modernism sought to examine, adapt and integrate scientific knowledge about natural systems into society, and to bring collective knowledge and understanding of planetary patterns. As one of the basic means of promoting and inducing modernist life, it demonstrated how the application of scientific and technological solutions can significantly improve everyday life. [1]

New and different ways of living were on the horizon - the interest in designing solar houses, which incorporated passive solar design strategies, is one indicator of the social conditions of the time. Experiments focused on the maximization of passive solar gains were carried out within the Department of Mechanical Engineering at the Massachusetts Institute of Technology (MIT), which were then presented to the public by certain journals. [2] In this sense, the publication *Tommorow's house* by Henry Wright, a prominent figure at Columbia University, stands out in terms of importance. [3] Wright, who was primarily involved in urban planning, created the first known heliodon in America in 1936. [1] In the book/manual *Tomorrow's house*, published in 1945, he tries to introduce potential house builders to innovative, simple but essential design strategies (including solar heating), through chapters conceived in the form of spatial units of the house. [4] In 1947, the publication *Your Solar House* attracted a lot of attention, and soon after its publication it gained the revolutionary status. [3] The tendency towards research programs and experiments directed to general public, was primarily expressed through the *Case Study Houses* program, in the *Arts and Architecture* magazine, initiated in 1945. This dynamic was followed by *House Beautiful* magazine, which in cooperation with the American Institute of Architects (AIA) founded the *Climate Control Project*. (Figure 1*)* Through the engagement and joint work of climatologists, physiologists, anthropologists and others, a multidisciplinary process was developed that includes applied knowledge of microclimate, study of geographic sites, innovative plan organization, new ways of optimizing ventilation etc. In 1947, with the article *Microclimatology* in the *Architectural Forum* magazine, one of the participants in the project - James Marston Fitch, presented an innovative concept of microclimate that indicates the diversity of climatic conditions within one geographical area, and emphasized the occupant's lack of knowledge of it. He sought to encourage cooperation between climatologists and architects and to awaken interest in climate science and present the ways in which its application can contribute to architectural practice. [1]

The course of architectural modernism was reflected in an effort to optimize and modernize everyday life. The scientific field of climate methodology experienced expansion in the twenties, to reach its peak in the post-war period. Inspired by the vision of modernist life, some architects recognized in science the possibility of reviving the mentioned ideals. Creating an interior space of controlled conditions, basing the design on the laws and principles of the ecosystem, was a challenge and an obstacle they faced at the time. In this sense, the facade of the building, with the help of certain dynamic systems, was a medium that would allow the flow of some environmental influences, while blocking others, and the building itself symbolized the new social and economic reality. [1]


How to build
a Climate-Wise House

Face up to the worst things
in your climate -
and *master them*

A lesson in Climate Control

Figure 1. Some of the articles in House Beautiful magazine (Source: MidCentArc on Flickr)

Architecture, in the context of the global economy and capital was supposed to create a unique scene of optimized and controlled conditions, a space of consistency and productivity. As such, it acted in a way of maximizing efficiency, through the interpretation of scientific and technological achievements, by shaping and modifying the spatial-physical and socio-cultural. As a result of such social circumstances, the concept of comfort as an indicator of optimal interior conditions has positioned itself as a significant aspect and a frequent topic of architectural discussions. Integrating climate knowledge into architectural practice meant understanding natural systems, in order to modify and optimize them. In this way, the natural habitat, or, the topographic-climatic unit, was considered an instrument - the subject of alterations in favor of creating an ideal place for living and working. [1]

The design method examined the spatial-geometric features of the space, adequate ways to protect from the sun and establish the flow of fresh air in warm climates/finding ways to heat the space in cold ones. The temperature regulation of the interior space was later achieved with the mechanical HVAC system (Heating, Ventilation, Air-conditioning), which based its working on these passive techniques. [1] However the application of this architectural techniques was possible only after studying and analyzing the natural conditions of the subject area - primarily, the characteristics of the terrain and microclimate. In this sense, architectural modernism advocated for a holistic design approach - the inclusion of the narrow and wider natural environment, their correlation and interaction with the created form. The discipline of bioclimatic architecture of the 1950s and 1960s which elaborates the aforementioned principles, is based on this methodology. By applying the concept that sees the design method as a complex interdisciplinary process involving knowledge of natural conditions and laws, the resulting product was in accordance with today's tendency towards energy efficiency and ecological sustainability. However the starting point of that concept was different from the present. With the absence of moral obligation, the goal of architects of that time was reflected in the creation of rational design and functional space.

After more than half a century since technological means, based on the burning of fossil fuels, entered the architectural process (in the form of devices for maintaining thermal consistency), the living environment is subject to significant changes. Global warming, degradation of ecosystems, extinction of plant and animal species describe the current state of the planet. In addition, architecture has also changed significantly: new instruments and resources, new knowledge and goals are available. The course in architecture from modernist era, described in the following chapters, often marginalized, also speaks of a possible future - many segments of today's ecological and energy-efficient architectural practice have their roots in the visionary ideas of certain architects from the period in question. However, many lessons from the past are yet to be discovered. They do not necessarily concern technical aspects of design, but cultural and social attitude towards the living space, the ability to adapt to the created conditions - the reconceptualization of comfort, the recognition of political implications and social patterns that play out in the background. [1]

2. IDEAS PROJECTS AND INVENTIONS

Many prominent architects of the modernist period showed interest in improving the relationship between the natural environment (atmospheric system and/or the entire ecosystem) and the internal thermal space. While their motives, stemming from subjective reflections shaped into their own ideologies and theories, differed significantly, the work product reflected the same aspiration. The course of their careers was followed by extensive research on the topics of biological and physiological mechanisms, social behavior, climate-atmospheric patterns, thereby creating new perspectives and possibilities in architecture. As a result, their ideas, projects and inventions, which will be discussed in the following text, stood out, pushing the boundaries of architectural practice at the time and leaving a deep mark on its future development.

Walter Gropius directed his engagement towards urban planning, and created “light and air diagram” that examines the relationship between climate and building’s disposition on site. These sketches and the concept behind them were the subject of discussions in the following years, among others at the International Congress of Modern Architecture in 1930. Mies Van Der Rohe was indirectly involved in the aforementioned narrative, when working on the Tugendhat villa project (1928), which southern facade was materialized in the form of glazed surfaces that enable passive solar gains. [1] **Frank Lloyd Wright's** complex theory of design is based on the respect for Nature, whereby the term and concept of nature is abstract and deviates in its meaning from the previously studied scientific and technical approach. Contrary to the attitude towards the natural environment characteristic of the period of industrialization, where it is a technical instrument of manipulation and optimization, Wright's point of view is based on spiritual values. To the *Organic architecture*, a term initiated by his mentor – Louis Sullivan, Wright gave a wider and deeper interpretation - he said that Organic architecture is in accordance with time, place and man. [5] During the ”prairie period“ he faced the challenges of the extreme climate of the prairie. Large variations in day and night temperatures and frequent storms characterized this climatic region of America - as a result, the house was given the function of a shelter, under the roof of exaggerated eaves that blocked solar radiation and protected the walls from precipitation. With the change of location and climate, the appearance of Wright's house also changed. A more moderate climate allowed the use of large glazed areas that emphasized the views and strengthened the contact with the natural environment. [6] The product of this ''usonian period" is a passive solar house for Herbert and Katherine Jacobs, *Solar Hemicycle* in Wisconsin, where he faced the challenges and obstacles of the geographical-climatic area in the most effective way. The semicircular form designed in accordance with the elliptical path of the sun, combined with the glazed southern facade maximizes solar gains, while the wooden canopy protects against excessive sun exposure and heating in the summer months. The northern facade is partially buried in order to create natural thermal insulation. [5] In the winter months, the interior of the house is fully exposed to solar radiation, where concrete and local limestone are used as the floor and wall covering, which have the characteristics of a thermal mass (Figure 2).


SUNKEN GARDEN FACES SOUTH. EXCAVATION PROVIDES EARTH FOR PROTECTING BANK AROUND NORTH SIDE OF STONE CYCLE

THIS solar hemicycle is one of a growing family of houses now known as Usonian. They are growing up all over the country—overlooking hill crowns or banked against hill slopes.

A sun-receiving, wind-checking form of earth-protected building, here is a house getting comfort and protection out of the circumstances of its location. Sun-heat is incorporate; protection from severe cold is a natural feature of the first floor area by way of the berm type earth banks around behind it.

The surrounding planting is yet to be done. It will include a polychromatic ground cover for the banks of the sunken garden and a large mass of evergreens standing to the left of the hemicycle.

The sunken garden in front of the hemicycle partly protects exposed glass surfaces from winds and affords a sheltered space in which children will play.

The effect of the whole house is unitary—a one-room affair—the interior space subdivided as may be desired. Here in one room is the whole affair of good living—the warmth and invitation of a true home.

NOTE: Here Wright demolishes the box which the "solar house" has come to mean in contemporary building by curving his basic form as a hemicycle. The hemicycle form can also, of course, be said to represent the complete logic of building to trap the sun; by curving the two sides of his building, Wright takes full advantage of the elliptical solar path.

Note how simply this mature plan handles basic principles apparent in Wright's earliest houses: demolition of interior partitions; grouping of utilitarian features so as to allow space to be uninterrupted so far as possible (circular stair, plumbing and heating channel). Here the basic horizontal unit from which the building plan is developed is a 6° sector. Non-architectural readers may want to study the plan to see how this basic unit or module is used to dimension all parts of the building (two units equal width of window, two units equal diameter of the circular fireplace, four units are allotted to utility core, etc.). It is interesting to reflect that the architect who has wrested the greatest amount of freedom from the basic limitations of structure (from the building as a box) should nevertheless hold, with such gentle care, to his self-imposed discipline of space: the unit system (square, rectangle, honeycomb hexagon, circle) as a basic measure insuring the harmonious relation of each part to the whole.

HERBERT JACOBS HOUSE II IN COUNTRYSIDE NEAR MADISON, WIS. TWO-STORY SOLAR HEMICYCLE BANKED AGAINST WIND.

ARCHITECTURAL FORUM THE MAGAZINE OF BUILDING

ALL PHOTOS © EZRA STOLLER, PICTOR

Figure 2. Solar Hemicycle project in Architectural Forum 1951. (Source: MidCentArc on Flickr)

The importance of **Le Corbusier** in the formulation of the climate design movement is undeniable, as is the fact that other architects who dealt with this topic, did so under the influence of this Swiss-French architect. A large number of Le Corbusier's projects are based on the solar and atmospheric characteristics of the area, and the level of complexity of their interpretation has increased over time. He believed that an approach which included an analysis of the climate conditions was the most effective way of inducing comfort, and as such, the future of architectural practice. [1] Le Corbusier's attitude towards the natural environment was analytical and functionalist - by adapting the building to the existing environment, the optimization of life within the walls is possible. This perspective, although insufficiently illuminated in the biographical literature, depicts the course of his career, manifesting itself in different ways, in the form of more subtle or radical ideas. Sketches and drawings of the sun's path along the sky followed many of Le Corbusier's projects, although to a greater extent in the later phase of his career. [1] He noticed the disadvantages of the 'transparent envelope', one of the main features of the International style, such as poor insulating characteristics and glare, early on. To avoid the use of *pan de verre*, Le Corbusier proposed his own variation of the glass facade as part of the Cité du refuge building project in 1929 – one of his first major projects in France. (Figure 3) *Mur neutralisant* is the term he used for this type of glass construction - it was a wall made of double glass with an intermediate space filled with warm air in the winter months and cold air in the summer. In this way, he believed, external influences would be neutralized and thermal consistency would be achieved. When the building was completed, in 1933, it turned out that this ambitious solution had no effect on the establishment of thermal comfort. Its inadequacy was reflected in the weak insulating power of the glass, so the hot/cold air filling was released into the atmosphere. The technological and bureaucratic barrier that made the *mur neutralisant* an inadequate solution permanently changed Le Corbusier's view of the machine age. Having lost faith in mechanical means, he continued his search for a climate mediator between building and environment within architectural design. [1] He expressed the new method while working on another housing project, the Immeuble Clarté in Geneva. (Figure 3) Although the regional climate did not require drastic methods of cooling, this project served as a template for the schematic explanation of the external facade element - brise-soleil. The technical drawings were accompanied by sketches showing seasonal variations and its effect on the object and methods of blocking the sun's rays as needed. Among other things, they also show the principle of different treatment of each facade depending on its orientation - a method that later became part of the bioclimatic design strategy. [1] Participation in a conference organized by the Centre National de la Recherche Scientifique (CNRS) in 1945 with the theme "Urbanism and the Daylighting of Buildings", where he presented his methods of climate adaptability, echoed in the architectural practice of the following years. On the socio-cultural level, it had a revolutionary character: the principles of climate methodology were gradually incorporated, and architectural practice became a field of experimentation on the topic of the relationship between climate, users and the facade as a mediator. Le Corbusier's lecture at this conference a year later was summarized and published in the journal Techniques et Architecture under the title Problems of insolation: The Brise soleil (Problèmes de l'Ensoleillement: Le Brise-Soleil). The extensive article introduced the reader to the basic premise of sun shading device in the context of its inevitable use with a glass facade, as well as with the seasonal path of the sun on the sky horizon, followed by a discussion on the topic of its economic benefits. Historically, this article represents the first publication of climate diagrams in the context of architecture in the French press. [1]

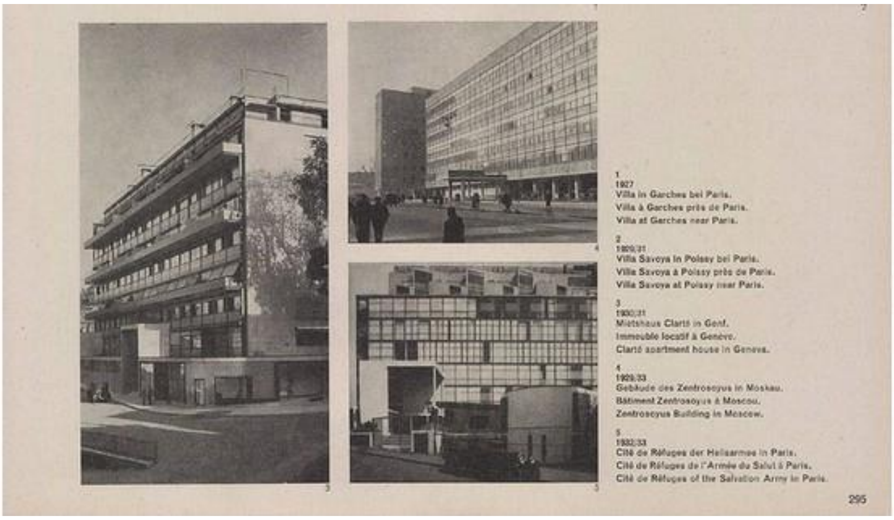


Figure 3. Immeuble Clarté (left) and Cité du refuge (bottom right) in Bauen und Wohnen 1957. (cropped, source: MidCentArc on Flickr)

As another architect whose career ran simultaneously with the industrial expansion, **Richard Neutra** belonged to the few who accepted the new products and methods without falling under its 'tyranny'. [7] The 'House of Health' project (1929), programmed to meet the needs and wishes of Dr. Lovell, will serve as a basis for ecological, ambient and psychophysiological interests that accompany his later projects. The Lovell House represents the epitome of the International Style – the space is experienced through mathematical relationships and geometric forms shaped by a steel frame and strip windows; the modular grid determines volume and visual coherence. In contrast to this project, the Kaufmann house, located in a desert landscape and built in 1946, is not characterized by visual legibility - instead, it amorphously 'flows' beyond its physical boundaries through large window portals and intertwines with natural environment. [8] In the following years and decades, this house stood out as the most famous climate-engaged design, due to its movable metal blinds placed outside the perimeter of the building and other features. [1] In the period between the construction of the Lovell house and the Kaufmann house, Neutra accomplished a clear career path - from restrained, functionalist aesthetics, of mathematical clarity to a unique psychophysiological architecture that generates ambient value and affects the psychophysical health of the user. In this approach, the focus is on the user of the space and his needs and characteristics that relate to the entire human race and him individually. [9] In this sense, Neutra's philosophy is based on the interest and study of the biological sciences in order to understand the complex neural pathways of man and the psychosomatic reactions to the immediate environment. [7] As a result, he formulated a theory based on a holistic spatial experience, which, in addition to compliance with the existing environment, also requires psychophysiological compliance (with the user). [10] "The more man moves away from the balanced integration of nature, the more the physical environment becomes harmful," he concluded in his collection of essays Survival trough design, where he explains the correlation of architecture, psychology and biology in the context of new social circumstances. [11]

Although in the general public, Richard Neutra is known as an architect who shaped the visual identity of the California coast with a pleasant climate, little is known about his participation in international programs. As the president of the US chapter of the International Congress of Modern Architecture (Congrès Internationaux d'Architecture Moderne - CIAM) he visited many South American countries where he met with architects Niemeyer, Costa and others. and gave lectures to architecture students there. On that occasion, Neutra, like Le Corbusier, encountered a series of historiographic obstacles in an attempt to understand how climate and other geophysical factors influence the aims of modern architecture. At the same time, there is a drastic difference in interpretation of new tendencies: unlike Le Corbusier who believed in the universality of the right design, Neutra insisted on using different materials and construction techniques depending on the region where it is built. At the end of 1943, he received an invitation from the governor of Puerto Rico, to lead a massive action to build public institutions. Neutra's engagement on the island was short-lived (a little longer than a year) but extensive - the initial construction scope was 150 schools and rural health centers and 5 large hospitals - which projects he elaborated to the smallest detail, although they largely remained unrealized. When designing the schools, he saw the school as a potential ground for the spread of infectious diseases - that's why the focus during the design was on achieving effective ventilation. In the classrooms, he used transparent portals which can be fully opened and thereby achieve a direct relationship with the green yard, but also increase the room's capacity by 50 percent. (Figure 4) The overhangs prevented the penetration of the sun's rays into the interior space, while the principle of flexibility was applied in plan design. Harmonized with the natural and cultural characteristics of the region, these institutions represented the epitome of socially engaged architecture. Considering the high hygienic requirements of hospitals and health centers, Neutra applied a special ventilation method during their design - he developed a mechanism called CSSA/LS (continuous subsoffit airchange over lowered spandrel). This term represented the space between the transverse beams - systematically placed in such a way as to enable the most efficient exchange of internal and external air. This and other applied principles of climate adaptability are schematically presented and explained in his book *An Architecture of Social Concern for Regions of Mild Climate*, and then published in many architectural journals - which makes him stand out as an architect who, alongside Le Corbusier, put this topic in the focus of the public. [1]

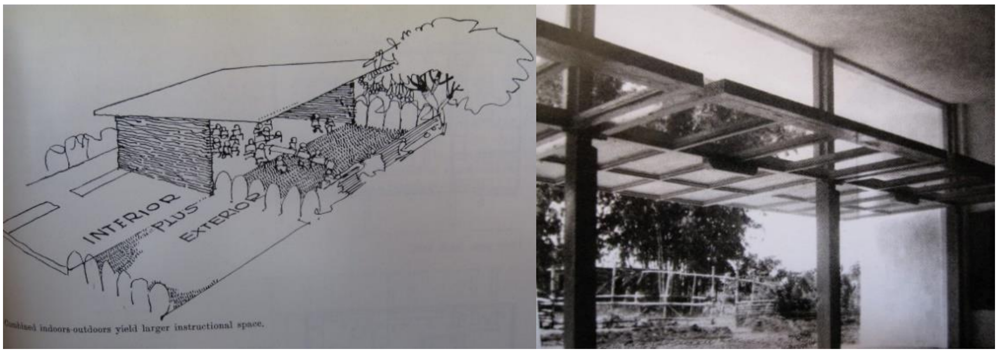
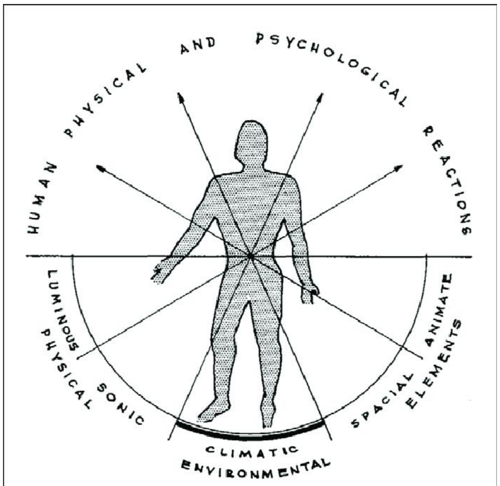


Figure 4. Merging interior and exterior on the project for school in Puerto Rico (Source: https://neutra.org/neutra-projects/ reproduced with permission of Raymond Neutra of the Neutra Institute for Survival Through Design)

3. BIOCLIMATIC ARCHITECTURE

Victor and Aladar Olgyay, born in Hungary, as admirers of the methods and research of Neutra and Le Corbusier, continued the process of integrating architectural and climate practices. They faced this challenge in the most practical and direct way, by creating diagrams and conducting experiments within the laboratories of universities. [1] The architectural method, which they formulated in this way, followed by calculations and diagrams, was a tool for uniting a wide group of parameters and factors. Before accepting the role of a professor in the USA, the Olgyay brothers were members of an avant-garde group of architects representing European modernism and active participants in the International Congress of Modern Architecture. [12]

Their method was created at a time when preoccupation with climatic factors and conditions was considered the pinnacle of architectural idea, and the application of scientific knowledge contributed to an optimistic narrative oriented towards the progress of humanity. Participation in the Building Research Advisory Board conference (BRAB) in 1952 marked the final acceptance into the research culture of American universities. In the same year, at the conference Housing and Building in Hot-Humid and Hot-Dry Climates, organized through BRAB, Victor Olgyay presented a research paper *A Bioclimatic Approach to Architecture*, while Aladar Olgyay presented additional arguments in the form of a paper on the topic *Solar Control and Orientation to Meet Bioclimatic Needs*. The importance of these presentations is reflected in their pioneering character - the term ”bioclimatic“ was used in the context of architecture for the first time; the first insight into the biometric charts; and finally, the first presentation of a method based on the interpretation of climate data in the function of housing. The focus of the presentation and, later, publications, was the architectural effort to induce a thermally consistent space in order to facilitate the social and personal progress of the inhabitants. 'Comfort zone' is the term they used to define this space, which meant a scientifically supported concept of absolute optimal interior conditions. [1]



34. Man as the central measure in architecture.

Figure 5. Illustration “Man as the central measure in architecture”, Victor Olgyay (Source: https://www.researchgate.net/figure/Victor-Olgyay-Man-as-the-Central-Measure-diagram-published-in-the-first-edition-of_fig1_329661276)

The method was originally developed in the laboratory of Princeton University, starting in 1952, by conducting experiments, methodological research and studying the relevant literature. Within the conceptual part of one of the projects they stated: "The intention is to fully develop an area of knowledge that has not been systematically researched until now: the relationship between man, his environment and the building. Many discursive generalities have been stated about this topic, hardly any of them are more than intuitive...". [1] The methodological process, based on diagrams, was gradually developed through numerous publications before reaching its mature stage in 1957. [2] *The Application of Climate Data* was the first of three books by the Olgyay brothers. In 1957, the book *Solar Control and Shading Devices* was published, and then, in 1963, the well-known book *Design with Climate: Bioclimatic Approach to Architectural Regionalism* was published. These publications, the importance of which has not diminished even half a century later, contain illustrations, graphs, etc. which are an inseparable part of the complex method of the Olgyay brothers. As admirers of the ideas and work of Le Corbusier, they incorporated a different types of blinds (brise-soleil) into a research, which they believed to be the most effective solution against overheating. [12]

The universality of the concept of the Bioclimatic approach is reflected in its essential part, which forms the basis of all further study - the influence of external factors on man. Man, with his physical and emotional needs, formed a central aspect of the bioclimatic narrative and represented a constant module in the design process. Thus, they continued the architectural flow of humanistic tendencies of certain architects (Vitruvie, Le Corbusier, Neutra, Alto), who expressed it in the form of illustrations and texts that are still relevant today (Figure 5). [2]

3.1. Epilogue

A combination of circumstances made up of the coming postmodernism (which found inspiration in historical styles, as opposed to the innovations of modernism) and a mixed reception among the professional public, led to a sudden shutdown of interest in the bioclimatic concept. The effort of the Olgyay brothers to make the human/user the subject of the design process was overshadowed by other discussions oriented towards technological achievements. This was also contributed by the conceptual framework - the form through which the idea and method was generated - due to its excessive complexity, there were difficulties in understanding the essence and significance. [2] One of the projects made within the Princeton laboratory, which is considered one of the last achievements in climate-architectural practice, was the Thermoheliodon device, designed in collaboration with engineer Sorenson. This device was intended for architects and engineers for the purpose of research and implementation of natural environment factors on a ''climate balanced house“. It functioned as a simulator: the sun's path was carefully calibrated, there was the possibility of adjusting the wind direction and a heating device to generate the desired temperatures; in the center of the atmospheric dome was a depression with soil from the site in question, which surrounded a model of the object made of original materials. The time it takes for the 'sun' to complete its path was 40 minutes and that is the simulation period of one day. In this way, it was possible to see the appropriate orientation, the effect of the sun's rays, the relationship between the mentioned factors and materials, the desired form, etc. However, several problems arose during use, and the impracticality and complexity largely limited its application in practice. Although some of the climate data application projects did not work out as the Olgyay brothers envisioned, their efforts resonate throughout the architectural-ecological research field today. Advances in technology today have made this idea of the climate simulator possible in the form of computer software. [1]

4. CONCLUSION

In the short period between the end of the war and the moment when energy consumption became part of the daily life, architectural methodology sought to find a way of efficient and rational use of energy, and to create an optimized relationship between achieving comfort and energy consumption. Architectural practice continued to focus on improving the quality of life, however, as time went on, design methods became increasingly reliant on fossil fuel. Soon after, architectural modernism was reduced to the mechanical control of heat and air conditions connected in a global network of destructive consequences. The predominance of this system in the field of architectural practice caused a change in motives and focus when approaching design - at the beginning of the seventh decade of the 20th century, interest in the natural environment suddenly died out, and this topic became marginalized. The conditions of the interior, behind a strictly sealed facade, were dictated by a mechanical HVAC system, thereby making the building itself isolated from its surroundings. As a consequence of this, architecture in its practice and education did not recognize the need to study the principles of nature, nor to analyze the terrain and microclimate. The global distribution and implementation of HVAC systems also influenced the formation of a certain vision of the future and its inhabitants- the individual became an inseparable part of the 'comfort zone'. [1]

From today's perspective, it is clear that the architecture and civil engineering played a significant role in the normalization of fuel burning for the purposes of everyday life and activities. At the moment after the start of the ’energy acceleration’, the architectural expression, striving to keep up with the world trend, based itself on fossil fuels, in the absence of awareness of the harmful consequences. This attitude defined the trajectory of architectural-construction practice, which is the same today - starting from the second half of the twentieth century, the built environment and fuel consumption became inseparable. A fact that testifies to this, and which is not emphasized enough by experts in this field, is that the construction industry is responsible for between 40 and 60 percent of the total carbon dioxide emissions. [1] Although knowledge about this topic has advanced significantly in the decades that followed, the awareness and approach to construction remained, to a large extent, unchanged. Today, we are witnessing rapid technological progress which opened the door to possibilities beyond human perception. In this regard, architecture in its design and education ought to utilize this capacity and direct it towards reconnection of the man and his habitat.

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SHEAR STRENGTH OF SELF-COMPACTING STEEL FIBER REINFORCED CONCRETE PUSH-OFF SPECIMENS

Aleksandar Šutanovac[1], Predrag Blagojević[2], Denis Milenović[3], Darko Živković [4]

Abstract

This paper presents the results of experimental shear tests conducted on „Z"-shape push-off specimens made with self-compacting concrete (SCC) and self-compacting steel fiber-reinforced concrete (SCFRC). This study aims to analyze the contribution of fiber volume fractions (Vf) and aspect ratio of fibers (l/d) on shear strength of SCFRC. Shear tests were carried out on specimens reinforced with steel hooked-end fibers with four fiber volume fractions (0,5%, 1%, 1,5% and 2%) and two aspects of fiber ratio (47 and 80). The results show that, as the Vf increase from 0% to 2%, the shear strength increases up to 57% compared to SCC strength. The aspect ratio of fibers has a certain influence on shear strength. Correlations between fiber volume fraction and shear strength were established based on the regression analysis conducted on experimental data. An equation for predicting the shear strength of self-compacting steel fiber reinforced concrete is proposed as a function of the fiber factor.

Key words: *fiber reinforced concrete, shear strength, steel fibers, push-off test, aspect ratio*

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1. INTRODUCTION

During several last decades, numerous studies testing the use of steel fibers as an admixture or substitution for the shear reinforcement have been conducted. Steel fibers prevent the onset and propagation of cracks in concrete [1]. Fiber bridging of cracks improve the mechanical properties of concrete such as tensile strength, shear strength [2,3,4] and ductile behavior [5]. The influence of steel fibers to a large extent depends on fiber volume fraction [3], fiber aspect ratio (l/d) and the fiber shape [6].

Cucchaira et al. [7] in their experimental research investigated the effectiveness of stirrups and steel hooked-end fibers as shear reinforcement. Tests were conducted on rectangular simply supported beams. Results demonstrated that the use of fibers in a certain percentage can substitute the vertical stirrups, and it can change the brittle mode of shear failure into a ductile flexural mechanism.

Casanova et al. [8] in their research demonstrated that a certain content of steel fibers is mechanically equivalent to the stirrups in the reinforced concrete beams.

There is an enormous interest for determination of the shear strength and study of the shear behavior under direct shear failure. Usually, the following types of specimens [9] are used for such tests:

- Z-shape push-off specimen,
- Double notched push-through specimen,
- Single notched FIP-shape specimen.

All three types of specimens are designed to achieve direct shear failure along the planned plane and avoid the flexural effect.

Testing of „Z“-shape push-off specimens is one of the most frequently used methods for testing of the shear behavior of concrete [10-16]. It is often mentioned in literature as the Hoffbeck-style or double L-shaped specimen. It is not a standardized testing procedure, so different types of push-off tests were used, with variations in the specimen dimensions, in the previous studies. In some studies, the notches are cast, while other researchers pre-crack the specimens before preforming push-off tests.

Barragan et al. [13] conducted a direct shear push-off tests on normal-strength C30 and high-strength C70 steel fiber-reinforced concrete specimens. The specimens were made with three quantities of steel fibers (0, 20 and 40kg/m^3). Owing to the fibers, there was a considerable improvement in ductility during the shear failure and certain increase of shear strength, both in normal-strength and high-strength concretes.

Cuenca and Serna [14] tested the shear behavior of „Z“-shape push-off specimens of SCC with a varying content of fibers (0, 40 and 60kg/m^3) and pre-cracked width and transversal reinforcement. They found out that the peak load increases in relation to the fiber content increase.

Navarro-Gregori et al. [15] tested ten reinforced concrete (RC) and steel-fiber reinforced concrete (SFRC) un-cracked push-off specimens. Specimens were made with varying amount of fibers (0 and 50 kg/m^3). SFRC specimens, owing to the steel fibers achieved a higher shear strength than the RC specimens just after cracking.

Double notched push-through specimen is developed by Japan Society of Civil Engineers JSCE-SF6, 1990. and was adapted by Mirsayah and Banthia [17].

Boulekbache et al. [18] conducted shear tests in accordance with JSCE-SF6 with some modifications.

Single notched FIP-shape specimen is a single notched prism used for a direct shear test [19].

2. EXPERIMENTAL WORK

The main goal of this research is to investigate the effects of steel hooked-end fibers on the shear strength of self-compacting fiber reinforced concrete SCFRC on "Z"-shape push-off specimens. The analyzed parameters were: fiber volume fraction (V_f) and fiber aspect ratio (l/d).

2.1. Materials and Fabrication of Test Specimens

For making of the concrete mixture CEM I 52,5R cement was used. Since the aggregate grains used for making of fiber-reinforced concrete are finer in comparison of the conventional concretes, a three-fraction aggregate was adopted, with the maximum grain size of 16mm. The sand grains were 0/4mm and two fractions of gravel 4/8mm and 8/16mm. For making of concrete, superplasticizer-hyperplasticizer Cementol Hiperplast 461 was used. The designed water to cement ratio was 0,45. Two types of hooked-end steel fibers were used. The steel fibers producer was the Spajić company from Negotin. The fibers were packed in 20 kg bags. The first fiber type, labeled ZS/N 0,75x60 had the length (l) 60mm, and circular cross section diameter (d) 0,75mm and the aspect ratio (l/d) 80. The second type of fibers, labeled ZS/N 0,75X35 had the length (l) 35mm, circular cross section diameter (d) 0,75mm and aspect ratio (l/d) 47. Tensile strength of the fibers is 1100-1400 MPa. The shape of steel fibers is shown in figure 1, and the dimensions and mechanical properties in table 1.

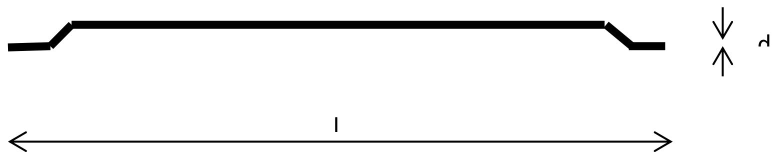

Figure 1. Shape of hooked-end steel fibers

Table 1. Properties of hooked-steel fibers used

Properties	Type I ZS/N 0,75x60	Type II ZS/N 0,75x35
Length l (mm)	60	35
Diameter d (mm)	0,75	0,75
Aspect ratio (l/d)	80	47
Cross-section area A_f (mm^2)	0,44	0,44
Tensile strength (MPa)	1100-1400	1100-1400
Cross-section	Round	Round

One reference mixture of self-compacting concrete without fibers labeled SCC was made and eight mixtures with the addition of steel fibers labeled as SCFRC. Four mixtures were made with fibers ZS/N 0,75x60 length 60mm, label SCFRC60, whereby the fiber volume fraction V_f was varied in mixtures. The mixture SCFRC60-0,5 has a fibers volume fraction of 0,5%, SCFRC60-1,0 has V_f=1,0%, SCFRC60-1,5 has V_f=1,5% and SCFRC60-2,0 has V_f=2,0%. Remaining four mixtures were made with fibers ZS/N 0,75x35 having length 35mm and the have the label SCFRC35. The fiber volume fraction was varied in these mixtures on the same principle, from 0,5% to 2,0%. The mix designs for all nine mixtures are identical, in terms of the used types and quantities of basic materials – water, cement and aggregate. In table 2 are given ratios of components in the concrete mixtures, and in table 3 the fiber volume fraction V_f in concrete mixtures.

Table 2. Mix proportioning of concretes (kg/m^3)

Properties	*SCC*
Cement	*420*
Sand 0/4mm	*820*
Gravel 4/8mm	*326*
Gravel 8/16mm	*493*
Limestone filer	*100*
Water	*189*
Superplasticizer	*2,2*

Table 3. Fiber volume fraction Vf (%)

Specimen designation	*Steel fibers ZS/N 0,75x60*	*Steel fibers ZS/N 0,75x35*
SCC	*/*	*/*
SCFRC60-0,5	*0,5*	*/*
SCFRC 60-1,0	*1,0*	*/*
SCFRC 60-1,5	*1,5*	*/*
SCFRC 60-2,0	*2,0*	*/*
SCFRC 35-0,5	*/*	*0,5*
SCFRC 35-1,0	*/*	*1,0*
SCFRC 35-1,5	*/*	*1,5*
SCFRC 35-2,0	*/*	*2,0*

The preparation of fiber-reinforced concrete was performed in three steps to avoid the effect of fiber clumping. In the first step, half of the total amount of fibers is mixed together with cement, sand and aggregate in a mixer. Mixing lasted for 2 minutes. In the second step, water with superplasticizer was added and the mixing of concrete continued for 1 minute. In the third step, the remaining amount of fiber was added and mixing was continued for 2 minutes. The total mixing time was 5 minutes. For each concrete mixture, three „Z“-shape push-off test specimens for testing of the shear strength were made, as well as three concrete cubes (150x150x150mm) for testing the compressive strength. The specimens were kept for 24 hours in moulds and then they were demoulded and cured in water and tested after 28 days.

2.2. **Specimen geometry and shear test**

Shear tests were conducted on “Z”-shape specimens. In figure 2 the geometry of “Z”-shape specimens is shown.

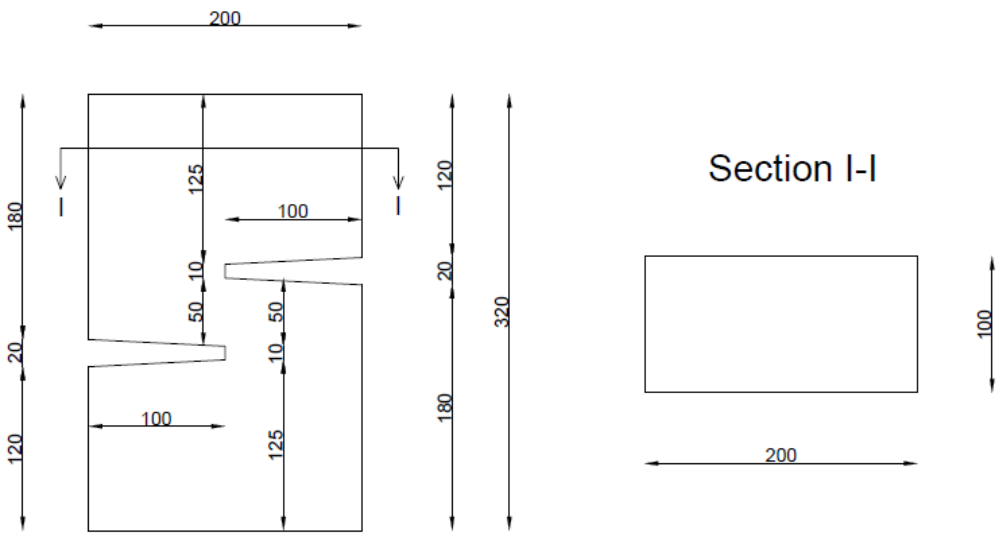

Figure 2. Dimensions of “Z”-shape test specimens (unit in mm)

In figure 3 the method of loading of “Z”- shape specimen in the press is shown. The shear strength of the specimen is calculated according of the following formula:

$$\tau_u = \frac{F_u}{A_\tau} \quad (1)$$

Where F_u – is the specimen failure force, and A_τ – surface area of the shear plane.

Figure 3. “Z”-shape specimen during testing

3. RESULTS AND DISCUSSION

3.1. Compressive Strength

In table 4 are provided mean values of the compressive and shear strength of concrete, at the age of 28 days with the varying fiber volume fractions. In the specimens SCFRC35 with the fibers 35mm long an increase of the compressive strength of concrete of 6,2% for V_f= 0,5% to 27,1% for the specimens with V_f=2,0% in comparison to the control specimens without fibers was observed. In the specimens SCFRC60 which were reinforced with 60mm long fibers, an increase of compressive strength of 26,8% and 24,9% for the specimens for which V_f 0,5% and 1,0% was observed, while in the specimens with a higher fraction of fibers of 1,5% and 2,0% a decline of the concrete compressive strength of 2,2% and 3,6% in comparison to the control specimens was observed. This phenomenon can be explained due to the disruption of the matrix structure due to the onset of clumping of fibers.

Table 4.Test results

Specimen designation	*Compressive strength (MPa)*	*Increase in compressive strength (MPa)*	*Ultimate shear stress τ_u (MPa)*	*Increase in shear stress τ_u (MPa)*
SCC	*43,11*	*/*	*5,70*	*/*
SCFRC60-0,5	*54,66*	*+26,80*	*6,10*	*+7,00*
SCFRC 60-1,0	*53,85*	*+24,91*	*7,70*	*+35,10*
SCFRC 60-1,5	*42,15*	*-2,23*	*8,50*	*+49,12*
SCFRC 60-2,0	*41,58*	*-3,55*	*8,95*	*+57,01*
SCFRC 35-0,5	*45,78*	*+6,19*	*5,89*	*+3,33*
SCFRC 35-1,0	*47,05*	*+9,4*	*6,82*	*+19,60*
SCFRC 35-1,5	*50,47*	*+17,07*	*7,99*	*+40,18*
SCFRC 35-2,0	*54,78*	*+27,07*	*8,96*	*+57,19*

3.2. Shear Strength

3.2.1. Influence of fiber volume factor and aspect ratio of fibers

After testing of “Z”-shape specimens SCFRC35 with the fibers 35mm long, an increase of the concrete shear strength of 3,33% for V_f= 0,5% to 57% for specimens with V_f=2,0% in comparison to the control specimens without fibers was observed. For the specimens SCFRC60 which were reinforced with fibers 60mm in length, an increase of shear strength of 7% to 57% for the specimens in which V_f was in the range between 0,5% to 2,0% in respect to the control samples was recorded. It was noticed that the increase of the fiber volume causes a linear increase of the shear strength. By using the regression analysis, the shear strength was expressed in the function of the fiber volume fraction V_f and shear strength of concrete without fibers τ_0 using the following expression:

$$\tau_u = 1{,}6 \cdot V_f + \tau_0 \qquad (2)$$

Figure 4 shows the results of the regression analysis. Coefficient of determination (R^2) is 0,93 and it indicates that there is a strong correlation between the fiber volume fraction and shear strength.

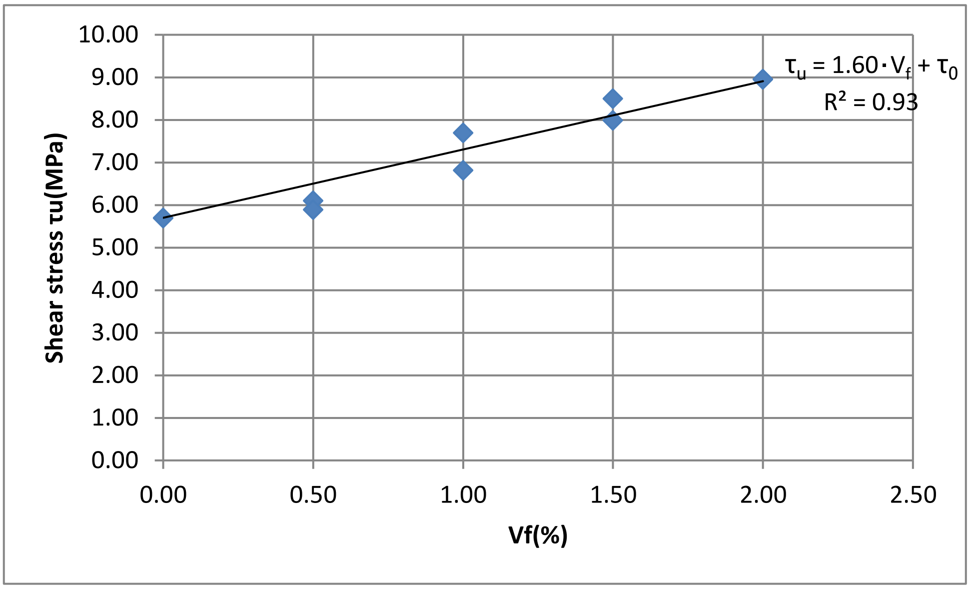

Figure 4. Relationship between fiber volume fraction V_f and shear stress

The aspect ratio of fibers has a very small impact on the shear strength of the specimens. Concrete mixtures in which l/d was 80 had up to 15% higher shear strength in comparison to concrete mixtures where l/d was 47. The fiber factor represents the product of the volume fraction of fibers V_f and the aspect ratio of fibers l/d. By means of the regression analysis, the shear strength as a function of the fiber factor was expressed by the following expression:

$$\tau_u = 0{,}02 \cdot V_f \cdot (l/d) + \tau_0 \tag{3}$$

Figure 5 showed the linear relation between these two parameters. The coefficient of determination (R^2) is 0,93 and it shows that there is a strong correlation between the fiber factor and the shear strength.

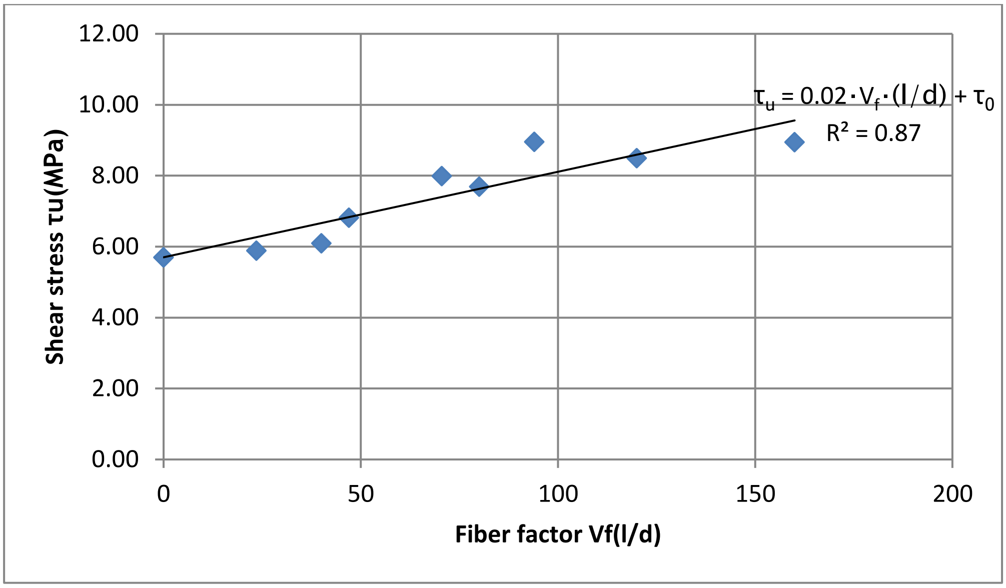

Figure 5. Relationship between fiber factor V_f(l/d) and shear stress

3.2.2. Failure mode in concrete

Figure 6 shows a typical failure model of “Z”-shape specimen with fibers. The fiber occurs due to the propagation of the vertical crack which occurs along the shear plane of concrete. The fibers bridge the cracks, until, under the high load there is a pull out of fibers. In the control specimens that do not contain fibers, there occurs a sudden brittle failure of concrete.

Figure 6. Typical Failure mode for SCFRC “Z”-shape specimen

4. CONCLUSIONS

The main goal of this research is to investigate the effect of steel hooked-end fibers to the shear strength of self-compacting fiber-reinforced concrete. Based on the obtained experimental results, the following conclusions can be made:

- The shear strength of self-compacting fiber-reinforced concrete increased with the increase of fiber volume fraction V_f. The shear strength increased up to 57% for a fiber volume fraction of 2% in relation to the control specimens without fibers.
- The balling of fibers was observed for fiber volume fractions larger than 1,5%. The optimal range of steel hooked-end fiber volume fraction, in terms of shear performance, is 1%-1,5%.
- The fiber aspect ratio has a small impact on the shear strength. Concrete mixtures with the fiber factor l/d of 80 had up to 15% higher strength in comparison to the concrete mixtures with the fiber factor l/d of 47.
- Based on the regression analysis a linear equation is provided (3) for predicting the shear strength of self-compacting concrete in dependence of the fiber factor $V_f(l/d)$ and the shear strength of the self-compacting concrete without fibers.

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WASTE-TO-ENERGY INCINERATION TECHNOLOGY- CASE STUDIES OF PLANTS THE SPITTELAU IN VIENNA AND COPENHILL IN COPENHAGEN

Petra Živadinović[1]

Abstract

In the last few decades, there is a growing tendency to consider the impact of waste management industries on the natural environment, as well as the possibilities of obtaining sources of new raw materials, as those are the basic principles of the waste management industry. In addition, the increasingly frequent location of industry next to built-up residential areas of the city imposes industrial facilities integration into the environment. This paper explores waste incineration with energy utilization, a practice gaining popularity in developed countries to reduce landfill waste sustainably and create essential facilities for community inclusion. Careful planning is necessary to minimize environmental impact and maximize benefits for the community. The subject of the scientific research work is to point out the importance of obtaining energy from waste burning, and its subsequent use for various purposes. Also, it is very important to emphasize the visual identity of the facilities and the possibility of existence public urban functions, like recreation and education, to foster citizen inclusion, especially considering their frequent location in city cores. Two examples of incinerators Spittelau in Vienna, Austria, and Copenhill in Copenhagen, Denmark were selected for the purpose of the research work, where thermal waste treatment solutions were successfully implemented. Individual examples were analyzed from the viewpoint of spatial and functional organization, architectural form, and materialization. Based on case studies, the importance of the place's context in relation to the environment and the creation of architectural features in the city is highlighted. The indirect purpose of the work is to raise environmental awareness by presenting applicable waste transformation solutions and their impact on environmental preservation and urban sustainability. The research methods employed include case study analysis, descriptive analysis, comparative analysis, and cause and effect analysis.

Key words: *waste incineration, energy utilization, case studies, public urban functions, architectural expression, the environment*

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1. INTRODUCTION

Rapid globalization and industrialization have brought about numerous changes that impact the world economy, society, culture, and the environment. Production and trade increase present new market opportunities, enhance productivity, and raise living standards in many countries. However, it also contributes to the growing inequality between nations. In recent decades, global waste generation has increased substantially due to the rapid growth of industrial sectors, urbanization, and evolving lifestyles. Waste proliferation leads to environmental pollution, natural resource depletion, and has a detrimental impact on biodiversity.As people become more aware of waste accumulation issues, there is an increasing emphasis on its proper management. In addition to promoting waste reduction, recycling, and reuse are highlighted as key strategies. Developed countries are implementing measures to regulate waste disposal and encourage responsible waste handling, with a growing inclination towards preserving the natural environment and extracting new raw materials from waste [1]. Today, there are numerous industrial facilities worldwide engaged in waste incineration and energy production from waste. Historically, industrial facilities have been predominantly located in industrial zones, typically far from urban cores. However, with the expansion of cities, many industrial facilities, and even entire industrial zones, now find themselves within built structures surrounded by residential areas. Consequently, modern architectural principles place increasing emphasis on integrating industrial buildings (such as incinerators) into the surrounding environment.

The subject of this scientific research paper is to highlight the importance of energy generation from waste incineration and the potential implementation of secondary public urban amenities within the architectural framework of incineration plants, particularly considering their increasingly prevalent placement in urban structures. In addition to these facilities' multifunctionality, increased attention is paid to their visual identity. Such practices are being increasingly adopted in developed countries as sustainable solutions to reduce the amount of waste in landfills while creating significant facilities for citizen inclusion. Based on case studies of two incineration plants in Copenhagen and Vienna, the importance of contextualizing the site in relation to the surroundings is emphasized, as well as the role they play in urban sustainability. The primary objective of the research is to demonstrate the impact of architectural design and the implementation of public urban amenities on creating architectural landmarks in natural settings. By studying the functional analysis of incinerators and applying eco-friendly and technologically sustainable solutions, the indirect goal of the study is imposed, creating environmental awareness in the context of differentiated solutions for waste transformation and the importance of environmental preservation, as well as the role incinerators play in urban sustainability in the city.

1.1. Theoretical Framework: Incineration in Industrial Production

The term "incineration" originates from the Latin word "incinerō" [2], which translates to "burn to ashes". Due to its disciplinary application in various fields such as technology, chemistry, ecology, mechanical engineering, and architecture, incineration can be seen through many different aspects.

In the context of industrial production, it pertains to the combustion of waste, while in the context of architecture, it pertains to facilities where such combustion takes place, namely incinerators. The theoretical framework of incineration in this research paper encompasses the energy production from incineration plants, the application of environmentally sustainable solutions, as well as the impact of such facilities on the environment. Incineration is a thermal treatment of waste in stationary or mobile plants, primarily involving burning. Its main purpose is to reduce waste mass by 75% and volume by 90% [2]. By employing this method, the need for landfill space is reduced, and the construction of existing landfills is minimized. Moreover, during the incineration of hazardous waste at high temperatures, it is possible to destroy harmful substances that would otherwise end up in landfills and have a negative impact on the environment. The research paper presents waste incineration with energy recovery, where the secondary purpose of incineration is the utilization of energy derived from waste to generate heat and/or electricity [2]. Due to the high energy potential of incinerated waste, this technology is widely accepted in many developed European countries. The generated electricity is fed into the grid and distributed to end users. Depending on the local infrastructure, hot water can be sent to nearby district heating (or cooling) networks. The steam produced can be utilized by nearby industries in manufacturing processes and further converted into electricity. By harnessing its energy recovery potential from waste, Europe could provide electricity to 17 million households and heat to 24 million households [3]. In addition to numerous positive aspects of implementing waste incineration as a treatment option in waste management, there are also several challenges and potential negative environmental impacts. During the combustion of waste, harmful particles (heavy metals, dioxins, furans, sulfur dioxide, and hydrochloric acid) are emitted from the flue gases [4], which can have adverse effects on the environment. Therefore, incineration systems must incorporate complex air pollution control systems to meet the necessary limits for safeguarding ambient air quality and human health. The complexity arises from the fact that modern systems include provisions to establish emission limits for harmful substances to levels that comply with legal regulations [2]. In the other hand, incineration plants located within the urban fabric and near residential areas are increasingly drawing attention to their connection with the surrounding city in terms of the programmatic content they provide. Connecting with the environment is essential by introducing urban functions that support citizen inclusion, thereby creating a facility that is open to all [5].

1.2. Theoretical Framework: Visual Identity of the Incinerator

Waste incineration facilities serve as crucial industrial plants prioritizing functionality. Nonetheless, the significance of architecture within these establishments should not be underestimated, particularly when considering their direct integration within urban environments. The concept of industrial buildings as integral components of urban and societal brilliance has given rise to novel typologies of construction and industrial aesthetics [6]. This case study delves into the analysis of applied architectural solutions and the form of the facility. When discussing waste management facilities, it is essential to consider their impact on the environment and the adjacent residential areas. Integrating these industrial structures into the urban fabric requires thoughtful planning and architectural ingenuity to ensure minimal disruption to the surroundings and maximum benefits to the community. The architectural design of waste incineration facilities has evolved significantly over the years. Architects are increasingly exploring innovative ways to make these structures visually appealing while ensuring they efficiently serve their primary purpose of waste disposal and energy generation.

1.3. Theoretical Framework: Urban Sustainability

The notion of sustainability is inherently complex, given its multifaceted nature that extends across diverse domains. The concept of sustainable development equally includes 4 aspects of development: economic prosperity, cultural vitality, social equity, and environmental sustainability. In the realm of architecture, sustainability is commonly associated with urban sustainability. To provide a precise response to the research paper, it is imperative to establish a comprehensive definition of urban sustainability within the context of architecture. Notably, Kibert (1999) affirms that urban sustainability primarily revolves around enhancing resource efficiency, leveraging renewable sources, curbing detrimental gas emissions, and safeguarding natural habitats [7]. Hence, when devising the design of an incinerator, extensive exploration is undertaken to optimize efficient energy generation while concurrently minimizing construction and maintenance costs. Furthermore, meticulous consideration is given to mitigate the release of harmful emissions. Continual monitoring and the implementation of cutting-edge technologies and innovations assume paramount importance in enhancing the operational performance of such facilities, thereby facilitating the realization of more ecologically sound and sustainable solutions. The energy harnessed through incineration bears manifold implications for sustainable architectural practices. The utilization of waste materials and their redirection towards alternative applications, aligned with the principles of the renowned "reduce, reuse, recycle" paradigm, represents a cornerstone of urban sustainability [7].

2. METHODOLOGY

The research employed several methods, including a case study approach focusing on two selected incineration plant examples, descriptive analysis, comparative analysis between the two incineration plant examples, and a cause-and-effect method. The selection of analyzed examples in the research was based on various criteria, including the following:

- The primary function of the chosen facilities is waste incineration and energy production.
- Modern principles of industrial architecture and design were applied during the design process of the analyzed examples.
- The facilities were designed to be energy-efficient, in line with national strategies and directives.
- In addition to their primary industrial function, the selected facilities also incorporate other urban functions (recreation, education, tourism) that contribute to the quality of life in the surrounding area.
- The architecture of the selected facilities aligns with contemporary architectural design principles.

In the world today, there are numerous successful solutions for incineration plants, and the following mentioned facilities are just a few that meet the criteria set in the research: The Gärstad plant in Linköping, Sweden; Värtaverket Biomass Power Plant in Stockholm; Returkraft in Kristiansand, Norway; and the Incineration Line in Roskilde, Denmark. For this study, two case studies have been selected: Spittelau in Vienna and Copenhill in Copenhagen, where successful waste thermal treatment solutions have been implemented. Individual case studies have been analyzed in terms of spatial and functional organization, architectural form, and materialization. Analyzing case studies is significant as it can provide guidelines for the construction of sustainable, high-performance, and environmentally friendly facilities that are crucial for citizen inclusion. Three research questions have been formulated based on the research objectives outlined in the introduction section, and they are as follows:

- **Research Question 1:** What are the significance of energy production and the control system for emissions of harmful substances in terms of urban sustainability?
- **Research Question 2:** What is the relationship between the spatial composition and visual identity of incineration plants and the built structure of the surrounding city?
- **Research Question 3**: What role does the integration of other urban functions such as recreation and education play in the operation of incineration plants?

Answers to all research questions are analyzed using the aforementioned methods. The descriptive method is used to describe the case studies, a comparative analysis is employed for comparing the two selected examples, and a cause-and-effect analysis is utilized to study the relationship between incineration plants and their surroundings.

3. CASE STUDIES

Based on the analysis of the examples of the incinerators Spittelau in Vienna, Austria and Copenhill in Copenhagen, Denmark, the importance of the use of electrical and thermal energy generated during waste incineration, as well as the importance they have on urban sustainability in the city, is shown. Basic information about incinerators is given in Table 1.

Table 1. Basic information about incinerators

	Spittelau incinerator, Vienna	*Copenhill incinerator, Copenhagen*
Architect	*Friedensreichu Hundertwasseru*	*Architectural firms BIG (Bjarke Ingels Group)*
Construction year	*Built in 1969, last renovation in 2015*	*2017*
Location of the facility	*Residential and business area, Vienna*	*Amager industrial area, Copenhagen*

The immediate surroundings of the facility	*Residential buildings, multi-family housing and business. Significant proximity to the railway station, the Wein Energie company building, and the university. (source Google maps)*	*In addition to industrial facilities, significant proximity to Margretheholm residental, urban district, marina and the autonomous community of Christiania, (source Google maps)*
Energy production	*Electricity < current Thermal energy <district heating district cooling center*	*Electricity < current Thermal energy <district heating*
The presence of public content	*Recreation and education*	*Recreation and education*

3.1. Spittelau Incinerator, Vienna

Vienna has three waste incinerators producing electricity and heat, while the Spittelau waste incineration plant makes a key contribution to Vienna's waste management system (Figure 1). The incinerator was originally built in 1969 and underwent extensive reconstruction and renovation in 1987 following a major fire. It is situated in the urban city center, surrounded by residential and commercial complexes. The facility currently processes separated plastics from the Wiener Neustadt area and its surroundings, which serve a population of approximately 150,000 [8].

The Spittelau waste incineration plant is one of the most advanced waste incineration facilities in the world, with a highly efficient gas cleaning system that ensures the highest level of environmental protection. The plant employs state-of-the-art filters and recycles waste to the highest ecological standards. For instance, the Spittelau facility was the first to install a selective non-catalytic reduction system (DeNOx system) in a waste thermal treatment plant. Carbon dioxide emissions are nearly 90% below permissible limits [8]. Between 2012 and 2015, Spittelau underwent a refurbishment process that resulted in significant improvements to its operations. The modernization efforts led to enhanced conditions in technological processes and the establishment of updated standards, ultimately resulting in improved efficiency and effectiveness of the facility. Before the refurbishment, the incineration plant operated at 70% overall efficiency and effectiveness, whereas today it has increased by 6% [8]. This increase indicates that the implemented changes and enhancements in the incineration plant's processes have contributed to better outcomes. Another notable change is related to energy supply. Before the refurbishment, the incineration plant supplied electricity to 16,000 households, whereas now it utilizes the electricity it produces for its own needs as well as the supply of up to 50,000 households [8]. In addition to electricity generation, the Spittelau incineration plant also produces thermal energy, which is utilized for district heating in 60,000 households in Vienna [9]. It is imperative to note that Spittelau recognized the growing demand for air conditioning systems within homes and introduced a cooling system in 2009 that complies with environmental standards [8]. This demonstrates the incineration plant's adaptability to changes and requirements for more energy-efficient and environmentally friendly solutions [8].

Presently, the Spittelau facility extends its range of services beyond mere energy provision, encompassing additional amenities such as electric vehicle charging stations, two photovoltaic installations, guided tours catering to diverse target groups, as well as hosting an array of events including exhibitions and festivals [8]. Moreover, alongside its multifunctionality, the facility exhibits notable aesthetic attributes. Following a significant conflagration in 1987 that ravaged the primary components of the plant, the incineration facility design was entrusted to the esteemed Viennese artist, Friedensreich Hundertwasser (Figure 2). Tasked with creating an artistic masterpiece within the urban nucleus, Hundertwasser's undertaking sought to exemplify a harmonious fusion of technology, ecology, and art [6]. The edifice's façade distinguishes itself through its striking and variegated structures, accentuated by a juxtaposition of black and white tiles, a resplendent golden sphere adorning the chimney, and sinuous contours. The integration of verdure on the façade further complements the overall design.


Figure 1 and 2. Spittelau incinerator, Vienna, Austria
https://www.euractiv.com/section/energy/interview/, https://www.dreamstime.com/

3.2. **Copenhill Incinerator, Copenhagen**

Copenhill incineration plant is located in Amager industrial zone, 5km from Copenhagen center (Figure 3). The architectural firm BIG (Bjarke Ingels Group) designed and built the 41,000m^2 facility after winning an international design competition. Construction began in 2013, and the plant commenced operations in 2017 [10]. The incineration plant processes waste generated by approximately 695,000 residents. In 2020, municipal waste from households in five municipalities accounted for about 23% of the waste incinerated at CopenHill, while the remainder was commercial and industrial waste [11]. Waste is sorted into different fractions before collection [12].

CopenHill is an energy recovery waste-to-energy facility that produces electricity and district heating. A significant portion of the waste received by the incineration plant is recycled, while the remaining portion is incinerated to generate electricity and heat, providing energy for approximately 150,000 households. In 2020, 600,000 tons of waste will be incinerated, producing enough electricity for 80,000 households and heat for 90,000 households [5]. The R1 efficiency of the plant (calculated based on designed parameters) is way above the 65 % required by the EU Incineration Directive 2008/98/EC for facilities for recovery of energy, meaning that the Copenhill plant recovers the energy from the waste combusted in a very efficient way [12]. Importantly, electricity and district heating production can be adjusted to meet consumer needs every day throughout the year [13]. The Amager Resource Centre (ARC) features the first SCR DeNOx installation in a Danish facility, designed to reduce NOx and dioxin emissions by over 95% [12]. This investment is part of Copenhagen's comprehensive strategy to become carbon-neutral by 2025 [14]. In addition to its successful technological system and energy production, Copenhill is also recognized for its distinctive architecture, which differs from conventional industrial facility designs. The primary structure of the plant is derived from the appearance of machinery and applied technology. The internal volumes of the power plant are determined by the precise positioning and organization of its machinery in vertical order, resulting in an efficient sloping roof. The building takes the shape of a wedge with a sloping green roof, while its twisted volume mimics the appearance of a mountain (Figure 4) [10] [13]. The continuous facade is uninterrupted, lacks straight edges, and consists of perforated aluminum blocks. All interiors are naturally lit through large glass surfaces located between aluminum blocks on the facade [10].

In addition to its primary waste incineration function, the incinerator offers visitors a rich recreational and educational architectural program, transforming the social infrastructure into an architectural landmark. Notable features include a ski slope, walking and running trails, a rooftop bar, and a climbing wall, as well as an educational center hosting various workshops, academic tours, and conferences on sustainable development [12] [5]. Visitors can access urban amenities via a cable car or a glass elevator that provides a panoramic view of the entire technological space of the facilities. The presence of numerous plants on the roof creates the ambiance of a public park on top of the building. Furthermore, the green roof promotes biodiversity, absorbs heat, filters out harmful particles, purifies the air, and reduces rainwater runoff [12].

Figure 3 and 4. CopenHill waste-to-energy incinerator, Copenhagen, Denmark, https://urbannext.net/copenhill/

4. RESULTS

The research findings, obtained through the answers to the research questions, pertain to the previous analysis of the case studies. Responses to research questions defined in chapter 2. Methodology are presented systematically in separate chapters.

4.1. Answer to Research Question Number 1

The answer to research question number 1 relies on chapter 1.3. theoretical framework: urban sustainability. In this vein, the reutilization of slag as a construction material for road infrastructure in the Spittelau incinerator exemplifies a tangible manifestation of its profound significance [8]. Additionally, energy generation from waste sources holds the potential to diminish reliance on non-renewable coal-based energy production, thereby concomitantly curbing greenhouse gas emissions and other detrimental byproducts stemming from the combustion process [12]. The proximity of Waste-to-Energy (WtE) facilities, such as Spittelau and Copenhill, to households, commercial, and business activities generating residual waste significantly influences the sustainability of waste incineration systems. By minimizing transportation distances, this proximity leads to lower emissions, cost savings, and reduced odor issues.

Considering that harmful particles are emitted into the air during waste combustion, the principle of urban sustainability, which focuses on reducing negative environmental impacts, highlights the importance of designing systems in compliance with legal frameworks and directives. The Amager Resource Centre (ARC) in Copenhill represents the first SCR DeNOx installation in Danish facilities designed to reduce NOx and dioxin emissions by over 95% [12], while the Spittelau incinerator has achieved a CO_2 reduction rate below 90%. It is noteworthy that Denmark is among the countries striving to achieve full CO_2 neutrality by 2025 [13].

4.2. Answer to Research Question Number 2

The causal-effect methodology is employed to determine the extent to which architectural assumptions and considerations of spatial composition and visual identity influence the final parameters of the object while taking into account the incinerator's relationship with the surrounding environment. Specifically, both examined incineration plants are situated within the urban fabric of the city, prompting the exploration of how these facilities assimilate into the existing contextual milieu of the site. By designing the Vienna waste incineration plant, the artist has demonstrated that an industrial complex can be harmoniously and spectacularly integrated into the urban landscape. The incinerator is an example of decorative postmodern architecture that renders the industrial building socially acceptable by introducing radical aesthetic modifications to its utilitarian appearance [15]. Vienna's waste incineration facility is characterized by a distinct design, vibrant facade, and bold colors. The artist has successfully incorporated unconventional elements into the incinerator's facade design using their distinctive style, creating a pronounced sense of place. Despite standing out in the cityscape, its form holds significant artistic value and serves as a prominent landmark in Vienna's urban structure, attracting tourists to the city [8] [15].

In the case of the Copenhill incineration plant located in an industrial zone, a key consideration during the design process was the proximity to residential areas, making the spatial composition of the building crucial. Copenhill was designed to eliminate barriers separating the facility from the local community, instead striving to seamlessly blend in with its surroundings. The creation of a public space, in this case, a green roof extending to the ground, allows for easier integration of the plant into the city. However, its appearance cannot be attributed to conventional industrial designs, even though the dominant form is derived from waste treatment solutions. The modern design, green sloping roof, and distinctive shape distinguish it from the surrounding structures, creating an architectural landmark. Based on the research findings, it can be concluded that both incinerators fit into the context of their respective locations and significantly contribute to shaping the identity of their immediate surroundings [10] [11] [12].

4.3. **Answer to Research Question Number 3**

Based on a detailed analysis of the functional program in the case studies, urban functions such as recreation and education are observed. Based on a detailed analysis of the functional program in the case studies, urban functions, such as recreation and education, are distinguished, which are important for citizens' inclusion. Their significance is reflected in the following aspects:

- Enriching urban life quality - entertainment and leisure,
- Tourism development,
- Job creation,
- Education on sustainability,
- Holistic personal development - raising awareness about the importance of incineration plants.

The recreational spaces in Copenhill can be used for physical activity, relaxation, and effective utilization of leisure time, while the public functions in Spittelau dedicated to various events, such as exhibitions, seminars, and museum exhibits, promote cultural life in Vienna. Additionally, organized visits to incineration plants can impact tourism development, providing economic benefits to the local community. With an enriched architectural and functional program within the incineration plant, there is a need for new job opportunities in the community, which improves the socioeconomic status of the local community and enhances the quality of life for its residents. Both incineration plants implement numerous educational activities aimed at raising awareness about proper waste management and environmental care. Activities such as lectures and facility tours for various age groups stand out. Visitors have the opportunity to observe technological processes, including waste import and unloading into the bunker, as well as the thermal conversion of waste. They can also learn about issues and solutions related to flue gas purification and electric and thermal energy production.. The Copenhill incinerator has an educational center where lectures on various environmental topics are held and conferences and get-togethers are organized for the youngest, where the problem of waste management is emphasized [8] [10] [12] [15].

5. DISSCUSION

Before conclude a scientific research paper, it is necessary to disscuse and summarize the results of the research questions. Energy-efficient incinerators are significant from several perspectives. Increasing energy production, reducing waste disposal, and reducing waste gas emissions contribute to sustainable development and reduce negative environmental impacts. Essential components for achieving high environmental protection standards are emissions control and the implementation of advanced technologies, which influence the creation of clean air, substantial for human health. In addition to their industrial and technological significance, incinerators can also impact urban planning parameters through their location in urban zones near residential areas and significant landmarks in the city. Case studies indicate that the assimilation of public functions such as recreation and education within the functional program of incinerators provides users with various benefits for space utilization, thus improving the quality of leisure time. Moreover, by introducing high-quality and diverse content, we bring incineration plants closer to people and create facilities that are not solely associated with waste. Case studies indicate that incorporating educational functions within incinerators causes people to become more aware of sustainability, biodiversity protection, and waste management practices. Among other things, learning about the technological incineration process leads to approximating the procedure for individuals. Therefore, bringing the issue closer to people within incineration plants raises awareness about the significance of waste and its proper treatment. Integration of an incinerator into its surroundings is often associated with its physical identity, which involves creating a recognizable, unique, or modern form. The combination of exterior design and aesthetics with functional organization contributes to the creation of an architectural landmark that enhances the quality of life for the people living in the area. As an example, in the case of the Spittelau incineration plant, integration has been achieved by designing a façade that adheres to the distinct style of Viennese modernism, whereas the integration process in Copenhagen was facilitated by including recreational amenities on the roof and creating a mountain-like shape. Overall, the design of such incinerators strengthens the location's identity, and the advancement of incinerators stimulates tourism development in the city.

6. CONCLUSION

Case studies WTE facilities in Copenhagen and Vienna allow us to conclude how these objects blend seamlessly into the urban landscape, becoming not just functional necessities but also cultural and social assets for the city. Efforts to heighten awareness and promote education are imperative to address and dispel misconceptions surrounding the utilization of incineration, which often stem from a limited knowledge of the incineration process. Through these actions, it will be possible to foster greater acceptance and implementation, particularly in developing countries where there is a pressing need to enhance their waste management systems. This presents a propitious occasion to ameliorate waste management infrastructure, elevate consciousness regarding sustainable development, and establish the bedrock for integrating advanced technologies. In conclusion, energy-generating incinerators have significant potential to contribute to sustainable development, environmental protection, and the refinement of the quality of life in cities. As architectural symbols that integrate public functions, aesthetic design, and educational programs, these facilities can strengthen the identity of a place and boost development tourism. Integrating visual aesthetics into the design of waste incinerators can also play a vital role in increasing public acceptance and understanding of these industrial structures. By including elements of public art, educational spaces or recreational spaces within buildings, they become more than just places to dump waste – they become symbols of environmental awareness and progress.

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APPLICATION OF THE CONCEPT OF BIOCLIMATIC DESIGN AND PLANNING OF FACILITIES IN CITIES TO PREVENT POLLUTANTS EMISSIONS

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Abstract

We are increasingly witnessing climate changes, which, according to scientists, are occurring faster than expected. Major causes of climate change can be found precisely in cities, where human action leads to an increase in carbon dioxide gas emissions. In this way, quality of life is collapsing in the name of people's perceived comfort. If certain principles of planning and bioclimatic design were applied in practice on a larger territory, the possibility of a better quality of life with less environmental pollution would be achieved. The city is a living organism and as such is subject to changes. It is up to people to ensure that these changes are following the specific conditions of the area where construction is planned. The principles that are described in this paper are followed to bring the buildings into proper relation to the environment. When planning and designing an area, analysis, and assessment of natural conditions of the given area should be done at the very beginning. This process gives us a clear picture of our ability to create a project as a whole. The processing of data from the analyzed climate parameters is a prerequisite for future planning activities and specific requirements that may affect later changes in the area's microclimate. Characteristic changes in the style of construction are visible throughout history, depending on its surrounding where and the level of use of modern technology and techniques. At the moment, attention to the principles of bioclimatic design in densely populated urban areas is more often a luxury than a norm. Significant efforts and resources must be invested, to adapt the existing urban fabric to the increasing influx of people.

Key words: *bioclimatic design, environmentally conscious construction, ecological urban planning, Duvanište settlement, a survey*

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1. INTRODUCTION

Energy renovation involves the execution of construction and other works on the existing building, where the structural elements are not changed and the safety of neighboring buildings, traffic, and the environment are not affected. The ultimate goal of energy rehabilitation is to increase the energy efficiency of the building, which was achieved in this work on the example of one building in the Duvanište neighborhood of Niš, characterized by a high rate of air pollution, especially in the winter months. There are different ways to make a building acceptable from the perspective of bioclimatic design, and this paper first analyzes some applied approaches through explanations of passive and active mechanisms, urban environments, and physical frameworks. Along with this topic, the impact that ecological architecture has on the prevention of emissions of harmful gases and particles, along with already existing financial benefits when achieving thermal comfort, inevitably goes along. After the presentation of all applied planning and design principles on a concrete example, an analysis was given of how this type of architecture would contribute to the community.

2. ANALYSIS OF THE LOCATION OF PART OF THE "DUVANIŠTE" SETTLEMENT

- The buildings in Duvanište built during the socialist period are distinguished by the fact that the housing and planning model in the former Socialist Federal Republic of Yugoslavia was influenced by the Eastern European housing model. Due to the applied values of social equality and "common interest", urban and architectural design was based on a mixture of rigid rules of socialist urban planning. However, the liberal nature of the Yugoslav self-governing socialist system resulted in better urban and architectural design and a higher quality of life in Yugoslavia than in Russia. [4]
- Duvanište settlement belongs to the municipality of Medijana, and it stretches between Nemanjića Boulevard, Majakovski Street, and Vizantijski Boulevard. This settlement got its name from the tobacco that was once planted there. The settlement is connected to the city by regular lines and it takes ten minutes to get to the center by bus or even less by car. Duvanište is also home to the "Dušan Radović" elementary school, which used to be called "Filip Filipović". In addition to the elementary school, Duvanište also has a high school of economics, a hospitality-tourism school, and a trade school. The settlement contains a health facility, as well as many catering and shopping facilities. This area is mostly dominated by multi-story buildings, but there are also family houses.
- The settlement is dominated by individual housing, while collective housing is on the eastern edge and the northern and northwestern sides of the settlement. The subject area where the research was conducted and where the population survey was conducted is in the central part of the settlement and includes exclusively individual housing.
- Natural macro-locational conditions include:

- green areas that are concentrated mostly around the school and in the area around the buildings, and less in the area next to individual buildings
- the configuration and exposure of the terrain, on which the insolation and humidity of the terrain depend, do not represent a limitation when planning the regeneration of buildings, because the terrain is flat,
- and sunlight is a very important factor, given that the settlement is located in an area of the basin that is sufficiently illuminated. Annual temperatures are in the expected range from 16 to 28°C, the maximum recorded temperature is 42°C, and the minimum is 8°C.
- dominant winds blow from the north to the south and the expected wind speed ranges between 7 and 9 km/h. Therefore, the settlement is in a basin and air currents throughout the year are unfavorable in terms of ventilation of the location. Thus, particle pollution is retained during the winter period, and during the summer, air conditioning and ventilation of buildings are difficult.
- the relative humidity of the air in the settlement is favorable throughout the year.

3. RENOVATION OF FACILITIES

The objective of the renovation of the facility is that it is in use again or that the performance is better than it was before the implementation of certain activities on the facility. Any renovation implies a performance that represents an ecologically correct procedure. In cases where there is a choice, rebuilding a building should always be preferred over demolition, for several reasons. The most fundamental thing is the reduction of waste material, which in itself is in most cases poorly degradable and does not have the possibility of recycling and reuse, while the construction of a new building requires the acquisition of new materials. New construction also requires more energy, which is used for these jobs and generates more noise. The renovation project is created so that measures are taken that will be in an adequate relationship with the environment, so the sequence of actions during the renovation of the building is as follows:

- first of all, planning and designing of all options is done and considering the advantages of each of the possibilities of performing works, until choosing the most favorable one;
- Carrying out work on the demolition of parts of the existing basic structure of the building if necessary,
- then, if also necessary, the dismantling of parts of the existing basic structure of the building or the introduction of new parts (partition walls or entire new floors);
- after that, work is done on improving the existing parts of the building structure, which includes, for example, adding a layer of sound insulation, thermal protection on the facades, and other systems to improve the comfort inside the building,
- repair and replacement of damaged and inappropriate parts of the building is a level that potentially overlaps with the previous one, and refers to the replacement of carpentry, installations, floors, and more,

- in the end, cleaning and surface treatment of the building envelope surfaces is done. [3]

If, after the analysis, the original parts of the building structure are characterized as favorable in terms of quality and environment, they should be preserved without changes to the greatest extent possible. This means that the interventions carried out during processing should be reduced to the necessary minimum, so that the lower the level of activity, the lower the unfavorable environmental impacts on the environment.

As most of the activities are reduced to the dismantling of existing and installation of new materials, it is necessary to take care to reuse the dismantled materials as much as possible, and if possible, on the spot. Each of the new materials that are part of the structure should be chosen according to their ecological quality. Possibilities that are examined and then carried out during the renovation of buildings should provide conditions for improving the future ecological properties of the building, primarily in terms of energy efficiency by introducing passive and active building systems. In the process itself, pollution of the environment should be prevented by a proper organization of the space, the choice of equipment, and a negative impact on the microclimate and disturbance of nature globally should be prevented. Another important item is efficient water management, in some of the known and tested ways. Solar energy can be used both in newly designed and existing buildings. [5] As this is the safest renewable source of energy, with its constant exploitation it is possible to achieve energy-efficient buildings, economically profitable, while at the same time improving the comfort of the users of the space. Costs related to building renovation using bioclimatic design are, according to examples from practice, returned and paid for in just five to ten years. During that time, the renovated building has a good quality of the internal environment and the emission of carbon dioxide and other components of air pollution has been reduced. According to the 2022 population census, there are 96,728 registered households in Niš, most of which do not have central and floor heating installations. [6] These are all facilities that could be renovated in terms of energy efficiency so that they produce less CO_2 and suspended particulate matter emissions.

4. SURVEYING USERS OF THE PREMISES

An important part of any research is the collection of data on the characteristics of certain individual buildings in the settlement, carried out in the field. Using a survey, data was collected from residents about the characteristics of the facilities. The area in question consists of 56 buildings, which by typology are mostly freestanding, but there are also 7 semi-detached houses, and the layout of the plot is given in Figure 1.

ANKETA

Lokacija:________________ Datum:__________________

I stanovništvo:

Pol ispitanika: a) muški b) ženski

Godište starosti: a) <18 b) 18-35 c) 36-55 d) 56-65 e) >65

Da li ispitanik stalno ili privremeno živi u objektu?______________________________

Da li je ispitanik zadovoljan toplotnim komforom u objektu u kome živi?______________

Da li je ispitanik zadovoljan stanjem vazduha zimi u naselju?______________________

II Građevinski fond

U kom periodu je građena kuća?____

Stanje objekta:____

Sistem gradnje objekta:____

Da li objekat poseduje termoizolaciju?__________________________________

Ako poseduje, koji je tip termoizolacije?_________________________________

Završna fasada objekta:____

Tip krova na objektu:____

Stanje krovne konstrukcije i krovnih pokrivača:____________________________

Stanje stolarije na objektu:____

III Parcela

U kojoj meri je prisutno zelenilo na parceli?_______________________________

Kakva je materijalizacija popločanja na parceli?____________________________

Da li se na parceli nalaze pomoćni objekti i koliko?__________________________

IV Komunalna opremljenost

Koji izvor energije za zagrevanje objekta se zimi koristi_______________________

Da li je voda ispravna za piće?____

Da li reciklirate otpad?____

V Mišljenje stanovnika

Zainteresovanost za uvođenje aktivnih sistema proizvodnje energije?_______________

Zainteresovanost za regeneraciju omotača objekta?_____________________________

Zainteresovanost za promenu stolarije?_____________________________________

Figure 1 - Layout of the survey conducted on the population of Duvanište in Niš, picture by the author

The survey was conducted from September 10 to 15 on 46 respondents, that is, according to the respondents, the collected data is valid for 46 facilities. The content of the survey is about the condition of the building, the plot, and the energy sources used by the household. The survey was conducted on 22 male and 24 female residents, none of whom were under the age of 18, 20% of respondents were aged 18-35 and 56-65. About 35% are aged 36-55 and about 25% are the oldest fellow citizens. Half live permanently in the building, and the other half rent the building, and only a small percentage of residents occasionally come to the building, because they live permanently in another location. 82% of respondents are satisfied with the thermal comfort in the facility, but 75% of residents are not satisfied with the air quality in the settlement in winter. As for the building fund, all the objects were built in the period from 1965 to 1995, but upgrades were made in the later period as well. 1/5 of the buildings are houses that are in poor condition, while the rest are inadequate or almost renovated. For the construction system, the answer was given by 34 respondents, of which 90% said: massive construction system, mostly with brick elements. Approximately half of the respondents claim that the building does not have adequate thermal insulation, and the other half that it does: 14 claim that EPS, 8 stone wool, and 2 respondents that Styrofoam was used as thermal insulation. For the most part, the final layer of the facade of all buildings is plaster, and 90% of buildings have pitched roofs. The roofs are generally in good condition, but a couple of respondents report leakage and the occasional repair of roof coverings. The carpentry of 60% of respondents is old. The windows are mostly double-glazed. Greenery is mostly buried in all plots where the survey was carried out. With the renovation of buildings, tenants are increasingly choosing to turn green areas into concrete ones for more accessible parking. In addition to concrete, the Behaton paver of various shapes appears on the plots. 30 respondents have one to two auxiliary buildings on their plots. Although a heating plant was built in Duvanište, 90% of respondents have gas connections, but only 35% use gas as the main source of energy for heating in the winter months. 16 respondents report that they are heated with wood, and one building has solar panels, but they are also heated with wood. 8 respondents use coal and the rest use pellets. For all respondents, the water is suitable for drinking, but as many as 13 families use additional water filters. 75% of the respondents received blue plastic recycling bins from the city, which are special compared to other waste. Most respondents have heard of and are interested in the introduction of active energy production systems. About twenty respondents are skeptical when it comes to this measure because finances and complicated technology are a problem. Only 12 surveyed residents believe that the regeneration of the building's envelope would be a useful and long-term solution for thermal comfort, for 5 surveyed, more believe that changing the carpentry would be efficient and more economical. It is important to note that as many as 60% of respondents are interested in the renovation of the building's envelope, which also implies that in the future it could have a positive impact on the environment of this settlement. Tenants are aware that the renewal of the envelope is key to saving energy because thermal insulation prevents heat dissipation, thus the need for additional space heating will be reduced and air pollution will be prevented in one of the most critical neighborhoods in Niš.

5. ANALYSIS OF THE CURRENT MICRO-LOCATION AND CONSTRUCTION PARAMETERS OF THE SUBJECT FACILITY

When designing passive solar systems, the possibilities offered by the building's environment, i.e. the location itself, are considered in detail. In the case of passive solar principles, natural factors and created conditions must be considered, before the actual development of the project. [1] The part of the settlement that was cultivated consists of three blocks with individual housing facilities, which are bordered by residential streets. According to the typology of housing, in the observed part of the settlement, the largest number of buildings are free-standing buildings, in addition, there are also semi-detached buildings, of which there are 7 in the location. 13 buildings are P+1 storeys, 15 are buildings with attics in addition to two floors, 8 buildings are P+3 storeys and two buildings on the site have attics in addition to three floors. Based on the research and data collected in the field and through the analysis of the survey, a facility was selected for regeneration and revitalization. The building is located on the southern block. Specifically, in the northeastern part, where Dimitrija Dragović and Filipa Filipović streets cross. The building has P+2 floors and was built in 1968. Based on research, it was concluded that buildings built in the late 70's and early 80's in terms of their usable area have higher CO_2 emissions than those built in the early 90's or later. [2] The object belongs to the cadastral municipality of Niš "Ćele Kula". The area of the plot on which the building is located is 308m2. The building occupies 97m2, and the second and third floors have two terraces in the north and east. The structural assembly of the building is surface-massive with vertical supporting elements (walls) in the direction of the longer and the direction of the shorter side of the building (cross system). Masonry elements from which the building is built are bricks (solid bricks) connected with an extension mortar. The basic structural assembly of the buildings consists of masonry load-bearing walls with a thickness of 25 cm, connected by horizontal AB cerclage and mezzanine structures. The height of the horizontal cerclage is 40 cm (the height of the mezzanine structure), and the width is equal to the thickness of the wall.


Figures 2 and 3 – Current appearance of the object in question, pictures by the author

The material of the internal hygienic-aesthetic or protective part of the building is plaster. The thermal protection part, as with most buildings built in Duvanište in the seventies of the 20th century, was not installed. The external protective and aesthetic part is a pale yellow plaster that has started to fall off the building in some places, as can be seen in Figure 2. Another view of the current appearance of the building is in Figure 3. Greenery is dominant in the free part of the plot, but poorly arranged considering that in some parts the tree tops reach the wires that connect the poles and conduct electricity through the settlement. The paths around the building and the paving on the plot are made of concrete and are in relatively poor condition.

6. REASONING OF THE ARCHITECTURAL SOLUTION TO REDUCE CO_2 EMISSIONS

According to research in Niš, the results of measuring CO_2 emissions were obtained using appropriate devices that were equipped, certified, and calibrated following standards and are the result of a three-year period of monitoring the total consumption of heat and electricity at five locations in the territory of the city of Niš. Using the obtained results, the total CO_2 emission was calculated before and after the revitalization of the energy characteristics of the selected structures. Measurements of thermal energy consumption are made for the heating season, i.e. from October to April, and for electricity throughout the year. The total CO_2 emission generated during the operation of the building is determined based on the data on the specific CO_2 emission for certain energy sources, by multiplying the annual primary energy required for the operation of the building according to the specific energy source with the corresponding specific CO_2 emission parameter. [2] The main goal of the project is the regeneration of the residential building, and passive design elements were used to reduce the energy required for heating and cooling, enable natural ventilation, and reduce the emission of CO_2 and particulate pollution.

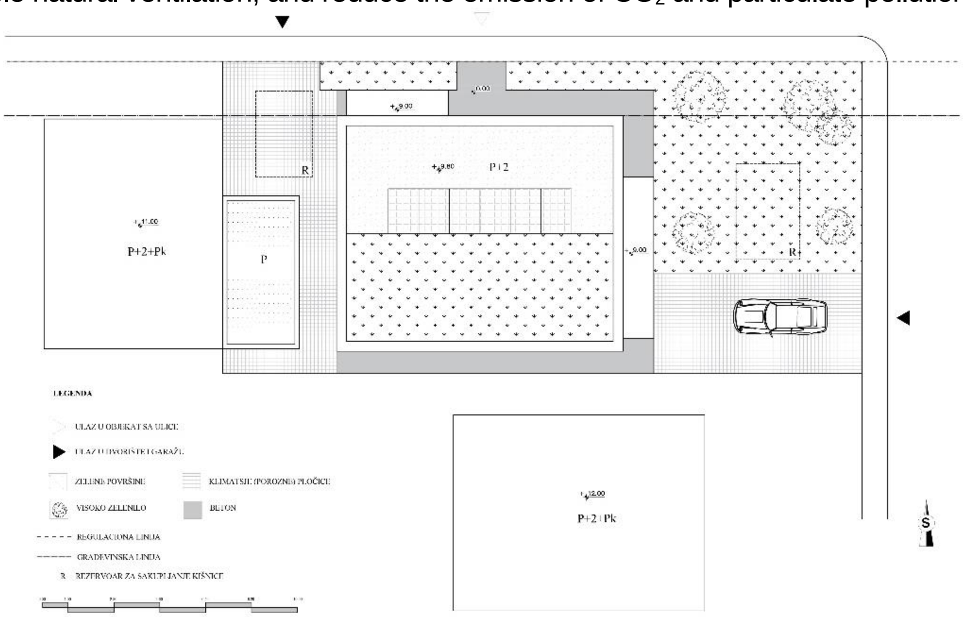

Figure 4 - Graphic attachment, the situation of the object on the plot, author's picture

The beginning of the project development implies the location of the object on the plot, and the situation is presented in Figure 4. Based on this, the application of passive and active systems was started.

6.1. Application of passive systems on the building

The biggest challenge is the current lack of thermal insulation, so an adequate thickness of thermal insulation was applied on the walls, roof, and floor, towards the unheated space, which will improve the building's energy class in a later calculation. Energy revitalization of the building was performed by adding heat-insulating material from expanded polystyrene (EPS) and extruded polystyrene

(KSPS) of appropriate thickness for each element of the structure (walls, flat roofs, and floors). The revitalization of transparent surfaces (windows and exterior doors) involved the re-installation of new ones in place of the existing ones but under the maximum allowed heat transfer coefficient. The new joinery must meet numerous aesthetic requirements, and provide adequate heat and sound insulation. Since there is a significant dissipation of thermal energy needed for heating and cooling through woodwork, their energy efficiency is one of the most important elements of the overall energy sustainability of buildings. In total, heat losses through the windows amount to over 50% of the heat losses of the entire building, which is ten times more than through the walls. During energy rehabilitation, the quality of the joinery must ensure good sealing, break the thermal bridge in the profile, make opening and closing simple, and enable a low coefficient of heat transfer. The carpentry is provided by the project as a combination of wood and aluminum, which is characterized by the best properties of both components - wood, with its naturalness and warmth, fits perfectly into the interior, while aluminum is ideal for external protection. Thermal insulating reflective glass is coated with a metal film that reflects part of the glass and absorbs part. The building does not change significantly in the interior. Given that the neighboring building located to the south of the building in question blocks the gains of solar energy on the south side, the living rooms, the living room, and dining room with the kitchen are placed on the east. The entrance to the building and the staircase are on the north side, while the two bedrooms are placed on the west. The layout of the rooms is the same throughout all three floors. Thermal insulation is added to the building envelope toward the unheated space. Part of the roof is green and is used to collect stormwater. Solar panels for the production of electricity are foreseen on part of the roof. Other elements of the "WSUD" system (Water-sensitive urban design) are the system of collecting rainwater from the climate tiles on the west side of the plot and from the rain garden on the east side of the plot and depositing it in reservoirs from where the filtered water would be used again later. Natural ventilation of the buildings is obtained by the proper formation of adequate window openings and doors. The high greenery that already exists on the plot is preserved to a certain extent. It is necessary to maintain or plant high greenery that does not reach the wires from the pole located at the corner of the block next to the building's fence. All the mentioned principles were applied to create very favorable conditions for people's lives and achieve the necessary comfort at any time of the year. On the lot, it is possible to park vehicles on the east side and the north side in the auxiliary building. The eastern side is intended for rest and recreation.

6.2. Application of active systems on the facility

Photovoltaic panels are planned to be installed on part of the roof. By analyzing the potential when installing photovoltaic panels on the roof surface, it is possible to achieve significant savings in electricity consumption, and reduce the emission of CO_2 gas and suspended particles, and by using the resources used. ski panels on the roof structure of the building. The energy consumption in kilowatt-hours (kWh) alone dictates the size of the active system. Solar Panels have a wide power range, and other factors such as local insolation, and orientation of the panels also have an impact. The most efficient way to determine the required number of panels on the roof of the building is to estimate current energy consumption based on past electricity bills for a period of 6 months to a year. The estimate of the total size of the system is obtained as the quotient of daily consumption (kWh) and sunshine hours for a certain area, all of which is divided by the failure factor (0.9). In this particular case, it is 9,865 kWh of electricity per year (in 2022), or 27 kWh per day. There are 5.5 hours of sunshine a day in Niš. According to the above, the power plant capacity is 5.4545 kW. Based on the formula, an approximate system size of 5.45 kW or 5456W is given. [7] From there, the last step is to divide this number by the panel power. Solar panels are rated by how much energy they use. Panels used in a residential environment typically range from 275 to 350 watts per panel. If we take 340W power panels as an example, according to the size of the system and the power of the panels in the system (5456W / 340W) in theory, 16 panels need to be placed on the roof of the building for efficient provision of electricity. As the application of passive building renovation systems will reduce the need for additional heating of rooms, the required number of panels would be even smaller.

7. THE PSYCHOLOGICAL EFFECT THAT THE BENEFITS OF BUILDING RENOVATION HAVE ON THE INHABITANTS OF THE SETTLEMENT

From a psychological point of view, a popular phenomenon is following trends, and even in the reconstruction of buildings, following the possible household. If they were to make a parallel with the study conducted in the scientific magazine "Nu sci magazine", where it is stated that people feel most comfortable if they follow the trend, that is, if they are not left out of the improvement brought by change. Then they decide who is part of the groups, that is, by mixing ideas with the trendsetters about how they can improve themselves and their names most efficiently, with the help of previous experiences, and with the assistance of others, the quotas themselves have already gone through the phase of change. [8] After the renovation of the building in question, in the same, cross and neighboring nearby streets, there was an incentive for the neighbors to approach the renovation of their old buildings in the same or similar way, which, according to the results of the survey, were of the same construction type as the building in question. The assumption is that more buildings within the settlement could thus be renovated and thus the emission of harmful gases would be reduced to a greater extent.

8. CONCLUSION

New buildings cannot be built without paying attention to health and general ecological principles in addition to costs and comfort. Nowadays, increasing the building's energy efficiency, energy optimization, and respecting the principles of sustainable construction are becoming increasingly important principles in building design. For energy rehabilitation to be successful, various measures to reduce energy needs should be considered. It is necessary to enable the introduction of new ecologically correct technologies, to use renewable energy sources, above all solar energy, which is dominant in the territory of the Republic of Serbia, and thus include the analysis of certain economic factors. Energy-efficient architecture or eco-architecture contributes to reduced CO_2 emissions and is part of sustainable construction by reducing heat losses from the building by improving the thermal protection of external elements and a favorable ratio of the surface of the envelope and the building; increases thermal gains in the building by the favorable orientation of the building and use of solar energy; uses renewable energy sources in buildings (sun, wind, biomass, etc.); increases the energy efficiency of applied thermo-energy systems. The profitability of using bioclimatic design principles is visible in itself within five to ten years. The philosophy of construction teaches that the built environment is the third health barrier of a person, after his skin and clothes. As such, it is necessary to design to be in harmony with nature and harmony with the human organism. The space that is being built does not only provide security from atmospheric phenomena but also needs to insulate, evaporate, absorb, and enable communication with the environment. The importance of applying the principles of energy efficiency in Serbia is more than evident. The application of bioclimatic principles is presented in the example of an object located in Niš. The recorded positive effect reflects on people and the environment. Regarding the initial hypothesis and the goal of this study, the revitalization of all buildings in terms of energy is needed to reduce CO_2 emissions, which is an indirect result of the improvement of energy efficiency after the revitalization measure.

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MERSI – FROM BASIC NEEDS TO INCLUSIVE DESIGN FOR ROMANIAN SPECIAL SCHOOLS

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Abstract

SCOPE: This paper proposes an interdisciplinary approach between architecture and special pedagogy. The goal of the MERSI research project (Mobility, Equity, Resilience, Inclusive Spaces) was to create a framework for future debates concerning the need of building new public educational facilities in Romania: inclusive and special schools.

METHODOLOGY: A post-occupancy evaluation (POE) focusing accessibility was conducted in the Special Secondary School No. 1, Bucharest. Our methodology included direct observation, guided tours, measurements, interviews, surveys, presentations, and workshops. The quantitative analysis considered entrances, steps, ramps, stairs, railings, handrails, the possibility of including elevators, doors and corridors' free widths, thresholds' height, windows' parapets, operating scenario, and redevelopment possibilities. The main functional areas studied in the qualitative analysis included: the school site, classrooms, cabinets, meeting rooms and other spaces for teachers, the culinary laboratory, arts and crafts zones, physical activities, and therapeutic areas.

RESULTS AND DISCUSSION: Children with moderate, severe, and associated mental disabilities need varied and accessible spaces, for safely exploring and continuous strengthening their personal autonomy. The ability to focus on certain tasks is directly affected by materials, colors, textures, sounds, lights, and shadows, inert and moving forms. This study found 8 categories of intergenerational elements needed in all interior and exterior educational spaces: worktops, sitting places, exhibition areas, presentation zones, different storage places, access to resources (electricity / internet / water), natural elements, playful areas (ludic elements that facilitate sensorial stimulation and movement).

CONCLUSIONS: A radical transformation in education is a complex, long-term process, which must be based both on the operating conditions of existing schools, and on the future needs of users: students, teachers, parents, and community members. Architects' awareness becomes essential for designing special and inclusive educational spaces. This research aims to influence the revision of design norms and guidelines towards high quality inclusive design.

Key words: *Inclusive Design, Post-Occupancy Evaluation, School Architecture, Special Education*

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1. INTRODUCTION

"Giving of your time and care to fellow human beings is the most elegant form to be an architect in the city" [1]. Building our research goal on these words, an architect can create meaningful and memorable spaces by engaging with the values, needs and aspirations of the people who inhabit and use them.

Among all meanings offered to the complex term of "sustainability", we further propose a focus on "the ability to sustain". In this fundamental way of looking at things, sustainable design includes, from the very beginning, the principle of supporting all abilities. We thus arrive at concepts such as *design for all*, *universal design,* or *inclusive design.* A broader sense can be found in the *person-centered design* definition: "that design process which places real people at the center of creative endeavors and gives due consideration to their health, safety and welfare in the built and virtual environments" [2].

MERSI (acronym for *Mobility, Equity, Resilience, Inclusive Spaces*) was a short interdisciplinary project developed in 2022 by the „Ion Mincu" University of Architecture and Urban Planning, Bucharest, Romania (UAUIM). One objective of MERSI research project was to develop an analysis model that opens new perspectives for special education teachers, for optimizing their work with students having special educational needs (SEN). An applied research of four months was conducted in Special Secondary School No. 1, Bucharest.

The educational environment, which is a mixture of natural environment variables, is a specialized setting for the formation of human personality, represented by the totality of internal and external factors that impact instructive activities. It can be defined as a *training dimension* that involves the interaction of people, objects, information, and emotional states, all of which have direct consequences for learning [3]. The internal conditions of the educational environment describe the cognitive, affective, and motivational processes that occur. The external conditions refer to the physical space, the psychosocial climate, and interpersonal connections. While moving through architectural space we are being shaped by the features of the built environment [4].

Our main connection with the world around us is through the senses - tactile, vestibular, visual, auditory, olfactory, and gustatory. Our brain processes sensations and allows the elaboration of responses [5]. Adaptive behaviors are then developed, depending on the sensory integrity of the senses and the neural capacity to process the stimuli. Thus, one of the main design goals is adapting space to different types of sensory integration. Under the impact of educational theories, the built environment allows multiple configurations.

The vision of an *Inclusive School*, or a *School for All* advocates for adaptable, sustainable educational environments designed to inspire and offer a variety of contexts fostering multisensory learning. This research based its premises on capturing the characteristics of a stimulating school environment:

What are the fundamental values of the educational space?

What elements of the built environment support these features?

What barriers in the existing school environment prevent the achievement of these values?

What changes could optimize the educational environment?

2. METHODOLOGY

Tools are not neutral objects. They are shaped by social and cultural factors and can influence how we think and act: „a tool is also a mode of language, for it says something to those that understand it, about the operations of use and their consequences" [6]. In other words, the tools we choose as researchers in the architectural field can also act as methods of dialogue that communicate something about the processes and their consequences. Based on sociologists' viewpoints, research approaches that investigate people and their actions may have a natural character (they allow real, natural, usual, undistorted behaviors) or a "non-natural" character, being built on prompted responses.

On one hand, *subjective assessments* often include feedback from various stakeholders; yet the information received is often retrospective and dependent on the degree of recall. For example, the exclusive use of observation does not access people's motivations, attitudes, knowledge, and intentions.

On the other hand, *objective assessments* (questionnaires, checklists, measurements) can provide some standard level across different spaces. In contrast, working techniques built on elicited responses have certain disadvantages. The evaluation is static and may omit those unique elements that do not appear in the written instruments. We can supplement the "non-natural" character of these responses through group work techniques.

Each technique and working tool have certain benefits and delivers its own outcomes, according to the specific way of measuring a certain phenomenon. As a result, their selection in a Post-Occupational Evaluation process requires careful matching with contextual variables and available resources.

2.1. **Observation**

Observation provides the advantage of collecting people's true behaviors in their natural context, with all inter-conditioned variables captured (rather than just the behaviors reported in surveys or interviews). The observation technique involves taking detailed notes, carefully selected field records, which emphasize descriptions, rather than impressions:

structured observation (quantitative work technique): the systematized grouping of the collected data is done through evaluation scales and analysis tables.

participatory observation (qualitative work technique): involves studying a community from within, by participating, for a certain period, in its activities.

Observation can induce changes in people's behavior, due to the physical presence of the researcher. However, these changes diminish over time; thus, as the observation extends over a longer period, "the transparency of the authentic increases" [7].

The architect as a researcher will play the role of a peripheral member of the investigated school community; unlike the status of "full member" or "active member" of a studied community, the researcher as a "peripheral member" interacts with the group to obtain a perspective from within the community, participates in certain group activities but not in those essential, which define it.

2.2. Interviews

A meeting technique between two or more people whose purpose is to gather information through a set of planned questions, the interview as a research technique can either be conducted as a:

systematic interview that completes the observation method, having the additional quality of capturing the future intentions of the people under study.

the unstructured (in-depth) interview which involves spontaneous, informal conversations, but also organized discussions, focused on certain topics.

The applied research at Special Secondary School No. 1 from Bucharest included both types of interviews: two systematic ones with psychopedagogue teachers, one in-depth interview with the school principal and one interview along the school tour with the school administrator.

2.2.1. Workshops

For architects to better understand the whole spectrum of differences at the sensorial, cognitive, and social level, 5 workshops were organized: 35 children with SEN from Special Secondary School No. 1 and 10 parents / legally designated tutors participated in 4 workshops; 7 architects and 10 teachers participated in an Inclusive Design Workshop.

The first workshop dedicated to children with SEN took place in an outdoor therapy center equipped with a sensory garden (33 beneficiaries): 3 architects, 13 children with mental disabilities, 9 teachers and 8 parents / legally designated tutors. The second workshop was held in an indoor Sensory Space within a recently established Step by Step Autism Center in Bucharest (14 beneficiaries): 5 architects, a teacher, 4 children and 4 parents / legal tutors. The children benefited from multisensory stimulation in 4 rooms. The third workshop outside the school took place at Joyplace, an inclusive indoor open space adapted for children with neuromotor disabilities (19 beneficiaries: one architect, 13 children and 5 teachers). Another creative workshop was held in Special Secondary School No. 1 (27 beneficiaries): 15 students, 10 teachers and 2 architects from the MERSI team.

The Inclusive Design Workshop had 17 participants: 10 teachers from the Special Secondary School No. 1 and 7 architects from the MERSI team. Teachers and architects discovered together possible operating scenarios of an ideal school for children with special educational needs.

2.3. Questionnaire

A relevant number of 34 teachers (from the total number of 45 in Special Secondary School No. 1) answered a survey regarding mobility and accessibility in their school. Questions about mobility included the main barriers that influence the decisions of choosing the transportation modes between home and school. This topic is not developed in the present research paper.

The accessibility section of the applied questionnaire for teachers had 12 questions, carefully selected after analyzing the results obtained in the visiting tours, interviews and accessibility measurements.

3. RESULTS

The architects' goal was to discover and learn from the team of school teachers about their true needs and expectations from the school environment, in order to provide meaningful learning experiences to their special students.

3.1. Quantitative analysis

All teachers answered they generally use the steps and not the existing ramps for accessing the school entrance. A percent of 35% of the respondents admitted they slipped in rainy or winter weather on ramps or on the school entrance steps. A larger number of teachers (38%) noticed a student slipping on the school entrance ramps at least once.

The different answers provided by teachers for the next question (Figure 1 below) show the design problems of the existing exterior ramps.

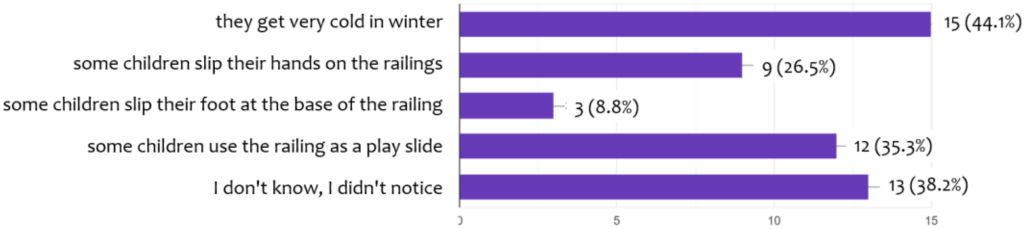

Figure 1. Question: Have you ever noticed any of the following situations regarding the handrails of school entrance ramps? (34 answers from teachers)

The Romanian legislation in use [8] explains that ramps should have a maximum inclination of 8% (recommended 5%), anti-slippery flooring finishes, tactile-visual warning surfaces and a minimum 10 cm base profile for the railing to prevent slipping.

Four teachers out of 34 respondents said they have tripped over a door threshold in their school building, at the main entrance or throughout the spaces on the ground floor.

An interesting result about using the school interior staircases by children with SEN is illustrated in Figure 2:

Figure 2. Question: Have you ever noticed any student tripping on the steps when going up or down the internal stairs in the school? (34 answers from teachers)

62% of the teachers answered they did not notice any situation where a student was at risk of injury on the stairs or near the sharp edges of some furniture or other wooden elements. At the same time, 8 teachers said they noticed these situations of risk for children related to stair tread nosing. Furthermore, 10 teachers associated injury risk situations with edges of the wooden furniture or sharp edges of a window's parapet.

Answers to the next question were balanced: half of the teachers think it would be useful for visual communication with parents and colleagues if the school had doors with glass areas, through which one can easily see inside the rooms. The other half of the respondents did not agree with the above solution. From these 17 teachers, only 10 explained their arguments:

- *It would be a distracting factor for the child with SEN.*
- *Parents can make pictures or video recordings without consent through those glass surfaces.*
- *Because the school is for students and teachers and if the presence of parents is needed, they can stay in the classroom (gym).*
- *I concentrate better.*
- *Distracting students.*
- *Children can get injured.*
- *Parents do not have unlimited access to all the school premises. On the other hand, large glass surfaces are a risk for children with mental disabilities and behavioral disorders.*
- *Too many stimuli for students with attention deficit disorder.*
- *Students with SEN can be distracted very easily.*
- *Children with special needs can easily get distracted during the educational act, seeing the outsiders watching them.*

The final question gave teachers the opportunity for open opinions. From all 34 respondents, only 4 teachers wrote ideas regarding accessibility improvements:

- *The classroom space should be used much better, in favor of the student. The furniture should be easy to handle (moved, pushed even by students) to make the educational process much more attractive and dynamic.*
- *There is no way to access the upper floors for children in wheelchairs or for children who cannot move.*
- *Larger steps and smooth slope.*
- *It would be desirable to install some elevators to facilitate going up to the cabinets / classrooms on the upper floors for students with motor difficulties. The school yard should be covered with tartan flooring or grass, to minimize the risk of accidents.*

3.2. **Qualitative analysis**

The first workshop between architects, teachers, children with SEN and their parents (legal tutors) comprised a sensory-guided tour that included visual, tactile, auditory, gustative, and olfactory stimulation, as well as two themed workshops with expert instructors.

The *sensory garden* is the place to explore the environment with the help of the senses (sight, hearing, taste, smell, touch) and functions as a memory stimulation tool for children. The sensory alley route incorporates various surfaces such as: gravel, sawdust, fir cones, shredded bark, circular logs, with a role in vestibular stimulation, developing dexterity and coordination. The *outdoor relaxation areas* invite children to silent reconnection, allowing for both individual and group activities. In contrast, the *garden of sounds* is intended for auditory stimulation, relaxation, and emotional expression. The *adventure garden* is equipped with structures made of different materials and has the role to stimulate the vestibular and proprioceptive senses. Children can learn to coordinate their movements, to control their posture and to maintain balance.

The indoor sensory space was equipped with educational materials, a tube with air bubbles and game of lights and colors, pool with balls, microphone, projector for interactive educational materials and a relaxation hammock. The architect observed and discussed behaviors with trainers and parents.

In the third workshop, children first explored the open space, freely or guided by their teachers. The playground area was adapted with multisensory stimulation elements: adapted swings, a zone having a playground slide arriving at a secured ball pool and a construction area with soft and modular geometric volumes. This “imagination playground” with construction toys contributes to stimulating creativity through a variety of assembly modes. The “tummy play zone” has a soft floor covering made by puzzle-colored pieces and is meant for children who do not walk independently. The "up and play” area was very challenging for children who can move by themselves.

After releasing their energy, the children were engaged in a clay modelling and painting activity coordinated by a specialized trainer. The ways in which the environment might help children improve their motor and cognitive skills were also observed in real time and analyzed by the architect from MERSI together with the architect in charge of Joyplace (who is also a mother of a child with severe neuromotor disabilities).

At the creative workshop in their school, children painted wooden houses and models of cardboard urban buildings, while the architects interacted with the pupils and teachers in their own environment.

Figure 4. Four Workshops: children with SEN, parents, teachers, and architects

The Inclusive Design Workshop with 10 teachers and 7 architects (5 participants and 2 trainers) included several individual and group activities.

At the beginning, the main barriers had to be discovered. Teachers received a “Top 3 places I don’t like in my school” exercise. The results described, in a descending order, 11 places: *the basement (canteen access), staircases, the students’ entrance, the entrance steps, school building’s attic, the corridors, canteen / cafeteria, arts & crafts room, classrooms, a balcony from one teacher’s cabinet* and *the school yard*. An architect drew on a whiteboard 7 criteria for teachers to consider while addressing discomfort reasons to their Top 3 disliked school spaces: 1. *Accessibility* (attributed by teachers for 6 spaces); 2. *Visual* (included for 9 spaces); 3. *Auditive* (included for 1 space); 4. *Olfactory* (included for 2 spaces); 5. *Hygrothermal* (included for 5 spaces); 6. *Lack of Resources* (included for 3 spaces);

7. *Psychological* (included for 5 spaces). Table 1 illustrates the results of filling out forms relating to the top three places from their school building that the 10 teachers dislike.

Table 1. TOP 3 places I don't like in the Special Secondary School No. 1 Bucharest

Space (no. of answers / total of 10 teachers)	Discomfort criteria		Teachers' detailed answers
Basement (Canteen access) (5 / 10)	1	Accessibility	*there are pipes we can hit our head on*
	2	Visual	*no natural light; visual*
	3	Auditive	*humidity*
	7	Psychological	*sad; scary*
Staircases (4 / 10)	1	Accessibility	*it is impossible to go in two directions at the same time; lack of accessibility*
	2	Visual	*visual*
	7	Psychological	*a sensation of suffocation*
Students' entrance (3/10)	1	Accessibility	*very narrow; it gets crowded quickly in the morning; inaccessible for people with locomotor disabilities*
	2	Visual	*colorless; visual*
	3	Auditive	*noisy; auditive*
	5	Hygrothermal	*cold in winter*
	7	Psychological	*looks sad*
Attic (3 / 10)	1	Accessibility	*lack of accessibility*
	2	Visual	*visual*
	4	Olfactory	*there are too many dead birds there*
	6	Lack of Resources	*cannot be used*
Corridors (3 /10)	2	Visual	*too loaded; visual disorder; lack of natural light*
	5	Hygrothermal	*lack of ventilation*
Entrance steps (2 / 10)	1	Accessibility	*we can trip (and fall) over the corner of the ramp*
Canteen / Cafeteria (2 / 10)	2	Visual	*outdated design; it is not bright*
	7	Psychological	*it doesn't seem like a very friendly place*
Arts & crafts room (2 / 10)	2	Visual	*visual - disorder; lack of natural light*
	4	Olfactory	*olfactory*
Classrooms (2 / 10)	2	Visual	*visually - the windows; the linoleum wall finishings (need to be painted)*
	5	Hygrothermal	*lack of ventilation walls (need to be sanitized)*
	6	Lack of Resources	*some equipment (benches, chairs) lack of special facilities for children with SEN*
The cabinet's balcony (1 / 10)	2	Visual	*visual*
	5	Hygrothermal	*thermal discomfort*
	7	Psychological	*psychological*
School yard (1 / 10)	1	Accessibility	*it is not a safe place for children*
	6	Lack of Resources	*there is no play furniture*

The next activity shifted the focus. Teachers had to fill in a "Top 3 places I like in my school" work file. The research found 8 categories of elements needed in all interior and exterior educational spaces [9]. Architects explained these features to the teachers and presented visual examples. The 10 teachers received a set of 24 cards (3 cards x 8 elements) and were instructed to attribute to each favorite place from the top 3 the cards that match. Figure 3 below illustrates the most liked spaces in the school and the arguments behind teachers' choices: icons from left to right, *worktops, sitting places, exhibition areas, presentation zones, storage, access to resources (electricity / internet / water), natural elements, playful areas (ludic elements that facilitate sensorial stimulation and movement).*

1.	Teacher's Room (9 teachers from 10)
2.	The entrance hall (7 teachers from 10)
3.	My cabinet / My classroom (4 teachers from 10)
4.	The kinetotherapy room (3 teachers from 10)
5.	The sports hall (2 teachers from 10)
	The logopedics cabinets (2 teachers from 10)
6.	The second floor terrace (*1 teacher from 10*) The first floor balcony (*1 teacher from 10*) The school terrace (*1 teacher from 10*)

Figure 3. Individual exercise: Which of the 8 categories of elements that encourage learning experiences can we find in the places we like in our school?

After these two individual activities dedicated to raising teachers' awareness (*Top 3 places I like / Top 3 places I dislike in my school*), the 15 participants were grouped in 5 teams of 3 specialists: two teachers and one architect.

The main functional areas studied [10] in the qualitative analysis of the MERSI project included: *school site, classrooms, spaces for teachers (cabinets, meeting rooms etc), the culinary laboratory, arts and crafts zones, physical activities* and *therapeutic areas*.

For the interdisciplinary group teamwork (one architect and two teachers) in the Inclusive Design Workshop, architects used a set of questions at hand:

What detail or general space configuration fit?

What exactly provides the feeling of protection?

What exactly delights users?

What perspectives do they want to have from the analyzed space?

What are the usual operating scenarios?

What actions are teachers doing in that specific space on an average school day?

What do the students do?

What do parents do? (Do they work next to their children? / Do they sit down next to them, or do they wait in another inner or outer space? Can the parents see their children from those adjacent spaces?)

In this manner, architects became moderators of the teachers' creative activities. They had to "read between the lines", explore theme requirements and guide the teachers from seeing only the barriers of their existing school environment to imagine possible solutions. The 5 teams had to create a concept for a specific school space function using one of the following techniques (Figure 5): mood boards, drawings, sketches, models, list of written criteria, a Lego game. Architects succeeded in translating stories related to the atmosphere of imagined spaces into written and drawn conclusions. Teachers were guided by architects, but they remained the principal actors, choosing the materials according to their wishes of an ideal school. Teachers presented the results in front of the whole group. At the end of the workshop, a round table was organized, for sharing feedback and ideas for future collaboration.

Figure 5. Inclusive Design Workshop, the 24th of November 2022, DST.LAB (Architectural Technology Laboratory, the Department of Technical Sciences, UAUIM)

4. DISCUSSIONS

A school cannot be understood solely through its architecture, but also through an awareness of its ongoing evolution and shaping during its day-to-day functioning scenarios. An architect needs to develop the ability to identify not only the types of specific functions housed by a new school building, but especially the way its occupants will be able to carry out their activities in the future and the internal relationships they will develop.

Three basic barriers were revealed: teachers have difficulties in expressing their needs and wishes; the educational environment is not perceived as a formative resource; teachers don’t know how to choose the most efficient design options or the suitable furniture and equipment for their special students.

Given this perspective, interdisciplinary workshops can be a valuable tool for mutual learning. It can provide *architects* with insights into the unique challenges faced by children with moderate and severe neuromotor disorders, as well as the approaches used by teachers to support their students. For *teachers*, it is a chance to learn about design principles and details of inclusive spaces. Teachers can also share their experiences and insights, which can help architects design school spaces that are tailored to those needs. As for *children* with moderate and severe mental disabilities, workshops become means by which they can participate in future design processes. This exposure can also help children to feel more engaged and empowered in their learning environment, which can have a positive impact on their overall wellbeing.

A stimulating physical environment assists children to develop their creativity, decision-making abilities, critical thinking, orientation skills, socialization abilities, and emotional expression. For the school environment to support learning, it has to:

allow children to make choices, such as arranging furniture in different ways based on the sort of activities performed, selecting things to engage with, and carrying out activities independently or collaboratively;

provide a sense of security and independence: equipment and furniture designed to allow their manipulation, independently and safely;

encourage creativity through the diversity of materials, textures, colours, objects, plants used, that are appealing to look at, touch, and smell;

enable flexibility in restructuring the environment in response to needs, allowing simple movement from one learning area to another;

foster collaboration and participation;

promote children's achievements, thus generating a sense of belonging;

ensure content for cultural diversity.

5. CONCLUSION

All children have the right to education. From existing mainstream schools and special schools to future inclusive schools having a variety of adapted spaces, the architectural environment of a school building has a significant impact upon the educational process: it can either constrain, sustain or even inspire the teaching and learning experiences.

Inclusive Design should therefore be a mandatory requirement in the initial training of all professions based on the built environment, at all levels and in all work sectors. The curriculum should be developed in close cooperation with users, including organizations dedicated to people with various (dis)abilities.

The MERSI research project [11] also aimed at fostering a culture of empathy, solidarity and generosity among architects and students in the faculty of architecture, as well as a sense of belonging and identity. Future research projects must challenge the conventional notions of architectural excellence, which are often based on aesthetic, technical or economic criteria, aiming to a more inclusive approach, which considers the social dimensions of architecture.

Turning back to the quote this paper started with, a responsive architect should continuously create opportunities for co-design and community-based projects. Architectural education should embrace human-centered design through participatory and collaborative methods and tools. An essential target will be to enhance students' awareness and skills on how to create sustainable architecture that responds to the real needs and expectations of urban society.

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REVIEW OF SPATIAL PATTERNS IN CONTEMPORARY INDUSTRIAL BUILDINGS

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Abstract

Unlike residential, public, or sacral, industrial buildings have a relatively short historical development. Thus, the term industrial building, as we perceive it nowadays, became widely used among architects only after the Industrial Revolution in the 18th century. Because of the specific building purpose – industrial production, which requires a high level of functional efficiency and a significant area for storage, industrial buildings are often huge and require economic, functional, and flexible designing. However, due to the complex architectural design program and different functional requirements related to industrial production spaces and different spaces for employees, administration workers, customers, and services, constant reviewing and evolving of spatial patterns in industrial buildings are noticeable. This paper defines the spatial patterns of contemporary industrial buildings by analyzing the functional organization of several existing industrial buildings. The spatial and morphological analysis and later evaluation of different contemporary industry buildings and synthesis of analytical findings of empirical research suggest that there are three basic spatial patterns: 1) the unified pattern, 2) the disunified pattern, and 3) the unconventional pattern. This research aims to perceive the multi-dimensional character of architectural patterns of industrial buildings, which result from different requirements. The defined spatial patterns are compared and discussed to determine the most suitable for the industrial purpose regarding various parameters for the industry – structural rationality, flexibility, the humanity of the environment, and architectural authenticity. The results of this analysis and classification may help the decision-making process in the design process.

Keywords: *industrial buildings, industrial production, spatial patterns, architectural design, functional organization*

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1. INTRODUCTION

Industrial buildings can be defined as types of structures that have the primary purpose of meeting the functional requirements of industrial production [1]. The classification of the industrial output is highly complex, resulting in a diverse range of industrial buildings in the overall inventory. In terms of functionality, the purpose of industrial architecture is to design flexible spaces for the storage of the necessary industrial production equipment, labor force, and auxiliary areas that contribute to the optimal functioning of industrial production [2]. Throughout the history of industrial architecture, very different functional organizations and spatial patterns have occurred, from simple rectangular to complicated, playful layouts. Designing industrial spaces is a very complex topic, and it can hardly be systematized, considering all the different types of industrial buildings built worldwide. Even though a significant portion of industrial buildings has some common features, such as adaptibility, structural rationality, spaciousness, etc., it is noticeable that these features do not represent a universal principle when designing industrial buidlings, and that there are deviations from those features. For example, there are numerous historic industrial facilities that are sufficient in terms of flexibility, resulting in an economic infeasibility of reusing them for production purposes. However, contemporary industrial buildings are evolving in a different manner, often with experimental functions and forms, but with clear sustainable vision of industrial architecture in the life of contemporary human beings, thus defining the most basic spatial patterns of contemporary industrial buildings is essential.

This paper defines the spatial patterns of contemporary industrial buildings by analyzing the functional organization of several existing examples of industrial architecture built in the 21st century. This research aims to review the most common spatial patterns in contemporary industrial buildings and to perceive the complex character of industrial buildings' architectural designs.

The research is divided into three main chapters. The first chapter deals with the theoretical background of the historical development of industrial buildings and the definition of industrial spatial patterns. The second chapter deals with the spatial and morphological analysis of several selected examples of industrial buildings, which were chosen based on the defined criteria. The third chapter evaluates and discusses morphological and spatial analysis. In the third chapter, the authors explain the three basic spatial patterns of industrial buildings and determine the most suitable spatial pattern for industrial production based on the parameters described in the Methodology chapter.

2. THEORETICAL BACKGROUND

As it is recognized and valued today, industrial architecture development can be traced back to industrialization and the First Industrial Revolution in mid-18th century England [3]. Historically, industrial architecture has significantly influenced the development of cities, the shaping of industrial urban landscapes, and the advancement of technology and engineering achievements [4]. Several different phases characterize the development of industrial architecture. Initially, industrial buildings have reinterpreted architectural forms and patterns from other building typologies (such as residential and public buildings). However, with the development of iron and steel production, the architecture of industrial buildings was redefined [5]. New architectural forms and patterns have become evident with the emergence of new industries.

From the First Industrial Revolution and up until the 20th century, industrial buildings were characterized as technical and engineering structures with two key attributes - efficiency and rationality, rather than a humane environment. During the early modernist ideas that emerged in Europe, the planning of industrial zones and sites and the design of industrial buildings held a significant place. French architect and city planner Tony Garnier presented a theoretical model called the Industrial City (in French *Cite Industrialle*), where he gives priority to industrial production and planning of industrial sites with high-quality and efficient technical characteristics, strictly defined regulations for sunlight quality, ventilation, and greenery implementation [6]. This modernist view of industrial building design responds to the accumulation of problems that industrial production has brought to cities. Nevertheless, these ideas are fundamental because they represent pioneers of humane models in designing industrial spaces [7]. After World War II, there was a notable division in views regarding the role of industrial production and architecture, which depended on the country's social and political organization. For example, in European socialist countries (Eastern Bloc), where the system recognizes the industrial worker as a vital element of economic development, industrial buildings offer a high level of comfort to the employees. Kojić (1962) [8] suggested that designing multiple smaller, well-lit, and comfortable, interconnected buildings with the modest materialization and a flexible, functional organization is favorable. However, by analyzing the built stock of industrial buildings in the Eastern Bloc, it is possible to conclude that this is not a universal rule and that there are well-known large-scale, unified industrial buildings built during the time of a stately-driven economy, usually with the position of production monopoly.

Damjanović (1980) [9] identified three basic spatial concepts in building industrial sites: the pavilion, block, and hybrid.

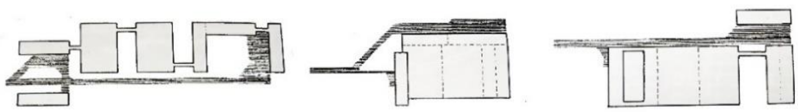


Figure 1. Three basic types of industrial spatial systems. From left to right: the pavilion, the block, the hybrid system. Source: Damjanović Vojislav: Industrial sites and buildings, 1980.

The pavilion physically separates all spaces (industrial, energy, auxiliary, and storage). In the block, however, all areas (industrial, energy, auxiliary, and warehouse) are placed within a compact unity. The third system, the hybrid system, combines the two. It combines specific spaces into a single unit (the industrial production, storage, and all related areas). In contrast, other rooms, especially those threatening human life, are physically separated from the unified spaces.

However, it is essential to note that this is a systematization of industrial areas based on building forms displayed on the exterior. Still, contemporary industrial buildings and sites are often designed and constructed with reference to this systematization. However, contemporary industrial buildings and sites come in various forms, functional organizations, spatial patterns, and design characteristics, resulting from the different intentions of both the architects and the industry. Online databases of architectural design projects provide examples of industrial buildings where the architectural composition does not even suggest that the primary purpose of a building is industrial production [10]. However, it is essential to note that this represents a tiny portion of the overall stock of industrial buildings, usually built as architectural and urban experiments by prominent, globally recognized architects (so-called *starchitects*).

The (industrial) spatial pattern can be evaluated based on criteria such as form, materialization, functional organization, innovation, authenticity, the appearance and expression of individual elements and details, etc. [11]. Industrial buildings are complex structures, and many factors directly dictate the spatial pattern and layout of the building. According to Fisher (2005) [2], the role of industrial architecture is to design flexible spaces that can adequately accommodate the necessary equipment for industrial production, the labor force, and other facilities that contribute to the optimal functioning of the industrial output. Damjanović (1980) [9] stated that the spatial organization of industrial buildings depends on various factors such as the scale of machines, the installation grid, the technological process, labor organization, etc.

However, in today's world of open market economies and globalization, the quality that essentially defines the overall value of industrial architecture is the production efficiency and potential for profits. Production efficiency can be achieved through various means and on multiple levels, and one key aspect is the quick and easy physical movement of workers and materials within the building, which relates to favorable functionality. A thorough understanding of functionality is critical in architectural theory and practice. According to authors van der Voordt and van Wegen (2005), advantageous functionality implies that the building should be accessible to all, provide sufficient space for required activities, be organized efficiently and comprehensibly, be flexible, and provide spatial and physical conditions that ensure a safe, healthy, and pleasant environment [11] in terms of the functional organization of industrial buildings, that would mean the position of spaces in a way that enables accessible and unhindered access to critical points of the building, without unnecessary delays or obstructions.

However, numerous factors with different social backgrounds shape the spatial patterns of contemporary industrial buildings. The need for a recognizable corporate identity, commercial image, and image of social and environmental responsibility, as well as the exploration of current materials and forms, are legitimate and standard motives in the design process of contemporary industrial buildings. The spatial patterns in industrial facilities are not strictly defined, but several categories can be identified by analyzing various examples of contemporary industrial buildings. This research aims to review the most common spatial patterns in worldwide industrial architecture.

3. METHODOLOGY

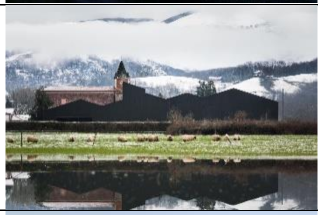
To review and define the spatial patterns of contemporary industrial buildings, a morphological and spatial analysis of several industrial buildings will be conducted in this research. The examples were found on free online databases of architectural design projects. For this research, the selection of contemporary industrial buildings was based on the following criteria:

- The buildings were built in the 21st century;
- The buildings are located across the globe (Europe, North America, South America, and Asia)
- The primary purpose of the building is industrial production;
- Industrial production space is not the only space in the building;
- A clear differentiation of the industrial production spaces and auxiliary spaces is visible.

Based on the criteria listed, eleven industrial buildings were selected for this research; the examples are listed in Table 1.

Table 1. Selected examples of industrial buildings

Name	Architect	Photo	Location	Year
Amplio Automation Headquarters *[12]; photography: Zsolt Batar*	*T2.a Architects*		*Szekesfehervar, Hungary*	*2018*
Zumtobel Group *[13]; photography: Relja Ivanić*	*Mapa architects*		*Niš, Serbia*	*2018*
Chocolaterie Bovetti *[14]; photography: CA/PA Architects*	*CA/PA Architects*		*Terrason-Lavilledieu, France*	*2010*
Greyder Shoe Factory *[15]; photography: Cemal Emden*	*CAA.Studio*		*Karaca Köyü, Türkiye*	*2015*
Bortolini Móveis Factory *[16]; photography: 4D-Arquitetura*	*4D-Arquitetura*		*Garibaldi, Brazil*	*2011*
Industrial Factory in Preci *[17]; photography: Enzo Eusebi + Partners*	*Enzo Eusebi + Partners*		*Preci, Italy*	*2015*

Winery in Oiry *[18]; photography:, Fabrice Dehoce*	*Giovanni PACE Architecte*		*Oiry, France*	*2012*
Dürr Systems Headquarters Facility *[19]; photography: Justin Maconochie*	*SmithGroup*		*Southfield, United States*	*2016*
HAWE Factory Kaufbeuren *[20]; photography: David Franck*	*Barkow Leibinger*		*Bavaria, Germany*	*2014*
Lozy's Pharmaceuticals Factory *[21]; photography: Rubén Bescós*	*Vaillo + Irigaray Architects, Galar, Vélaz*		*Lecároz, Spain*	*2016*
Oatmeal Factory *[22]; photography: Schran Images*	*JSPA Design*		*Ningwu, China*	*2021*

This research will conduct a morphological and spatial analysis of these eleven examples, while other architectural elements will not be considered. The buildings will be analyzed and described based on the following points:

- The overall form of the layout **- Point 1;**
- The position of industrial production spaces and other (auxiliary) spaces **- Point 2;**
- The spatial relation of the production and auxiliary spaces **- Point 3.**

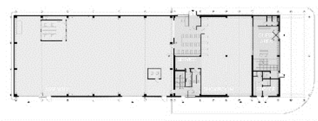
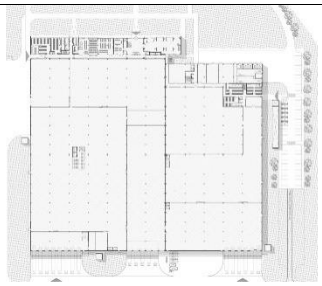
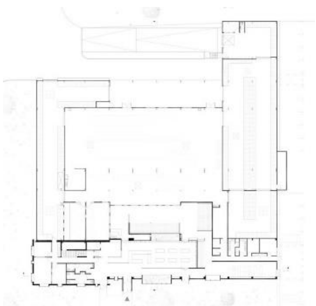
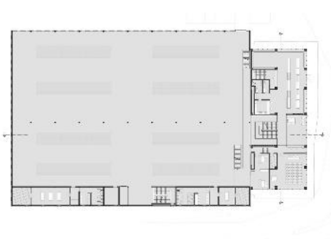
In the discussion chapter, based on the morphological and spatial analysis, the selected buildings will be categorized into three spatial patterns, named, evaluated, and compared based on critical parameters for industrial buildings design and their key evaluation points:

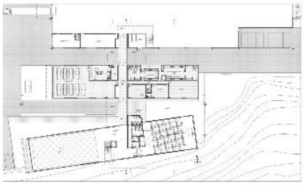
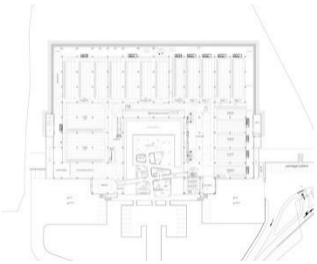
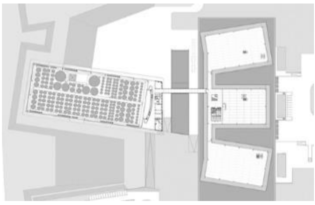
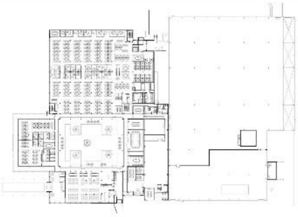
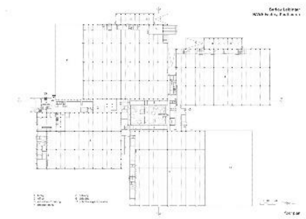
- Parameter 1: structural rationality; key evaluation point - uniformed structural greed and regular floorplan geometry.
- Parameter 2: flexibility; key evaluation point - a compact and continual interior and expansion potential.
- Parameter 3: humanity of the environment; key evaluation point - natural lighting and natural ventilation.
- Parameter 4: architectural authenticity; key evaluation point – unusual shapes.

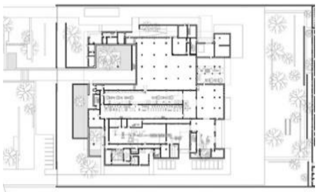
4. MORPHOLOGICAL AND SPATIAL ANALYSIS OF SELECTED INDUSTRIAL BUILDINGS

In Table 2, floor plans of selected industrial facilities will be presented and morphologically and spatially analyzed based on the parameters defined in the previous chapter.

Table 2. Floor plans and morphological and spatial analysis of selected buildings

Name	***Floor plan***	***Morphological and spatial analysis***
Amplio Automation Headquarters, *type of industry: manufacturing electronic parts for the automobile industry**.***	 *Source: [12]*	***Point 1****: the layout is rectangular.* ***Point 2:*** *The entire space is placed within eleven structural grids. The entrance, showroom, offices, guest area, services, and flexible area are placed within the first five structural grids, while the other six are for the purpose of industrial production.* ***Point 3:*** *all spaces are unified.*
Zumtobel Group, *type of industry: manufacture of lighting.*	 *Source: [13]*	***Point 1****: the layout is a square.* ***Point 2:*** *the building is divided into two functional zones. The building has three entrances, all in the first functional zone, with spaces for employees (wardrobes, relaxation areas, dining, etc.). In contrast, the largest part of the building is an ample, flexible space for industrial production.* ***Point 3:*** *all spaces are unified into a single form.*
Chocolaterie Bovetti, *type of industry: food industry, production of chocolate.*	 *Source: [14]*	***Point 1:*** *the layout is a square with minor irregularities.* ***Point 2:*** *the building is divided into two zones. The spaces in the first zone are dedicated to employees in the production process (wardrobes, bathrooms, etc.) and office employees. The second zone is dedicated to the industrial process, and it is an ample, flexible space comprised of several smaller rooms for industrial production.* ***Point 3:*** *all spaces are unified into a single form.*
Greyder Shoe Factory, *type of industry: manufacture of footwear.*	 *Source: [15]*	***Point 1:*** *the layout is a rectangle.* ***Point 2:*** *the entire space is placed within twelve structural grids. The first two grids are dedicated to areas for employees, (dining, bathrooms, wardrobes…). The other ten grids are a flexible space dedicated to industrial production, with toilets in the industrial production space.* ***Point 3:*** *all spaces are unified into a single form.*

Bortolini Móveis Factory, *type of industry: manufacture of wooden furniture.*	 *Source: [16]*	***Point 1:*** *the layout is irregular.* ***Point 2:*** *the building is divided into three spaces – The first part is dedicated to conference and customer service. The second part is devoted to areas for employees (dining and wardrobes). The third space is dedicated to industrial production. All three volumes are physically separated but connected by a corridor.* ***Point 3:*** *the spaces are disunified.*
Industrial Factory in Preci, *type of industry: food industry, production of ham.*	 *Source: [17]*	***Point 1:*** *the layout is irregular.* ***Point 2:*** *the building is divided into two main spaces – the industrial production space and auxiliary spaces. The rooms are physically connected with corridors. The industrial production space is ample with the form of the Cyrillic letter P (П). In contrast, the auxiliary area is divided into several smaller, trapezoidal rooms with curved edges.* ***Point 3:*** *the spaces are disunified.*
Winery in Oiry, type of industry, *type of industry: wine production.*	 *Source: [18]*	***Point 1:*** *the layout is irregular.* ***Point 2:*** *the building is divided into several rectangular spaces dedicated to producing wine (fermentation room, cellars for wine aging, tirage spaces, etc.), spaces for employees, and dining spaces, connected with corridors.* ***Point 3:*** *the spaces are disunified.*
Dürr Systems Headquarters Facility, *type of industry: robotics and prototype testing for painting systems.*	 *Source: [19]*	***Point 1:*** *the layout is irregular* ***Point 2:*** *the building comprises several rectangular volumes physically connected to each other. The industrial production space is separated from the office spaces and spaces dedicated to employees. All office spaces revolve around a large, central atrium.* ***Point 3:*** *spaces are connected but in an unconventional way.*
HAWE Factory Kaufbeuren, *type of industry: manufacture of mobile hydraulic systems**.***	 *Source: [20]*	***Point 1:*** *the layout is irregular, with a star-like shape* ***Point 2:*** *there are four large spaces for industrial production, with smaller auxiliary spaces attached to them (offices, employee wardrobes, etc.) revolving around an atrium.* ***Point 3:*** *unconventional for industrial buildings.*

Lozy's Pharmaceuticals Factory, *type of industry: healthcare, pharmacy.*	 *Source: [21]*	***Point 1:*** *the layout is a rectangle with irregularities.* ***Point 2:*** *the industrial production space is positioned in the central building areas, while the office spaces, wardrobes, toilets, and dining areas are around the industrial space.* ***Point 3:*** *unconventional for industrial buildings.*
Oatmeal Factory, *type of industry: food industry and agriculture.*	 *Source: [22]*	***Point 1:*** *the layout is entirely irregular.* ***Point 2:*** *the building comprises several rectangular and squaric spaces physically connected. The industrial production spaces form a unity but intersect with different auxiliary spaces.* ***Point 3:*** *the spaces are connected in a complicated and somewhat unconventional way.*

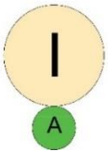
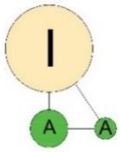
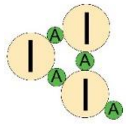
5. DISCUSSION

Based on the synthesis of analytical findings of empirical research, spatial patterns of contemporary industrial buildings can be categorized into three primary groups:

- Buildings that have a geometric layout (rectangle or square, with minimal deviations) and have all spaces (industrial, auxiliary, storage, office, etc.) connected in the form of a continual unity can be classified as the unified spatial pattern - **The Box.** (analyzed buildings that can be classified as **The Box** are: *Amplio Automation Headquarters, Zumtobel Group, Chocolaterie Bovetti, and Greyder Shoe Factory*). This pattern aligns with the traditionally recognized block concept of industrial facilities.
- Buildings that have a somewhat irregular layout, comprised of several buildings that are physically separated but connected with internal and external corridors, can be classified as the disunified spatial pattern - **The Cluster** (analyzed buildings that can be classified as **The Cluster** are: *Bortolini Móveis Factory, Industrial Factory in Preci, and Winery in Oiry*). This pattern aligns with traditionally recognized pavilions.
- Buildings that have both regular or irregular layouts, but the spaces form a rather complicated and unconventional connection can be classified as the unconventional spatial pattern - **The Knot** (analyzed buildings that can be classified as **The Knot** are: *Dürr Systems Headquarters Facility, HAWE Factory Kaufbeuren, Lozy's Pharmaceuticals Factory, and Oatmeal Factory*). This pattern somewhat differs from the traditional hybrid concept due to its more compact form, but it is still mostly aligned with it.

The spatial schemes and characteristics are shown in Table 3.

Table 3. Evaluation of each spatial pattern.

	The Box	***The Cluster***	***The Knot***
Scheme	 *Source: authors. I - industrial production, A - auxiliary spaces.*	 *Source: authors. I – industrial production, A– auxiliary spaces.*	 *Source: authors. I – industrial production, A – auxiliary spaces.*
Structural rationality	*a uniform structural grid, regular geometry of the floorplan. The simplicity and regularity of the floor plan can be organized into several structural grids.*	*doesn't have a uniform structural grid. Singular spaces can be geometrically regular, but the building has a unique floor plan because of the distance.*	*often does not have a uniform structural grid. Floor plans are complex and often irregular.*
evaluation	✓	—	—
Flexibility	*compact and continual interior. The massiveness of the building indicates low expansion potential.*	*The continual interior is not very compact due to the large building envelope caused by numerous spaces. Excellent expansion potential.*	*It has no continuous interior and is not very compact because of floorplan irregularities. Expansion potential is low.*
evaluation	✓—	—✓	—
The humanity of the environment	*the cumbersome nature of the building imposes lighting and ventilation challenges.*	*a favorable for natural lighting and ventilation.*	*floorplan playfulness enables the natural lighting and ventilation of numerous spaces*
evaluation	—	✓	✓
Architectural authenticity	*does not provide unusual shapes and forms due to the simple and regular geometry of the floor plan.*	*can be very authentic in terms of unique forms.*	*unusual and complex floorplans represent excellent potential for experimental and unusual shapes and forms.*
evaluation	—	✓—	✓

The results presented in Table 3 show that each spatial pattern has its advantages and disadvantages.

- In terms of structural rationality, **The Box** has an advantage because of the simplicity and regularity of the floorplan that can be organized within several structural grids. Distinctive floorplans of **The Cluster** and **The Knot** can potentially face structural difficulties.

- In terms of flexibility, **The Box** has shown that a centralized floorplan with a continual interior provides a more straightforward and more flexible work organization and spatial and economic rationality. However, **The Cluster** provides greater expansion potentials due to the physical distance of spaces.
- In terms of the humanity of the environment, **The Cluster** and **The Knot** can quickly provide well-lit and well-ventilated spaces for employees due to the playfulness of the floorplan.
- In terms of architectural authenticity, **The Knot** has shown that the architectural composition of industrial spaces can have a creative and authentic note. **The Cluster** can also have an authentic floorplan, which is relatively exceptional and not universal.

Based on the evaluation of each spatial pattern, the results indicate that **The Box** format is the most favorable regarding structural rationality and flexibility. At the same time, **The Cluster** and **The Knot** are more advantageous in terms of environmental humaneness and architectural authenticity. However, considering the contemporary industrial production standards and operations, rationality, and flexibility take precedence due to the inevitable dimension of economic profit, a vital attribute of the contemporary industry.

6. CONCLUSION

Certain conclusions about spatial patterns of contemporary industrial buildings can be drawn from the previous discussion. By pointing out the characteristics of the three defined spatial patterns, the key advantages and disadvantages of each spatial pattern can be helpful in the decision-making process when designing industrial structures. It is important to stress that industrial buildings have a multi-dimensional character. In this research, the focus was on rationality and flexibility and their precedence compared to architectural authenticity and humanity of the environment because of the inevitable dimension of economic profit that is present in the era of globalization. However, in some industrial buildings, a humane environment and architectural authenticity may have precedence over rationality and flexibility, which can be attributed to dimensions such as tourism, ecological responsibility, social and civil rights advocacy, image and reputation, etc. This statement is supported by the initiative New European Bauhaus, where the exploration of sustainable, nature-based materials is key, as well as factors such as sustainability, aesthetics, and inclusion [23]. With a wide variety of possibilities, it is up to the architects and designers to carefully consider all the necessary factors that have a role in shaping contemporary industrial buildings.

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BIAS CORRECTION AND WEIGHTING METHODS TO SHAPE PRECIPITATION UNDER THE CLIMATE CHANGE OPTIONS

Luka Vinokić[1], Milan Stojković[2], Srđan Kolaković[3]

Abstract

This research paper proposes a methodology of precipitation data analysis under changing climate using both bias correction and weighting techniques. It focuses on using regional climate models (RCMs) for climate change analysis at the site of Leskovac meteorological station. Records are gathered from the Republic Hydrometeorological Service of Serbia (RHMSS). The RCM data are corrected using quantile mapping methods, where empirical quantile mapping (EQM) and theoretical quantile mapping (TQM) are applied. The results show that TQM produces better and more consistent results than EQM, particularly for the 1% exceedance probability or lower. Once bias correction methods are applied, weighting techniques are used to evaluate the RCMs. Two weighting techniques are implemented: the tricube weight function and the modified Gaussian weight function. The outputs of the analysis with the use of the General Extreme Value (GEV) distribution indicate an increase in 100 years return period precipitation by 11-20% for the moderate climate option (RCP 4.5) and 28-33% for the worst-case option (RCP 8.5) by using the GEV distribution. If LP-3 distribution is used, there are indications of a 3-4% and 32-35% increase for the same return periods for 4.5 RCP and 8.5 RCP climate options, respectively. The research paper shows that both weighting techniques generate similar results. The study concludes that the proposed methodology is a useful tool to reduce the uncertainties in RCMs and can provide valuable information related to precipitation climate signals. It contributes to the understanding of the changes in precipitation patterns and can be useful for policymakers and planners to make informed decisions related to water resource management and flood protection.

Key words: *bias correction, quantile mapping, weighting, climate change, precipitation*

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1. INTRODUCTION

As the reality of climate change becomes increasingly noticeable, so too does the urgency to understand its impacts, particularly on the hydrologic cycle [1]. One of the critical areas of interest for hydrological engineers represents the analysis of precipitation data under climate change conditions, as it directly influences water resource management, flood control, and environmental planning [2]. Ensuring accuracy and reliability in the representation of such data is paramount as it directly feeds into policy decision-making processes.

In the past decades, meteorologists have developed different Global Climate Models (GCMs) based on a variety of parameters, which are more precise than their previous versions [3]. However, these GCMs aren't exactly perfect because of a significant amount of uncertainty [4]. The uncertainty from GCMs (with a relatively low resolution typically between 200 and 500km) is cascaded to RCMs – Regional Climate Models [5]. The purpose of climate downscaling via RCMs is to shape climate model data to stimulate the climate variables (such as temperature, precipitation, humidity, wind speed, etc.) for a higher spatial resolution to [6]. However, climate downscaling presents an additional source of uncertainties.

Eden et al. (2012) categorized errors in GCM precipitation fields into three main types. The first type is caused by unrealistic large-scale variability or response to climate forcings. The second type is due to unpredictable internal variability that deviates from observations. The third type of error is a result of convective parameterizations and unresolved subgrid-scale orography [7].

There is a need to reduce the bias error from RCMs to a minimal level. For this reason, bias correction is introduced to shape the climate data to reflect the actual data. However, since bias correction only impacts the third type of error, the uncertainty caused by the first two types of errors still remain unsolved [4]. Although, the second error type could be managed to some extent with large enough recorded data [4]. Having this in mind, bias correction can only improve the climate model by reducing a portion of existing error types, where uncertainty cannot be significantly diminished by the statistical tools, and therefore the term uncertainty management may be more suitable.

This study focuses on Leskovac meteorological station in Serbia, and uses precipitation data collected from the Republic Hydrometeorological Service of Serbia (RHMSS), while climate model data comes from the RCMs gathered from the EuroCordex database [8]. Two Representative Concentration Pathways (RCPs) options are used: RCP 4.5 and RCP 8.5. The collected precipitation data is provided as follows: (1) an observed data set (for a period 1950-2005), (2) an ensemble of 9 RCMs (for a period 1950-2005), and (3) two future scenarios of an ensemble of 9 RCMs (for a period 1950-2005).

The methodology proposed combines bias correction and weighting techniques, aimed at reducing uncertainties and enhancing the accuracy of the RCMs. Quantile mapping methods, both empirical (EQM) and theoretical (TQM), are employed to correct the data. Climate models are often weighted based on certain criteria and combined to provide more reliable information than a single model [9]. Although many authors oppose multi-model weighting, warning it might give misleading results, thus suggesting equal weighting may be more appropriate in some cases, the weighting approach is still widely used [10].

2. BIAS CORRECTION

There are several tools available for diminishing bias correction. One of the most frequently used methods is quantile mapping (e.g. Simonovic, Stojkovic, Cannon, Maraun, etc.). Quantile mapping is based on the assumption (hypothesis) that observed and modeled data produce similar cumulative distribution curve functions with different ranges of frequencies. Therefore, certain quantiles from climate models, which represent the projected precipitation or any given value for a certain probability (e.g. 1%, 10%, or 50%), are mapped on the corresponding quantiles from observed data. This is performed by a transfer function, which can be presented differently depending on the method used. Different authors utilize diverse several approaches, such as the use of empirical quantiles that are linearly interpolated, while others prefer the application of parametric models such as a normal distribution for temperature and a gamma distribution for precipitation [11].

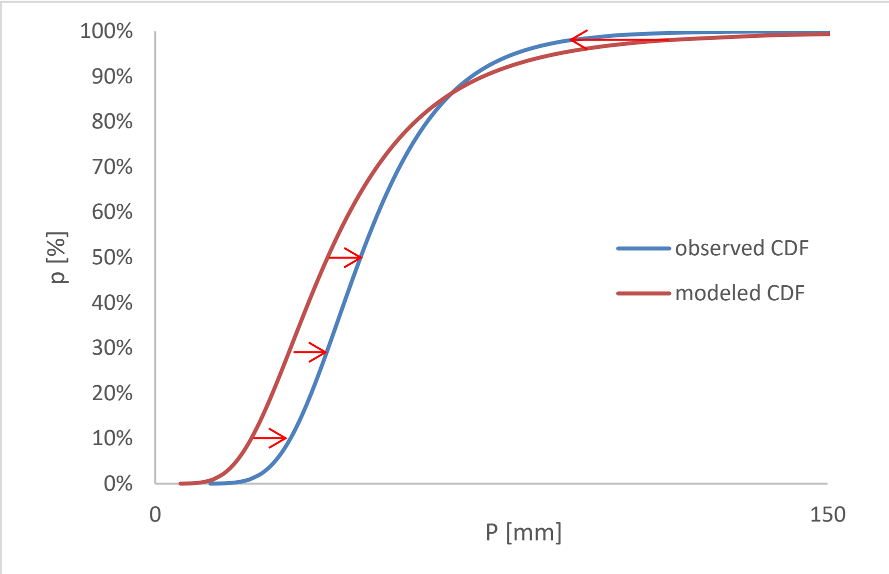


Figure 1: Graphic representation of quantile mapping

2.1. Empirical quantile mapping (EQM)

EQM is frequently used because of its simplicity, where mapping occurs for the quantiles where data is available using empirical distribution. EQM corrects the bias by ensuring that the empirical cumulative distribution function (EDF) of the model matches that of the observed data [12]. The general idea is that if a certain quantile in the observed data corresponds to a certain value, the same quantile in the model data should also correspond to that value [11]. The general transfer function for quantile mapping is given by the following expression [4]:

$$\hat{x}_{RCM}^{fut}(T) = F_{obs}^{-1}\left(F_{RCM}\left[x_{RCM}^{fut}(T)\right]\right) \tag{1}$$

where x represents any climate change variable, F and F^{-1} represent cumulative distribution functions (CDFs) and inverse CDFs (also known as quantile functions) respectively. RCM denotes modeled data/function from Regional Climate Model, while obs denotes observed data, and fut denotes a future (projected) period.

The simplest way to do this is to calculate and assign the probabilities to precipitation values for both modeled and observed data and form a set of K coefficients, that represent the modeled to observed data ratio:

$$K = \frac{P_{obs}}{P_{RCM}^{ref}} \tag{2}$$

where P_{RCM}^{ref} represents simulated daily precipitation for the reference period, and P_{obs} represents observed daily precipitation for the same period.

Multiplying the K with the same exceedance probability as the simulated daily precipitation for the future period (P_{RCM}^{fut}), the bias-corrected future daily precipitation is obtained ($\hat{P}_{RCM}^{fut}$):

$$\hat{P}_{RCM}^{fut} = K * P_{RCM}^{fut} \tag{3}$$

If the range of projected climate data is larger than the historical range, which is the case in this study, interpolation and extrapolation of the K ratio are required [4].

2.2. Theoretical quantile mapping (TQM)

The key difference between EQM and TQM is the use of theoretical distributions such as the Generalized Extreme Value (GEV) or the gamma distribution, allowing for better representation of the tails of the distribution, which are critical in the study of extreme weather events [13]. The TQM (also known as parametric quantile mapping) can provide better results for the modeled data, as the EQM might not perfectly adjust the extremes and the tails of the distribution, which is critical in the study of extreme events related to climate change [4]. Theoretical distribution is chosen as the best match with the empirical distribution [14]. The criteria used for selecting the best distribution is the Standard Error of fit (SE) [15]:

$$SE = \sqrt{\frac{\sum_{i=1}^{n}\left(P_i^{empirical} - P_i^{theoretical}\right)^2}{n-k}} \tag{4}$$

where $\sum_{i=1}^{n}(P_i^{empirical} - P_i^{theoretical})^2$ represents a sum of all squared errors between the empirical and theoretical distribution of the same probability of exceedance within a dataset, n denotes the number of data within a dataset, while k represents the number of parameters of a theoretical distribution.

Log-Pearson Type 3 (LP-3) and GEV distributions led to the lowest standard error compared to the empirical distribution, with $SE = 2.3$ for LP-3 and $SE = 2.6$ for GEV, while other distributions, such as Normal, Pearson or Weibull, produced significantly higher standard error of fit. Both theoretical distributions are adopted, based on the fact that they reproduce significant matches in terms of extreme precipitation. Both are three-parameter distributions, which means they provide more accuracy in modeling the observed data in comparison to their two-parameter counterparts, considering the sample size is large enough [16].

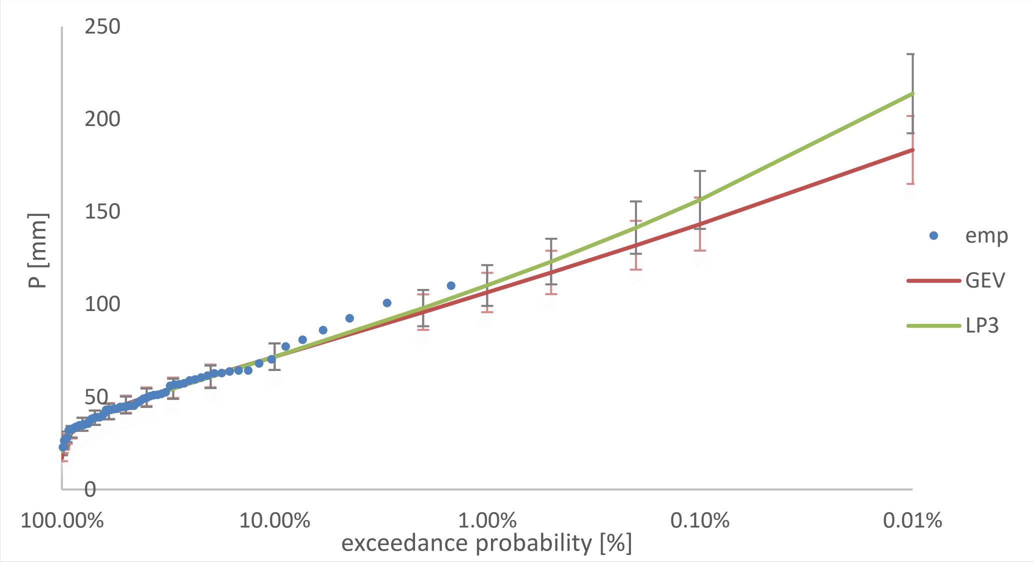


Figure 2. Inverse CDF curves

The inverse cumulative distribution function (inverse CDF) is used to calculate the precipitation for the given exceedance probability. The approximation of inverse CDF for LP-3 is given in the following equation [17]:

$$F^{-1}(T) \approx \exp\left[c + \frac{\lambda\mu}{\alpha}\left(1-\frac{1}{T}\right)^{\alpha} + \frac{\lambda\nu}{\beta}\left(\xi - \left(\frac{1}{T}\right)^{\beta}\right)\right] \tag{5}$$

where T denotes a return period in years, c represents a scale parameter, and κ and λ are shape parameters. The coefficients μ, ν, α, α, and α are dependent on the shape parameter κ.

The GEV distribution combines the Gumbel (EV1), Frechet (EV2), and Weibull (EV3) distributions, with three parameters: ξ – location, λ – scale, and κ – shape [18]. The inverse CDF of GEV is given in the following equation [4] [17]:

$$F^{-1}(T) = \xi + \frac{\lambda}{\kappa}\left[\left(-\ln\left(1-\frac{1}{T}\right)\right)^{-\kappa} - 1\right] \tag{6}$$

The bias correction ratio for TQM is calculated in the same manner as for EQM, where quantiles are obtained using the above-mentioned inverse CDF.

3. WEIGHTING

Once bias correction is applied, 9 RCM outputs still suggest diverse results. Thus, all RCM outputs are assigned weights in accordance with modeling efficiency during the reference period. Weighting aims to evaluate the climate model's performance and reduce the modeling errors in the outputs of RCMs [19]. The idea is to make a unique data series based on the normalized weights of all ensemble members [14].

Weight functions are founded under the same principle: climate models that *fit* better into the observed data get a higher weighting factor. Weight assignment is a probabilistic issue and it can be done through skill scores [20] and/or with multiple individual metrics, that take into consideration daily and sub-daily simulated temperatures and precipitation, annual data discrepancy, minimal and maximum values, as well as spatial patterns and other factors [19]. Even though multi-metrical weighting provides better and more accurate results, as there is a deficit of all the needed data, the weighting will be done by using a single weighting function. The main criteria for a weight function is to be smooth with a peak where the deviation is zero, and that weight smoothly decays as deviation increases [21]. Two weight functions are used in this research: (1) the tricube weighting function [14], and (2) the modified Gaussian weight function [22].

3.1. **Tricube weight function**

The weight function proposed by Turkey (1997) is shown as follows [14] [23]:

$$w_i = \left(1 - \left(\frac{\Delta_i}{h}\right)^3\right)^3, \text{ for } |\Delta_i| \leq h \tag{7}$$

where h represents a half-window length defined as a standard deviation of the whole series of average percent deviation for different models, and Δ_i represents the percent deviation of the simulated and observed values:

$$\Delta_i = \frac{1}{N}\sum_{n=1}^{N}\left(\frac{\hat{P}^{ref}_{RCM,i}(T_p) - P_{obs,i}(T_p)}{P_{obs,i}(T_p)}\right), i = 1,2,\ldots,N \tag{8}$$

where N represents the number of periods selected (return periods of 10, 20, 50, 100, and 1000 years), and $\hat{P}^{ref}_{RCM,i}(T_p)$ represents the bias-corrected modeled precipitation from the GEV distribution for a specific return period i.

To avoid the scenario that negative errors have higher weights than no error at all, absolute values of metrics are used in the calculation. Therefore, the final tricube weight function is provided as follows:

$$w_i = \left(1 - \left(\frac{|\Delta_i|}{h}\right)^3\right)^3, \text{ for } |\Delta_i| \leq h \tag{9}$$

$$w_i = 0, \text{ for } |\Delta_i| > h \tag{10}$$

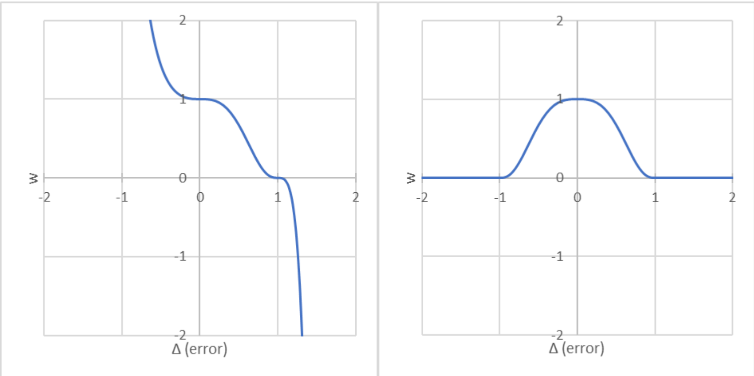


Figure 3: Tricube weight function (without and with correction)

3.2. **Modified Gaussian weight function**

The Gaussian weighting function assigns weights based on the similarity between the simulated and observed values of the RCM outputs, with higher weights given to simulations that are closer to the observed ones.

The Gaussian weight function is delicate because it assigns non-zero weights to all simulated values, even those that are far away from the observed values. However, the weights decrease rapidly with increasing distance from the observed values, so simulated values that are far away from the observed values are assigned very small weights. This makes the Gaussian weighting function more sensitive to low discrepancy between the simulated and observed values, compared to other weighting functions that assign zero weights to simulated values that are far away from the observed values.

$$w_i = \exp\left(-\frac{\frac{1}{N}\sum_{n=1}^{N}\left[\hat{P}_{RCM,i}^{ref}(T_p)-P_{obs,i}(T_p)\right]^2}{2h^2}\right) \tag{11}$$

where h is a bandwidth parameter that controls the width of the Gaussian distribution. The bandwidth parameter can be set to a value that gives similar results as the tricube weighting function for small errors.

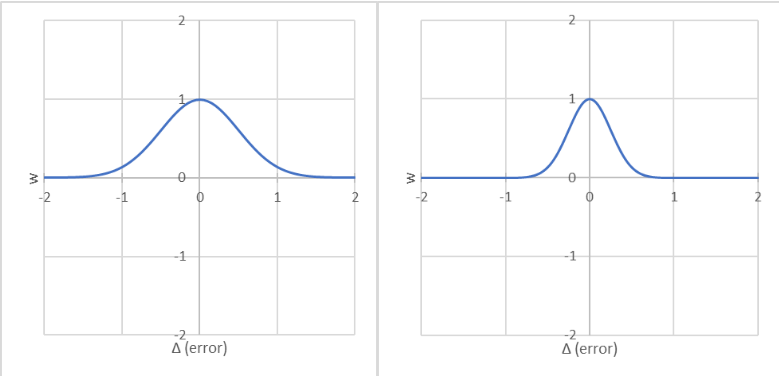


Figure 4. Modified Gaussian weight function for h=0.5 and h=0.25

4. RESULTS AND DISCUSSION

4.1. Bias correction

Due to a lack of observed data and given that projected values fall significantly beyond the historical range, EQM hasn't produced satisfactory results. Furthermore, the dissimilarity in the tails of empirical distribution causes instability of the K ratio for the lower end of exceedance probability (this can be seen in Figure 5), which is crucial for this study. This would make the coefficients difficult to evaluate by extrapolation, hence the TQM is further implemented.

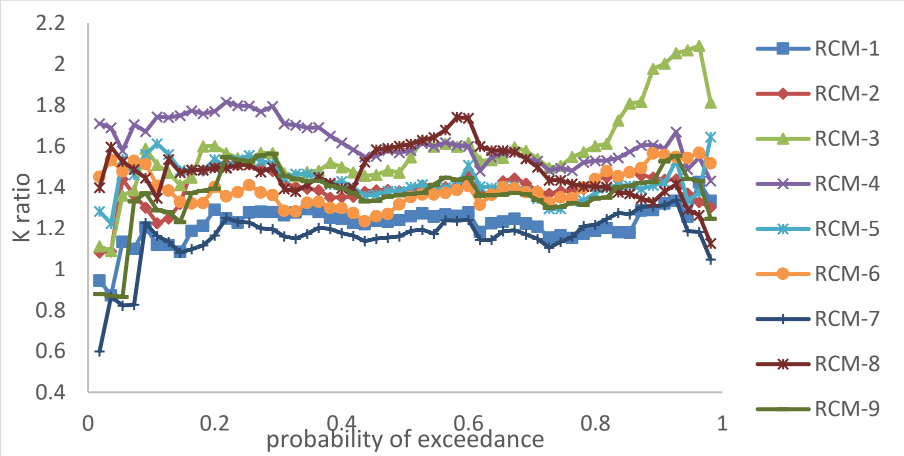


Figure 5. K ratio for EQM for the entire ensemble (9 sets of n=55 coefficients)

The ratio for the TQM is given in Figure 6 through the continuous function for all nine climate models.

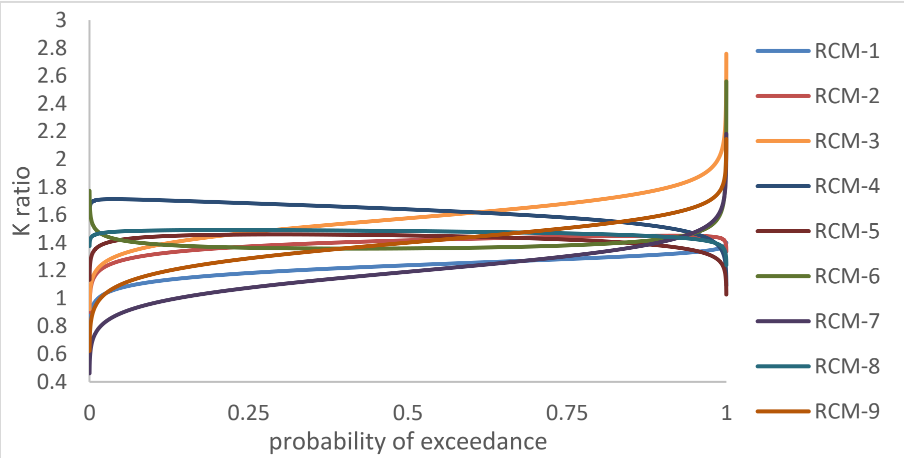
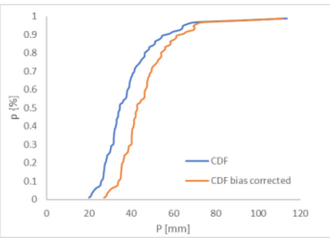
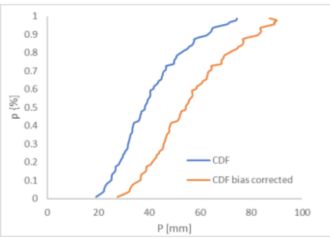


Figure 6. Ratio functions for TQM for all 9 climate models

Figure 6 demonstrates that, through the application of the TQM method, bias correction factors (K ratio) are easily determined for any probability. In the next segment, bias-adjusted CDFs for projected precipitation, fitted using the GEV distribution, are shown in comparison to CDFs where bias correction was not implemented. CDFs for RCP-4.5 are shown in Figures 7-15, while Figures 16-24 show CDFs for RCP-8.5 (the number shown in the parentheses represents RCMs).





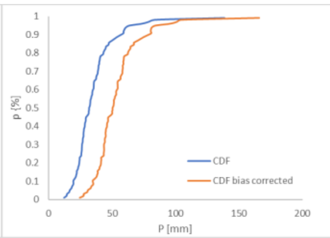
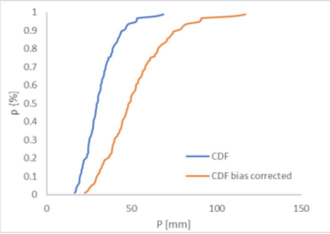
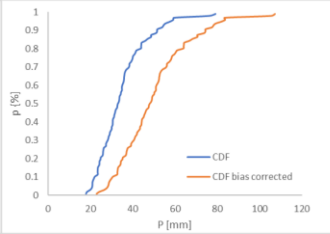


Figure 7. CDF RCP-4.5 (1) *Fig. 8. CDF RCP-4.5 (2)* *Fig. 9. CDF RCP-4.5 (3)*





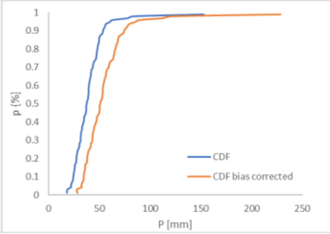
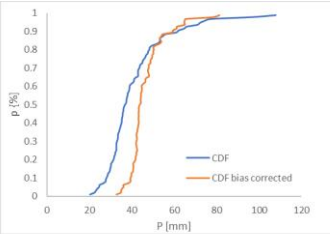
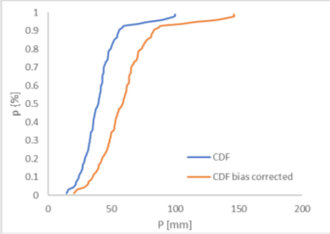


Figure 8. CDF RCP-4.5 (4) Fig. 11. CDF RCP-4.5 (5) Fig. 12. CDF RCP-4.5 (6)





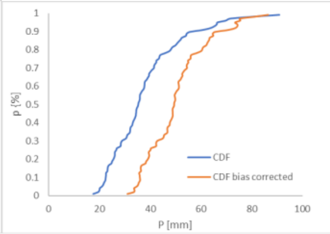
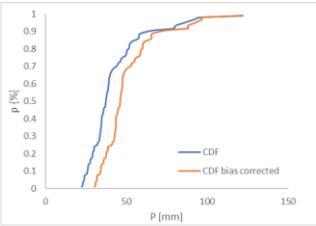
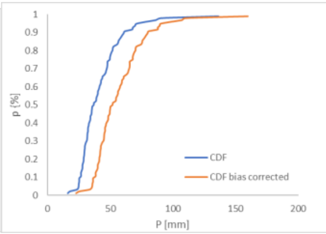


Figure 9. CDF RCP-4.5 (7) Fig. 14. CDF RCP-4.5 (8) Fig. 15. CDF RCP-4.5 (9)





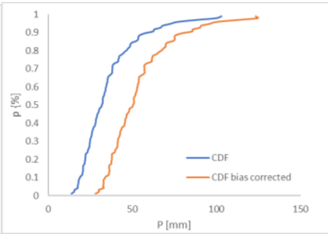
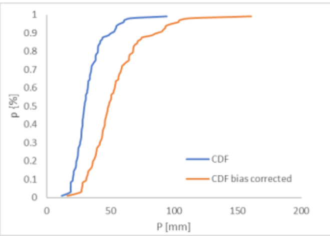
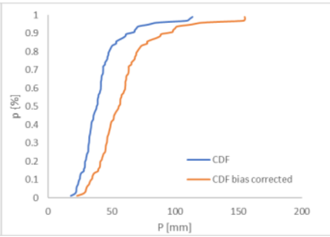


Figure 10. CDF RCP-8.5 (1) Fig. 17. CDF RCP-8.5 (2) Fig. 18. CDF RCP-8.5 (3)





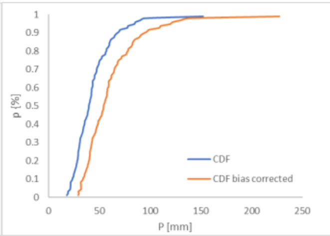
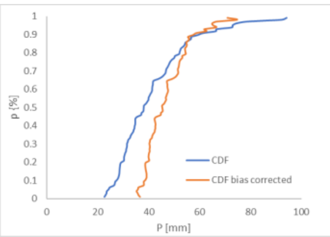
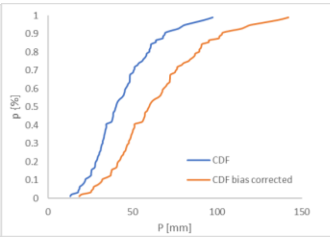


Figure 11. CDF RCP-8.5 (4) Fig. 20. CDF RCP-8.5 (5) Fig. 21. CDF RCP-8.5 (6)





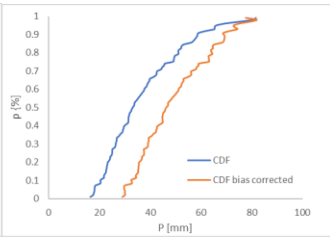


Figure 12. CDF RCP-8.5 (7) Fig. 23. CDF RCP-8.5 (8) Fig. 24. CDF RCP-8.5 (9)

4.2. Weighting

Upon the application of bias correction methods and the subsequent weighting of the nine Regional Climate Models (RCMs), a distinct dataset from the ensemble is created. Figures 25-26 display the inverse CDFs of these unique series across the entire ensemble. These were obtained through the aggregation of weighted precipitation, utilizing normalized weights. Results differ based on theoretical distribution and weighting functions used.

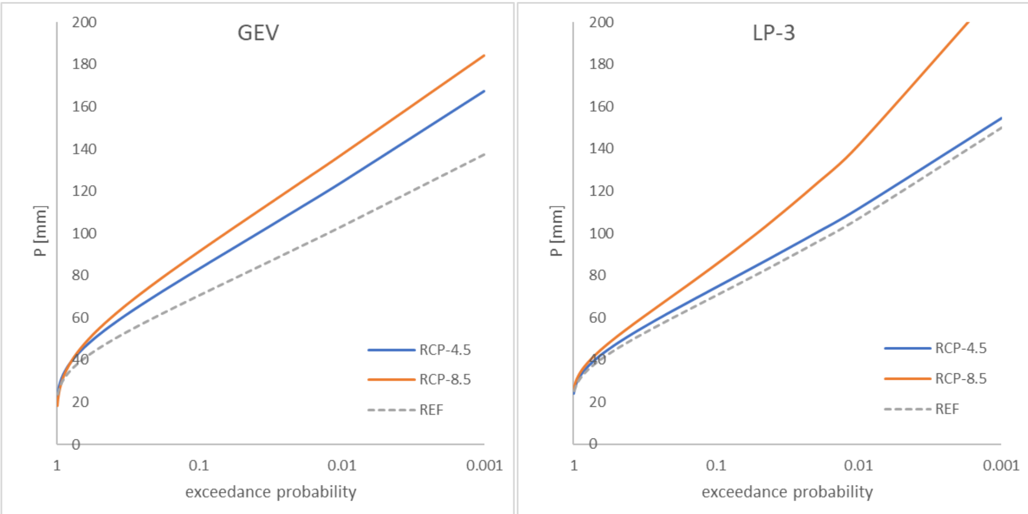


Fig. 13. Inverse CDFs under changing climate for unique series weighted via tricube weight function

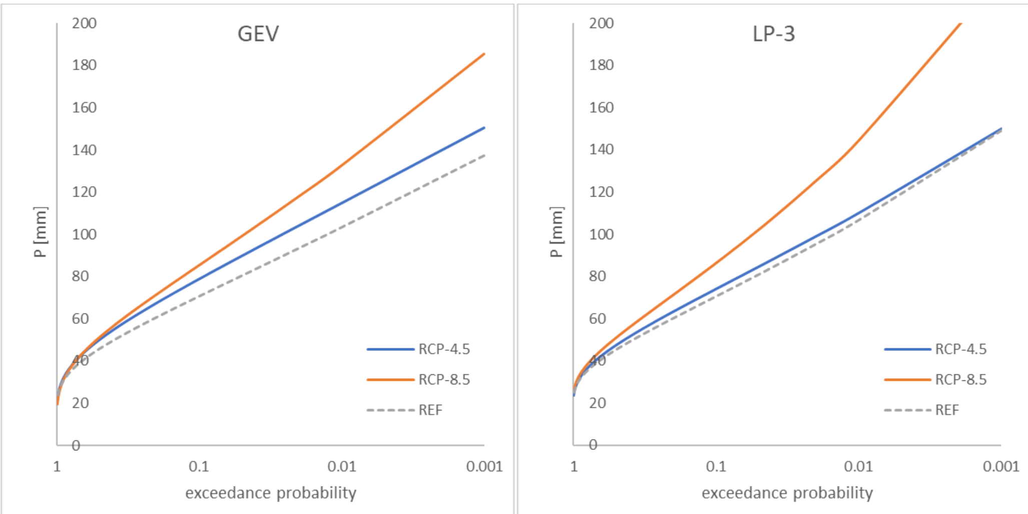


Fig. 14. Inverse CDFs under changing climate for unique series weighted via modified Gaussian weight function

Inverse CDFs where LP-3 distribution is used manifest a larger discrepency between the two climate options compared to GEV distribution, which signifies the impact of theoretical distribution on the results.

The weighted model for the future period under changing climate can be compared to the weighted model of the reference period, where an increase in precipitation for larger return periods (e.g. 100 years, 1000 years) is suggested. The results indicate an increase in 100 years return period precipitation by 11-20% for the moderate climate option (RCP 4.5) and 28-33% for the worst case option (RCP 8.5) by using the GEV distribution. If LP-3 distribution is used, there are indications of a 3-4% and 32-35% increase for the same return periods for 4.5 RCP and 8.5 RCP climate options, respectively.

Table 1. Increase in precipitation for different return periods based on theoretical distribution and weighting function used

T	tricube weight function				modified Gauss weight function			
	GEV		LP-3		GEV		LP-3	
	4.5	8.5	4.5	8.5	4.5	8.5	4.5	8.5
1000	22%	34%	3%	45%	10%	35%	0%	49%
100	20%	33%	4%	32%	11%	28%	3%	35%
50	20%	32%	5%	29%	12%	26%	4%	31%
20	19%	31%	5%	24%	12%	24%	5%	26%
10	18%	29%	6%	21%	12%	21%	5%	23%
5	17%	27%	6%	17%	11%	18%	5%	19%
2	14%	20%	5%	12%	10%	12%	5%	13%

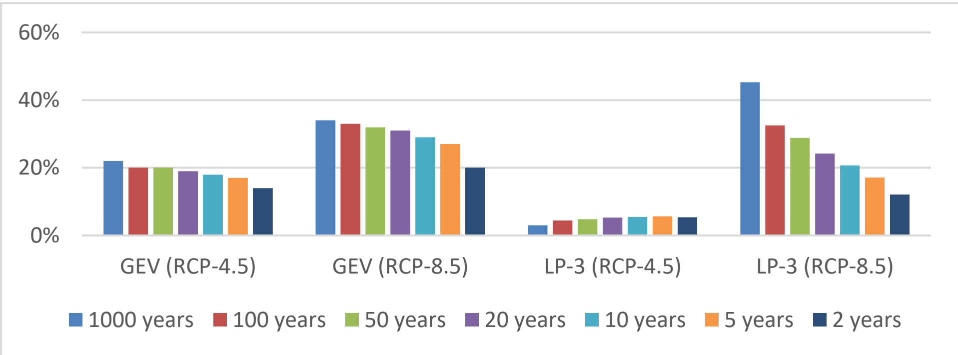


Figure 15. Increase in precipitation under changing climate after bias correction and weighting using tricube weight function

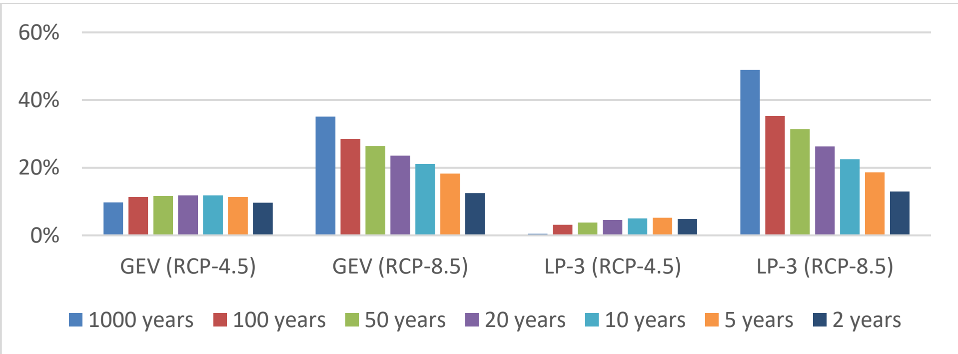


Figure 16. Increase in precipitation under changing climate after bias correction and weighting using the modified Gaussian weight function

5. CONCLUSIONS

This study presents a comprehensive investigation into bias correction and weighting techniques, with a specific emphasis on their implementation in refining the representation of precipitation data derived from Regional Climate Models (RCMs). The application of TQM was significant in overcoming the shortcomings of EQM, namely its inadequacy in dealing with the lower end of distribution tails. By assigning weights based on performance during the reference period to each RCM from the ensemble with bias-adjusted data, both weighting methods produced unified datasets which generated CDF curves with higher precipitation values. The research paper's findings highlight that the selection of the theoretical distribution plays a much more substantial role in influencing the results compared to the choice of the weighting function, which emphasizes the crutial role of selectiang an adequate theoretical distribution to ensure accurate and reliable results.

The study concludes that the proposed methodology is a useful tool to reduce the uncertainties in RCMs and can provide valuable information related to precipitation climate signals. It contributes to the understanding of the changes in precipitation patterns and can be useful for policymakers and planners to make informed decisions related to water resource management and flood protection. Given the significant impacts of climate change, refining and improving climate models and their outputs still remain an area with high potential for improvements.

It is important to note that the research focused on a single meteorological station. Therefore, further research with broader spatial coverage, including multiple meteorological stations, is suggested to generalize the conclusions. Moreover, the exploration of alternative bias correction and weighting techniques might be beneficial in further reducing uncertainties in RCMs.

ACKNOWLEDGMENTS

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ARCHITECTURE – THE MOST INFLUENTIAL ART

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Abstract

Having in mind the theoretical controversies concerning the artistic status of architecture, the author starts from the assumption (1) that architecture belongs to the corpus of arts: it is (1.1) an activity that could "present to sense" the aesthetic ideas of our imagination, although (1.2) limitations of material and purpose do not preclude the importance of the aesthetic dimension; by its forms, architecture (1.3) arouses appropriate aesthetic experience, in which the meaning/sense of the particular could be hinted at; architecture is (1.4) an important framework of urbanity and a factor of aesthetic culture. The author further (2) argues the following theses: (2.1) an impact of other arts and pseudo-arts could be avoided, but (2.2) the influence of architectural buildings, amongst them those in which all of us spend our lives, is constant, silent but unavoidable; (2.3) these buildings – architectural works of art or architectural junk and kitsch, all the same – inevitably mold our taste; therefore, (2.4) architecture is the most influential art, a document of the epoch, but also a significant organon of its shaping – our spirit takes the form of the "containers" we inhabit. (3) That is why (3.1) neither the impact of architectural forms nor the "silent work of taste" should be underestimated, because (3.2) taste is not "just a taste", but an important building factor of the autonomy of aesthetic, moral, social and political judgements of free individuals; therefore, (3.3) the influence of the so called "investor architecture", profit- and consumerist-oriented civil engineering (despite occasional architectural masterworks), is not only an aesthetic "incident", but a kind of cultural, moral, ecological, health-related, civilizational "sin" and, finally, (3.4) "an anthropological evil".

Key words: *art, architecture, taste, aesthetic culture, investor architecture, anthropological evil*

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1. INTRODUCTION

In the world globally reigned by the capital and the ideology of consumerism, technological growth – which is inappropriately equated with "progress" – goes hand in hand with intensive construction works and the controversial spacing of industrial, residential, and other buildings required for modern society to function. In such market-oriented construction industry architecture has been losing autonomy in its creative connection with construction, becoming a servant (*ancilla*) to the expansive ideology of production and consumption. Aware of such trends in architecture and construction industry, in the present paper the author shall try to point at their detrimental aesthetic, artistic, but also educational and more general cultural, political, and anthropological consequences.

2. ARCHITECTURE IS ART

There have been discussions on the concept of "art" and disputes over the classification of individual arts since antiquity. Within them, architecture has received various treatment. However, with some simplification, one can claim that at least since the 18th century its position within the system of (fine) arts has not been questioned [1: 20–76], regardless of whether it was perceived as occupying the bottom of the hierarchy of arts, as with Hegel and Schopenhauer, or it was seen as closer to the top. Lexicons of aesthetics commonly contain an entry named "Architecture" [2; 3, 4]. Yet, in early 2023 the well-known architect Boris Podrecca stirred the waters among the professional public over this issue. Namely, on the occasion of an exhibition of his works in the Museum of Applied Art in Belgrade, entitled *Archiculture*, he gave an interview, in which he provided an "apophatic" definition of architecture – as he denied that it belonged to the corpus of arts. At one point, he said: "Architecture is not an art, as some think it is, because you cannot invest emotions in it." However, apart from the fact that it is not quite true that in architecture one cannot find, and in its reception one cannot recognize, emotions, one should add that emotions are not a relevant distinctive feature of the class of "arts". Therefore, this statement should be taken with a pinch of salt. Podrecca also says that the goal of architecture is to "provide a roof over one's head", to give us "safety" and "enable a long life", which are all primary functions of culture. Hence in his work he favors functionality over likability (not excluding what he calls a "mental aesthetics", "the aesthetic hygiene of a city") and he also highly values the dialogue between the local natural/cultural traits of the space and most modern materials. This is precisely why he claims that everything in architecture pertains to "anthropology and archiculture" so that architecture has to break away from the "aesthetic and the sugary", from the "stylistic", and turn to "anthropological problems". For this reason, architecture is a "monument of an age", "a document of a period", and its each such form "represents the durability of time". He says he does not view himself as an artist, but "rather an anthropologist", and in response to those claiming that architecture is an art, he provides a quarrelsome remark: "like hell is it an art. Not true. Architecture looks upon art, it flirts with art, but down deep, architecture is anthropology." Because it provides us with shelter, housing, protection, framework in space enabling safety and longer life – "architecture is anthropology." Architecture begins with the transition from knots of plants used for cover and from tents to a wall, roof – to a house. This is why he himself does not do something that is merely “pretty” or represents “design.” “Here we touch upon those who claim that it is art, and for me this is too little and not deep enough. Therefore, architecture is more.” Architecture is actually archiculture, and not something stylistic, shallow, likable, aesthetic… A durable architectonic form, a document of a time, must reach deep, must give form to conflict as well, because, if it does not do so, “it is but a candy. A beautiful form.”[2] Podrecca’s “more” unmistakably recalls Hegel’s claim that the perceptual shaping of the form of works of art “possesses a higher and profounder meaning and significance” [5: I, 103].

In short, Podrecca rejects the view that architecture is an art of pretty and likable forms because it must reach deep so as to resolve the most profound problems of human survival.

In my view, architecture is not the same as anthropology, yet it needs to reach the anthropological so as to give us what we need most: protection, but also atmosphere. Architecture should indeed do this, and it manages to, but precisely as art. It is true that today the public at large views art as something stylistic, likeable (and the predominating theory of art also views it as a conceptual act, proclaiming as art various objects and acts.) Alternatively, art is not taken seriously at all. And architecture is art in its most profound sense, which means that as art it has anthropological foundations and an anthropological striving (as is actually the case with all arts.) As such, architecture today needs to fight – with little chance of success – against the ephemeral but aggressive flood of “turbocapitalism” and stylistic vanity. Podrecca’s central architectonic category would be “good” rather than “beautiful”, or at least a category assuming the unity of “beautiful” and “good” – an architectonic kalokaghatia (καλοκαγαθίᾱ).

The Serbian architect and aesthetician of architecture Milutin Borisavljević (1889–1969), who defined art and the artwork in an almost Kantian way, by means of the concepts of the beautiful, self-purposefulness, absolute freedom and aesthetic feeling (satisfaction), considered architecture a (decorative) art, a symbolic art, and thus “most primitive” and “poorest in expressing” ideas (which is quite Hegelian). However, at the same time he viewed it as superior, since it represented creation, reality, as opposed to the other arts, which are imitative, mimetic. Thereby he held that one must completely separate the competences of the architect, a man of imagination, an artist, on the one hand, and of the construction engineer, a man of science, that is applied science, on the other. “Architecture is *an art*. Being an architect means being an *artist*” [6: 265–294].

2.1. Architecture presents aesthetic ideas to sense, too

In the vast variety of definitions of art, in which each new attempt of defining this concept means treading the field of numerous theoretical, epistemological and aesthetic controversies, after many years of research I have constructed a Kantian position: art is the process of presenting aesthetical ideas of the imagination to sense

[2] Nikoletić Dragana: Izložba: **Igre linija i površina** [Exhibition: **A game of lines and surface**]. *NIN*, no. 3762, 02 February 2023.
Ristić Snežana: **Plezir života u dobroj arhitekturi** (Intervju: Boris Podreka, arhitekta). **[The pleasure of life in good architecture,** an interview with Boris Podrecca], □□□□□□□□, 28 January 2023.
Ristić Snežana: **Boris Podreka u Beogradu: Putuj sa mnom** (Intervju, izdvojeno) [Boris Podrecca in Belgrade: Travel With Me (interview, selection)]. https://www.gradnja.rs/boris-podreka-izlozba-arhikultura-intervju/ *(30 January 2023)*

(of inexponible representations of the Imagination, which do not correspond to any concept of reason), whose works through its form, the constellation/composition of its structural elements, in the aesthetic experience composed of judging and satisfaction (or dissatisfaction), by means of the aesthetic, suggest the meaning of the particular or the suprasensory itself.

Architecture, which is inevitably marked by functionality, also creates works whose form derives from our aesthetic ideas. Naturally, this is not the case with numerous structures which only implement concepts of reason (translated into plans), yet which are not works of art.

It is quite unusual that precisely Borisavljević, an architect and aesthetician of architecture, defined this through the concept of "aesthetic ideas." "Architecture is a symbolic art; it expresses aesthetic ideas through symbols, therefore indirectly and imperfectly." And this art, most primitive and poorest in expression, and superior in creation, in addition to drawing aesthetic ideas from imagination, also "draws its formal ideas from the history of architecture," from that inexhaustible richness of forms, styles, and combinations [6: 270 –273]. It is solely because of his introduction of the "aesthetic idea" category into the definition of art in general and the art of architecture that this aesthetician has been singled out among so many great figures of architecture to support the thesis that architecture is indeed an art.

2.2. **Limitations of material and purpose do not preclude the importance of the aesthetic dimension**

It is true that works of architecture are always made after specific requirements and constraints pertaining to intent, functionality, materials, and capacities for implementation on the part of craftsmen and industrial technology. However, this does not imply that such limitations, nor the plans and mathematics of implementation, preclude the aesthetic dimension of construction, which overwhelms us at first sight. After all, this is the fate of all applied arts. Everything can be a motif, a theme, the material basis for art, while, according to Friedrich Schiller, "the real artistic secret of the master consists in his annihilating the material by means of the form" [8: letter 22].

In that way the architect uses the form to "annihilate" the raw, crude nature of the material, the banality of its purpose and function, the physical weight of the building, so that his masterpiece flies like a "light pigeon" in its firmness and immutability. However, in the words of Nicolai Hartmann, this "annihilation" is not a concealment of the practical purpose and the raw material, but rather their visible synthesis with the form, a victory of the mind (of the construction) against the matter, where however the visibility of this synthesis of form, on the one hand, and of matter, on the other, is no longer only perceptual, but it provides an insight of "a higher order", insofar as the technical moment of construction, which causes the form, functions as an "appearing background" , while "its content is the spiritual work of architecture" [7: 150–152].

2.3. **Architectural forms also suggest the meaning of the particular**

Although the encounter with works of architecture forces us to think about their purpose and functionality, a comprehensive observation of the form of particular buildings, or even of an urban constellation of a number of buildings, causes in us an overwhelming experience of the purposiveness of form (without a concept of any particular purpose), which hints at the meaning/sense of the particular: of each individual element in the building's composition, of the individual building in a constellation, or of the entire constellation in the broader environment, including our own position in it. This resembles listening to music, although in architecture, naturally, one cannot expect the critical, disruptive impact of atonality, dissonance, and of the ugly as tools of subversive denunciation of the meaningless and the absurd in the world.

To support the thesis that meaning is suggested in works of architecture, such that can be sensed in our experience, I will call upon the following opinions. Boris Podrecca himself talked about a "mental aesthetics", an "atmosphere of the city", about architecture as a "document of a period", and about the works of architecture giving us a "passepartout for life" – a framework that is not only physical, but also provides us with the sensation of meaningful dwelling at home. And Milutin Borisavljević, using "a headstone" as an example, also said that in it there was "something located above (d'au-delà)" [6: loc. cit.]. Nicolai Hartmann, on the other hand, in his conclusion that in the work of art as objectified spirit, the structure of the aesthetic object contained two planes, the foreground (Vordergrund) and the background (Hintergrund), thought that only in second-order perception, that of the higher plane, could one experience the important, unsensed, which appears in the foreground. He claimed that in architecture too, although it is certainly subjected to its non-aesthetic purpose and constrained by the potentials and limitations of the material, therefore, in spite of its dual boundedness, by both "heaviness of matter" and "practical purpose", it is possible to have both a free play of form and the emergence of the irreal (background) in the real (foreground). The synoptic process of encompassing the entirety of the building, which our perception can only grasp in successive instances, presents "something beyond the spatial and material form"; within that process of observation appears some age, with all of its traits, appear various historical periods and epochs (and not only in monumental pieces) with their lifestyles and cultures, as a rule within one dominant style: "This has bestowed upon architecture an entire world of appearing background" [7: 146–149].

2.4. Architecture is an important component of aesthetic culture

As they originate, civilizations make the most important steps when they transition to a sedentary, stationary way of life, but even more decisively when they supersede village-based social organization and start founding cities. Joint life in the city encompasses solving the problems of residence, communications, production, religious and political activities, etc. This always requires specially constructed, more or less permanent buildings, which become incorporated in appropriate lifestyles. However, rural cultures, and then also urban cultures, function as locations in which man is gradually transformed from the natural, sensual and instinctive state, towards the moral condition. This process, schematically represented in Friedrich Schiller's aesthetic anthropology, in fact represents the activity of aesthetic culture – which cultivates the crude human being, at the same time preserving and refining his sensual nature. Schiller wrote that "one of the most important tasks of culture [is] to subject man to form even in his purely physical life", which is possible only by means of the aesthetic, through the "laws of beauty" [8: letter 23], therefore, through aesthetic culture, which enables man "to make of himself what he chooses" and restores "to him the freedom to be what he ought to be" [8: letter 21]. In all fields of life, man not only aestheticizes artefacts, himself and his environment, through naturalistic or stylized ornaments of the magical, mythological, religious, etc. kind, but he also gives these objects as a whole a purposeful, artistic form. Who can say that this is not precisely what happens in the domain of construction/architecture! In this process, in addition to satisfying his elementary biological needs, man also satisfies his spiritual needs, which is accompanied by specific satisfaction or dissatisfaction. In this way man makes a step forward, from the necessities of life toward the freedom of art. Kant says: "in all beautiful art the essential thing is the form, which is purposive as regards our observation and judgement, where the pleasure is at the same time cultivation and disposes the spirit to ideas" [9: § 52].

3. ARCHITECTURE IS THE MOST INFLUENTIAL ART

Based on the analysis above, one can draw a reliable conclusion that architecture, with all of its peculiarities – in terms of the possibility to present aesthetical ideas of the imagination to sense, suggest the meaning of the particular, hint at the suprasensory, act by means of its form in the aesthetic experience, and finally, act within the totality of aesthetic culture – belongs to the realm of art. In short, we could say that architecture is the presentation to sense (Versinnlichung) of aesthetical ideas in the vocational, industrial, scientific, technological, aesthetic and artistic shaping and building of private and public spaces. In addition, in any attempt to analyze the phenomenon of architecture and define it as a concept, one cannot overlook the strong and long-term influence of buildings and architectonic forms.

3.1. Influences of most art and pseudo-art forms can be avoided

Historical and personal experience tells us that man has become exposed to the effect of some arts willingly (literature, rhetoric, music, theatre...), while others have entered his perception and reception regardless of his will (sculpture and architecture in antiquity, for example). Likewise, in the present day we can move away from the effect of all arts, excluding architecture, works of applied art in public spaces and the design of artefacts for daily use. To be fair, today one can barely escape the influence of music, mediated through sound carriers, amplifiers and loudspeakers. All of this applies to both works of art and works of pseudo-art, i.e. kitsch. One can decide not to read books, not to go to theaters and concerts, not to visit exhibitions and galleries, one can even choose kitchen utensils, appliances, clothing and other everyday items, one can choose the form of one's house; one has the right to stay amusic and banausos (βάναυσος), with a risk that one should be self-excluded from various social circles and forms of social life. However, there is something one cannot do.

3.2. The influence of architecture is constant, quiet, and unavoidable

One cannot choose or avoid the effect of buildings from one's city, settlement, region; one cannot run away from the radiating forms of buildings, streets, squares, parks… nor can one avoid various instances of ugliness, caused either by poverty or, much more, by wealth. It is clear, perhaps not to everyone, that the influence of architectonic buildings, in which we all live our lives, is constant, almost unnoticeable, but inevitable. It is not quite equal to the influence of the natural forms, such as mountains, plains, rivers, or seas, although the technological civilization can now change their effect as well, to an extent. From birth and until death, whatever one does, wherever one moves, one is surrounded, swallowed, expelled, pressed or elevated by squares and streets, by secular or sacral buildings of one's area; one watches them become erected, and then degraded and demolished; one takes part in both processes; one watches the buildings of other cities and countries, comparing them, willy-nilly, with one's own and, willy-nilly, judging their forms as beautiful, ugly, sublime, graceful, etc., or at least as attractive and repulsive, desirable and undesirable. Even if one is not fully aware of the effect of the forms of construction and architecture, one is subjected to their effect – up to an extent, we do not know how strongly, they participate in the formation of one's own being. We cannot see the air either and we still breathe it in, instinctively, and sometimes also as a result of training.

3.3. **Architectonic forms shape our taste**

Architectonic forms are not a requirement of life, but they are a necessary element and precondition of living at a particular degree of civilization, at a particular matrix of culture and identity, in a truly human spirit. Architectonic forms produce this effect through forming or by contributing to the formation of our taste, which enables us to judge the forms of objects, activities and behaviours on the basis of specific satisfaction or dissatisfaction, approval or disapproval, in the aesthetic experience. All architectonic buildings – whether artworks or trash and kitsch – inevitably shape our taste, our attitude to the objects of our activity, in the local environment, society at large, or before ourselves.

3.4. **Architecture is a document and organon of the Zeitgeist**

For all these reasons it turns out that architecture – whether or not we like it – is the most influential art, which has used our taste to construct an important part of our spiritual and cultural being, throughout the history of civilizations. Since its styles reflect the Zeitgeist, a view of the world of a period, its vision of the world and its values, architecture is a document of time periods. Austrian writer Hermann Broch, who wrote in 1933 that the sensual expression of his time was "to be looked for in mechanical engineering and athletic events rather than in the architectonic view of cities or works of art" [10: 267], in a 1950/51 university lecture still said that precisely "the image of a particular architecture […was…] paradigmatic of each epoch" [10: 250/251]. However, architecture is not just a document of a time. Rather – to paraphrase F. W. J. Schelling – it is also this time's organon, i.e. activity articulating the organization of a living space; at the same time, its works enable us to understand both our time and other epochs; ultimately, they help us gain a certain amount of understanding of the course of history, of the development, remarkability, fragility, and firmness of the human world. This is why I hold the idea of architecture being the most influential art, the most efficient in shaping and developing our imagination, spirit, judgment, and taste, to be one of the truist axioms of anthropology and anthropological aesthetics. Our spirit indeed receives the form of "containers" that we inhabit.

4. THE PROFOUND AND FAR-REACHING EFFECT OF ARCHITECTURE

If we accept this claim, then, in order for us to ponder whether we can build a truly human world and life, it remains to explore – along with other forms of creativity, knowledge, action – the potential and actual forms which architecture has assumed in shaping our taste and spirit through history, and also to be aware of their beneficial or harmful effect.

4.1. The influence of architecture must not be underestimated

Excluding architecture from the domain of arts, just like the underestimation of its aesthetic and formative effect, can make us indifferent to the aesthetic dimension of architectonic buildings, and thus to the permanent aesthetic and artistic influence of our environment. The consequence is that such an important domain can be left solely to the market, capital, and greed. Underestimation of far-reaching effects of kitsch provides a certain road to becoming subjugated to its reign. We know that financial interests cannot be excluded from construction industry, yet we may introduce applicable norms to subject them to certain rules of social life; likewise, appropriate education may serve to modify these interests toward aesthetic and humanistic visions. The effect of architectonic forms best illustrates Schiller's words about "the quiet work of taste in the outward and the inner man." In turn, this work cannot be properly assessed if our only measure of value is "the trouble of acquisition and the palpable profit" [8: letter 10]. Naturally, that which applies to the underestimation of "the quiet work of taste" applies at least as much to the careless consideration of the loud work of distaste, of bad taste.

4.2. Taste is never "only taste"

Indeed, taste is not "only taste", "mere taste", the assessment of satisfaction, likeability and the domain of liking. Taste is an important social power of shaping our sensual and spiritual being, a tool of aesthetic culture and one of the pillars of culture for social groups and individuals. For he who is capable of free and autonomous judgement of aesthetic phenomena and works of art shall, in principle, be capable of free and autonomous judgement of the morality of action and behaviour, and, finally, capable of autonomous and free judgement of practical and political positions, programs, and actions – capable of living in a free, democratic, enlightened, and creative society. Taste is, therefore, an important factor of the autonomy of the aesthetic, moral, social, and political judgement of free individuals. Are we truly left completely indifferent by the fact that there are significant correlations between certain types of taste and certain political preferences? Does it not seem indicative that autocratic regimes gladly finance, promote, and popularize various types of kitsch and trash, as resources to pacify their subjects? When you vote in an election, the houses, streets, and squares in which you live vote with you as well. If you spend your life in an ugly town, you may compensate for the disruption of taste and spirit by intensive contact with works of art – literature, music, theatre, visual art; yet this compensation can never be complete.

4.3. The influence of "investor architecture"

In a world reigned by the ideology of globalism, and the overall economic, political, and cultural globalization practices, construction and architecture are becoming a field of expansive consumerist industry, which cares for no tradition or identity, for no humanistic formation of the individual, no human communities, no principles of human ecodomics[3] and – aesthetically – domopoietics[4]. In spite of the occasional inspired architectonic masterwork, this ideology by and large generates or at least supports the urbanistic, architectonic, cultural and civilizational fall of the human being.

An obvious example of profit- and consumer-oriented construction is the anti-architectural "investor architecture", which marginalizes and even suspends the art of architecture and its "accompanying" art forms, unifies cities and cultures, thereby jeopardizing man's physical, cultural and spiritual life (even though at first glance it appears to enable such life). Therefore, the social influence of "investor architecture" is not just a sporadic aesthetic "incident" but rather a global cultural, moral, ecological, health-related and civilizational "sin", which – given the fact it is consciously committed and repeated – cannot be forgiven.

Construction cannot be separated from particular economic conditions and possibilities, while construction industry cannot work without profit. However, one cannot imagine a human society in which institutions for protecting nature, cultural monuments, for urban planning, for adopting strategies of social development and passing corresponding norms, remain blind and deaf to such "sins", either not to mention that they are often accomplices.

4.4. From an aesthetic incident to anthropological evil

Hermann Broch thought that the category of the beautiful applied to kitsch as well, yet that in art the category of the good should apply (which should be interpreted as criticism of the predominance of ethically irresponsible aestheticism, a "religion of beauty"). He also wrote that the "system of kitsch" is analogous to "the system of the Antichrist": "Kitsch is evil in art's value system" (10: 262).

However, in addition to decorative and gigantistic kitsch, in architecture we also encounter industrial brutalism, close-fisted functionalism, pauperized dwellings turned into barracks, and the predatory process in which life space is being made chaotic. By means of its pseudo-artistic forms, this aesthetic or anti-aesthetic evil becomes incorporated into our taste, our image of the real world, our vision of a possible world, our cultural codes and identities, our human powers and capacities. By piling up such shards and leaving an ever larger trace in our aesthetic, moral and political culture, in cultural patterns, cultural evolution, cultural habitus, in our human

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[3] Ancient Greek:
οἰκοδομέω, οἰκοδομήσω – 1) a) build houses, *in general*, build, construct, erect, fortify, b) *fig,* found on something, 2) build for oneself *or* have (a house) built
οἰκοδόμησις, εως, ἡ, οἰκοδομία, ἡ, οικοδόμημα, τό, construction, 1) constructing; a way of constructing, 2) a construction, building
οἰκοδομικός, which belongs to construction; τὰ οἰκ. the activity of construction
Gorski Oton, Majnarić Niko: **Grčko-hrvatskosrpski rječnik [Greek-Croatoserbian Dictionary]**. *Školska knjiga*, Zagreb, 1960.
[4] Ancient Greek:
δόμος – building; apartment, house, castle; temple; *fig*. home, homeland
ποίησις – creation, activity, making; a work; poetic creation, poetry writing

being, which is a being of culture, the artistic fall of architecture grows into an anthropological evil.

Against such evil one cannot fight overnight. Rather, we need long-term programs of institutional education, of alternative education mediated by the media and networks, we need aesthetic culture, commendable model examples of urbanistic and architectonic culture, we need to cherish the grand values of civilization, where we shall respect major traditions and acknowledge the highest points of our own tradition, and we need to esteem the freedom of modern creative work, followed by the freedom of thought and judgement – of criticism. Evil cannot be eradicated, but it can be suppressed by the culture of the good, which encompasses the domain of “aesthetic art” but does not exclude the subversive potentials of “conceptual practices.”

5. CONCLUSION

If we have accepted that, as an art, architecture reaches back to our anthropological roots, and that this includes architecture which represents pseudo-art, then it is clear where one should seek the causes of the separation between civil engineering and the art of construction; it is clear that the synergy of the two is one of the means for struggling against evil; and it is also clear that the struggle for constructing a space of living worthy of the human being must be equally economic, ecological, and ecodomic – domopoeitic.

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EXPERIMENTAL DETERMINATION OF DYNAMIC PARAMETERS OF HEAT PASSAGE THROUGH THE FACADE WALL OF A WEEKEND COTTAGE ON MOUNTAIN KOPAONIK, SERBIA

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Abstract

In this paper, using a dynamic RC model for heat transfer in a room on the ground floor, the three-time constants of heat transfer that corresponds to the different parts of a weekend cottage on Kopaonik were determined. The model considered the heat accumulation and losses through the facade wall, floor and interior part of the room. The time constant of the wall is the characteristic time for establishing a stationary state of the temperature inside the wall during rapid changes in the external air temperature and it represents a measure of the thermal inertia of the wall. The model was validated by experimental measurements of air temperatures and wall surface temperatures. Measurements were carried out in situ continuously for 21 hours in real conditions in the winter period. Air temperature measurements were made with standalone data loggers. The paper presents the results of the measurements, the parameters and the electrical diagram of the RC model and the results comparing the measured temperatures with the same temperatures obtained by this model. Satisfactory agreements were obtained.

Key words: *heat transfer, RC model, time constant, in-situ temperature measurement*

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1. INTRODUCTION

The measurements and numerical simulations related to the heat transfer through the exterior buildings' envelope are of the enormous practical interest for estimating buildings' thermal performances and energy efficiency [1]. The building's thermal performances are essential regarding the thermal comfort requirements [2]. In the real dynamical conditions, the thermal behavior of the whole building structure depends on different building parts, including the building's exterior envelope, floors, windows, indoor air and different interior structures [3, 4]. The electrical analogy models based on RC circuits have been extensively used in thermal simulations [5, 6]. In this approach, the thermal resistance and thermal capacity of the individual building elements are modelled using the electrical analogy with the electrical circuits consisting of the resistors and capacity elements. In this way, the temperature and heat flux are equivalent to electric voltage and current, respectively. In the literature, this approach is now known as Lumped Parameter Model (LPM) [7].

Ke-Lun He et al. developed an improved unit circuit model for heat transfer in multi-layer insulation materials based on additional nodes in the control volumes on the interfaces between different materials [5]. This approach has been used for the optimization of multi-layer structures to minimize heat losses. The heat transfer model inside a multi-layer wall based on a RC circuit has been validated in a real dynamical regime using experimental data by Jiaojiao Duan et al. [6].

Fraisse et al. have presented a numerical procedure to produce simplified RC circuit models for modelling multi-layer building walls [8]. In this way, the multi-layer planar structure could be modelled with only a few RC elements. The results obtained by the simplified RC model are compared with the reference numerical solution. In the same paper, all heat transfers in the entire building are represented using the electrical analogy and multi-zone building model.

The dynamical heat transfer model based on the electrical analogy with RC circuits and Kron's reduction of graphs has been developed and utilized in building retrofitting applications [9]. This technique is based on Schur's complement of the original Laplacian matrix that corresponds to the graph of the considered electrical circuit. A similar approach has been utilized for the zonal thermal model in a single room by Rivo et.al [10].

In this article, the electrical analogy and simplified RC circuit have been used for modelling of the heat transfer and temperature variation inside a room on the ground floor of a weekend cottage on the mountain Kopaonik during the winter period. The model has included the thermal envelope of the room, the heat losses through the floor and heat capacities of the thermal envelope, floor and the indoor space. Besides this, in-situ measurements of the inside and outside air temperature during 22.33h have been performed. During this period, the heating system has been switched off, and only cooling processes are analyzed. The numerical results obtained by the RC circuit are compared with the experimental data. The selection of the observed object for investigating its thermal properties was based on several pertinent considerations. Firstly, due to the small volume of the object, external temperature variations have a greater impact on the internal temperature and heat losses. Secondly, due to the high altitude and climatic conditions, the variations of the outside air temperature in the winter period are significant. Lastly, the object is isolated and exposed to greater influence of external factors, thereby making it an ideal candidate for this study.

2. DESCRIPTION, THERMAL PARAMETERS OF BUILDING CONSTRUCTION AND EXPERIMENTAL SET-UP

The measurements were taken in a cottage located in Kriva Reka, on the northeastern slope of Kopaonik, Serbia (Figure 1). The cottage is located at an altitude of 1330 meters above sea level, at 43°21'59" north latitude and 20°51'40" east longitude.

Figure 1. Exterior view of the weekend cottage in Kriva Reka, Kopaonik

The base of the outer walls has an overall dimension of 6.85x8.35 m, and the ridge is positioned in the east-west direction. The ground floor plan and vertical section of the weekend cottage with all relevant dimensions are shown in Figure 2. The entrance to the building is from the east cardinal direction. The entrance to the ground floor bedroom is on the left from the corridor, while the bathroom is positioned on the right. The living room is positioned in the front and it's connected to the dining room and the kitchen. An interior staircase leads from the living room to the hallway in the attic. The attic has two bedrooms with terraces.

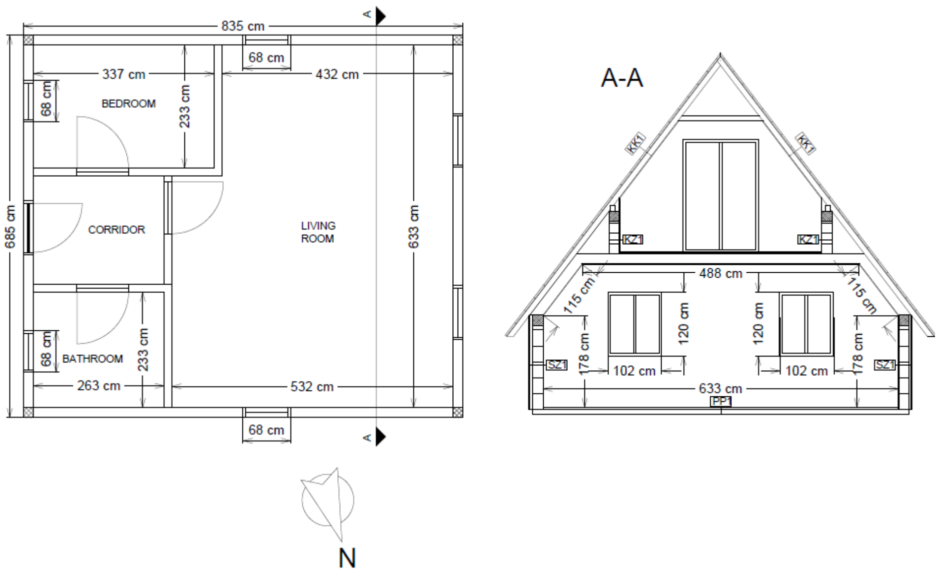


Figure 2. Ground floor plan and vertical section A-A of the weekend cottage

The foundation of the building is on strip foundations, which are connected by reinforced concrete foundation beams. The supporting structure of the building is made of hollow clay blocks with tie columns. The floor construction on the ground floor is a reinforced concrete slab, while the attic floor is a hollow-block floor (Light assembly ceiling). The interior partition walls are also made of hollow clay blocks.

The roof structure is made of wood, while the roof covering is based on bitumen and glass fibers (roof tile - tegola).

The building is heated by a central system with the boiler located in the kitchen area, and radiators are installed throughout all rooms. Radiator dimensions are adapted to the area of every individual room. The exterior joinery (windows) is made of PVC with double glass, while the entrance door to the building is made of aluminium.

Figure 3 shows the "data logger" used to measure the temperature inside and outside the weekend house. The external and internal temperature was measured simultaneously every 5 minutes. The measuring range and the response time of the device to step temperature excitation were from -35 [ºC] to 80 [ºC] and 20 [s], respectively.

Figure 3. Data logger for temperature measurements

Figure 4 shows the temperature measurement accuracy curve. In the measurement range of 5-40 [ºC], the maximum absolute measurement error is less than 1 [ºC] (the minimum at 25 [ºC] is 0.5 [ºC]). The device's sensor is located inside a plastic case that is conveniently designed and allows the internal flow of outside air, which also protects against wind and rain. Two measuring devices were used to measure the temperature.

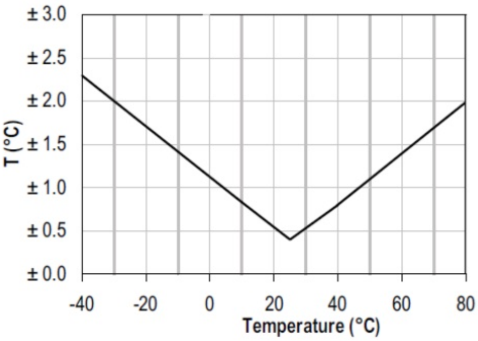


Figure 4. Temperature characteristics of data logger

The internal air temperature was measured in the middle of the living room and the external one under the eaves, in a place protected from the direct influence of the Sun and precipitations (Figure 5).

Figure 5. Positions of the data loggers in the living room and under the eaves

The thermo-physical parameters of considered building components used in the presented model in the section 3 of this paper are given in Tables 1-4.

Table 1. Thermal parameters of the outside façade wall (SZ1- Figure 2)

Material	d_w [cm]	ρ_w [kg/m^3]	λ_w [W/m·K]	c_w [J/kg·K]
Mortar (inside)	1	1900	0.7	1050
Hollow clay block	19	1400	0.61	920
Styrofoam	5	90	0.041	1260
Demit façade (outside)	1	1900	0.7	1050

Table 2. Thermal parameters of the roof above the slope wall (KK1- Figure 2)

Material	d_r [cm]	ρ_r [kg/m^3]	λ_r [W/m·K]	c_r [J/kg·K]
PVC	0.1	1200	0.19	960
Mineral wool	10	30	0.032	840
Wooden beam (10x8 cm) distance 60 cm	10	91	0.044	1727
PVC	0.1	1200	0.19	960
Wooden boards	2	520	0.14	1670
Permeable films	0.1	1000	0.19	1250
Roof tile	0.3	1100	0.17	1050

Table 3. Thermal parameters of the slope wall (attic floor-Figure 2)

Material	d_{sw} [cm]	ρ_{sw} [kg/m^3]	λ_{sw} [W/m·K]	c_{sw} [J/kg·K]
Light assembly ceiling	1	1900	0.7	1050
Styrofoam	19	1400	0.61	920
Mortar (inside)	5	90	0.041	1260

Table 4. Thermal parameters of the floor (PP1-Figure 2)

Material	d_f [cm]	ρ_f [kg/m^3]	λ_f [W/m·K]	c_f [J/kg·K]
Ceramic tails	0.4	2300	1.28	920
Reinforced concrete structure	10	2400	2.04	960

3. PHYSICAL MODEL

The heat transfer inside the ground floor room under dynamic conditions has been analyzed. The thermal model is based on an electrical analogy using a RC circuit and includes the thermal envelope of the considered room with windows, the influence of the floor and the thermal capacity of indoor space. The model can include real variations of the outside temperature. It has been assumed that the heating system during the calculation was turned off.

The presented LMP model is based on the assumptions that all thermo-physical parameters of the building components are constant and that the considered thermal system is linear, also it has been assumed that the indoor air temperature has uniform distribution during the time. Only thermal losses through the outside thermal envelope of the room and floor are considered, while the thermal losses through the ceiling and adjacent rooms are neglected. The thermal capacity of the windows was neglected. The thermal envelope is modelled as a simple equivalent RC circuit that consists of one capacitor and two thermal resistances. Besides this, the heat transfer in all solid building components (i.e. walls) is modelled as a conductive process. The heat transfer due to convection and radiation between air and outer surfaces has been modelled by the heat transfer coefficients in the boundary layers. The thermo-physical parameters of the observed building structures used in the considered thermal model are given in Tables 1-4. The RC circuit used for thermal modelling of the considered dynamical system is shown in Figure 6.

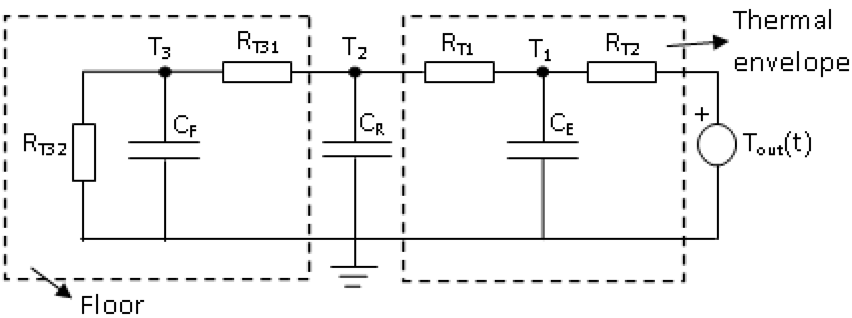


Figure 6. RC circuit used for thermal modelling of the considered dynamical system

The model consists of three parts: thermal envelope, floor and interior space. Interior space is represented by thermal capacity CR. The quantities Tout(t) and T2 in the Figure above represent the time-dependent outside and inside air temperatures, respectively. As mentioned, it has been assumed that indoor temperature is homogeneously distributed.

The thermal envelope includes a façade wall, a slope wall with part of the roof construction above, windows and boundary layers.

The positions and relevant dimensions of the modeled building elements are shown in Figure 2. The boundary layers are included through the inside and outside heat transfer coefficients α1=7.69 [W/m2·K] and α2=25 [W/m2·K], respectively. The constant numerical values for these parameters are adopted according to the Domestic Rulebook on the Energy Efficiency of Buildings [11]. The thermal resistance of the thermal envelope RTE is calculated according to the equivalent electrical scheme shown in Figure 7 and Equation 1.

$$R_{TE} = R_{T\alpha 1} + \left(\frac{1}{R_{Tw}} + \frac{1}{R_{Tsw}} + \frac{1}{R_{Twin}}\right)^{-1} + R_{T\alpha 2}; R_{T\alpha 1,2} = \frac{1}{S_w \cdot \alpha_{1,2}}, \quad (1)$$

where RTw, RTsw and RTwin are thermal resistances of the façade wall, slope wall with part of the roof construction above it and windows, respectively, and RTα1,2 are thermal resistance that corresponds to the inside and outside boundary layer ,respectively, that are calculated according to the above relations. The Sw in the above equation is the effective area of the façade wall which excludes the area of the windows.

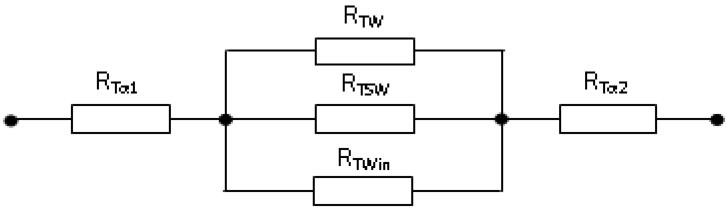


Figure 7. Equivalent electric scheme used to calculate thermal resistance of the thermal envelope used in the model

The thermal resistance of windows is calculated according the next relation:

$$R_{Twin} = \left(S_{glass1} \cdot U_{glass1} + S_{frame1} \cdot U_{frame1} + \cdots\right)^{-1}, \quad (2)$$

where Sglass and Sframes are areas of window glass and frameswhile Uglass and Uframes are U-values for window glass and frames, respectively. In the above relation the summation has to include all windows. The U-values for glass and frames are used according to the Domestic Rulebook on the Energy Efficiency of Buildings [11]. The following U-values of glass and frame are assumed: Uglass =3.0 [W/m2·K] (double glassing 6-8-6 mm) and Uframe =2.2 [W/m2·K] (PVC two-chamber frame).

The areas of window glass and frames for two types of windows used in the considered model are given in Table 5.

Table 5. The areas of window glass and frames

Window type	*Glass area [m²]*	*Frame area [m²]*
Type 1 (front view A-A, Figure 2)	*0.6336*	*0.5904*
Type 2 (side windows)	*0.3483*	*0.4677*

Besides this, the thermal resistance of all building walls and roof construction is calculated according to the Domestic Rulebook on the Energy Efficiency of Buildings [11].

The sum of the thermal resistances RT1 and RT2 used in the model represents the thermal resistance of the thermal envelope in stationary conditions, i.e. RTE = RT1 + RT2. Also it has been assumed that RT1 is the thermal resistance of the façade wall from the inside surface to the middle of the wall. Accordingly, the temperature T1 in Figure 6 is approximately the temperature in the middle of the façade wall. For the layer inside the roof construction that consists of wooden beams and mineral wool (Table 2), the averaged thermal parameters are used, and the same approximation is used for the light assembly ceiling (Table 3). All thermal capacity elements are calculated using the following approximate relation for the thermal capacity of a multi-layer structure:

$$C = S \cdot \sum_{i=1}^{N} d_i \cdot \rho_i \cdot c_i, \quad (3)$$

where C [J/K] is thermal capacity, N is the number of layers, S is the area of the considered structure and d, ρ, and c are thickness, density and specific heat, respectively. In Figure 6 CE, CR and CF are the thermal capacities of the thermal envelope, indoor space (room) and floor, respectively. The thermal resistance of the floor is obtained using the U-value of the floor that is calculated according to ISO 13370 international standard by the following relation:

$$U_f = \frac{2 \cdot \lambda_s}{\pi \cdot B + d_s} \cdot ln\left(\frac{\pi \cdot B}{d_s} + 1\right), \quad (4)$$

where Uf is the U-value of the floor, λs is the thermal conductivity of soil (value 2 [W/mK] is assumed), B is the ratio between the area and half perimeter of the floor, and ds is the effective thickness of building construction [12]. The quantity ds is obtained by the following relation:

$$d_s = w + \lambda_s \cdot \left(R_{se} + R_f + R_{si}\right), \quad (5)$$

where w is the thickness of the building's external wall, Rse is R-value between air and floor, Rf is R-value for floor construction, and Rsi is the R-value between soil and floor construction, for Rse and Rsi the value of 0.17 [m2 ·K/W] is assumed [12]. The overall thermal resistance of the floor is equal to the sum of thermal resistances RT31 and RT32. The ratio RT31/ RT32 is considered as a fitting parameter, and the best agreement with the measurement data is obtained if this ratio is equal to 0.07. This approximately corresponds to the position of the point with temperature T3 in Figure 6 at the interface between tales and concrete inside the floor. All model parameters are listed in Table 6.

Table 6. The model parameters

Parameter	R_{T1} [K/W]	R_{T2} [K/W]	R_{T31} [K/W]	R_{T32} [K/W]
Value	0.00662086	0.0283374	0.00226435	0.0300836
Parameter	C_E [J/K]	C_R [J/K]	C_F [J/K]	
Value	$1.31575 \cdot 10^7$	$8.47332 \cdot 10^5$	$7.60729 \cdot 10^6$	

The air temperature measurements collected during the time period of 21.33 h have been used as time-dependent outside temperature load $T_{out}(t)$ in numerical simulation. During the measurements, the heating system in the building was turned off. The air temperature T_2 for time-dependent loads $T_{out}(t)$ and appropriate initial conditions have been obtained in the complex domain. Utilizing the inverse Laplace transform, the time-dependent room temperature has been obtained in the time domain in the following form:

$$T_2(t) = g * T_{out} + \tau_E \cdot g(t) \cdot T_1(0) + g_1(t) \cdot T_2(0) + g_2(t) \cdot T_3(0);$$

$$g * T_{out} = \int_0^t g(\tau) \cdot T_{out}(t-\tau) \cdot d\tau, \quad (6)$$

where g(t) is the Green function, T1(0), T2(0) , T3(0) are the initial temperatures in the middle of façade wall, inside the room and in the floor construction, respectively. τE is the characteristic time related to the thermal envelope defined as τE = RT2·CE = 103.57 [h]. The initial temperatures used in the simulation had the following values: T1(0) = 16.989 [ºC], T2(0) = 17.5 [ºC], T3(0) = 12.9648 [ºC]. The T2(0) is equal to the initial measurement of the inside air temperature. The values for T1(0) and T3(0) are obtained using the initial measurements for inside and outside air temperatures and assuming the steady-state temperature distribution inside the façade wall and floor at the initial time moment. The functions g1,2 (t) are dimensionless characteristic functions that determine the temperature response to the initial conditions. The integral in the second relation of equations (6) is the convolution integral which determines the influence of time-varying outside temperature loads on the inside temperature variations. In contrast, the last three terms in the first equation represent the response due to the initial conditions. The Green function g(t) has the dimension of reciprocal time, depends only on the thermal characteristics of the observed building structure, and in our case it is given by the following relation:

$$g(t) = g_{01} \cdot exp(-t/\tau_1) + g_{02} \cdot exp(-t/\tau_2) + g_{03} \cdot exp\,(-t/\tau_3), \quad (7)$$

where the numerical values of the constant parameters are listed in the following table.

Table 7. The constant parameters that appear in the Green function

Parameter	*g_{01} [1/h]*	*g_{02} [1/h]*	*g_{03} [1/h]*
Value	*-0.00782131*	*-0.000110488*	*0.0079318*
Parameter	*τ_1 [h]*	*τ_2 [h]*	*τ_3 [h]*
Value	*0.487603*	*4.50222*	*61.1361*

The parameters τ1,2,3 have the dimension of time and represent the characteristic times of the considered building structure. It can be noticed that the last term in the Green functions in equation (7) with parameter τ3 is dominant as other terms decrease much faster. In this way, characteristic time τ3 determines the "thermal inertia" of the whole building structure.

4. RESULTS AND DISCUSSION

In Figure 8, the Green function g(t) multiplied with characteristic time related to thermal envelope τ_E together with functions $g_{1,2}(t)$ are shown. At initial time moment t=0, function $g_1(t)$ must be equal to one due to initial conditions, i.e. at the initial time, the room air temperature T_2 must be equal to $T_2(0)$, on the same time $g_2(0)$ and g(0) must be equal to zero.

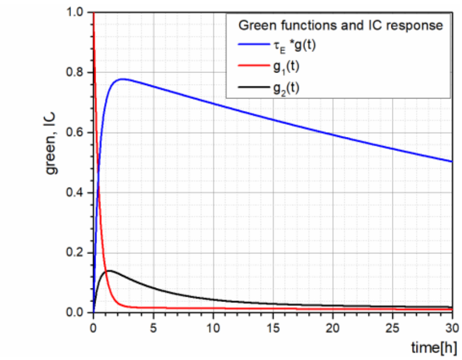
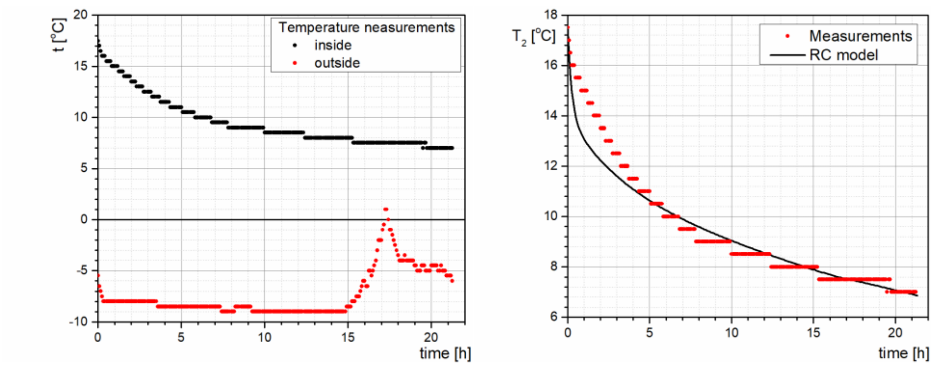


Figure 8. Green function g(t) multiplied with characteristic time τ_E and functions $g_{1,2}(t)$

The convolution integral in equation (6) at the initial moment is equal to zero, which means that the influence of the external temperature loads is not instantaneous. This condition provides that only the third term in equation (6) at the initial time is different from zero and equal to the initial temperature T2(0).



a) b)

Figure 9. a) Inside and outside air temperature measurements, b) comparison between inside air temperature measurements and results from RC model

In Figure 9a are shown the inside and outside air temperature measurements. The temperatures are continuously measured during a time period of 21.33 [h] with a sampling rate of 5 min. It could be noticed that almost all the time during this period, the outside temperature was below 0 [ºC]. As the heating system inside the building was turned off, during this period, the internal temperature continuously decreased from the initial value T2(0)= 17.5 [ºC] to 7 [ºC]. In Figure 9b, the comparison between measured inside air temperature and results obtained by RC simulation have been presented. The maximal deviation of the model prediction from the measurements was 2.09 [ºC] at the time moment equal to 1.16 [h].

5. CONCLUSION

The thermal model for the heat flow in the room on the ground floor of the weekend cottage on Kopaonik under dynamic conditions during the winter period has been developed. The electrical analogy has been used, and an equivalent RC circuit for thermal modelling has been proposed. The model has included all the main parts of the building on the ground floor, including the thermal envelope, floor and interior space of the considered room. The model for the thermal envelope included the façade wall, windows, slope wall and roof construction. All thermal parameters of the models are assumed according to the Domestic Rulebook on the Energy Efficiency of Buildings and to the ISO 13370 international standard [11, 12]. The measured outside time-dependent air temperature has been used as input load. During the measurements, the heating system has been turned off. According to the proposed RC circuit, the inside air temperature has been obtained in the complex domain considering input temperature excitation and initial conditions. The room temperature in the time domain has been obtained using Laplace transformation. The Green function of the system was obtained, and the influence of the external temperature loads has been taken into account through the convolution integral. The three characteristic times, as a measure of “thermal inertia” for the considered system, have been obtained. The characteristic corresponding to the dominant term in the response relation was 61.1361 [h]. The numerical results obtained by the proposed RC circuit have been compared with temperature measurement, and satisfactory agreements are obtained.

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MULTICRITERIA CHOICE OF THE METHOD AND NUMBER OF FIELD TEAMS FOR CONTROL AND REVISION OF THE GEODETIC NETS FOR SURVEYING LOWER ORDER POINTS ON THE TERRITORY OF BELA PALANKA MUNICIPALITY

Nenad Ćirić[1]

Abstract

Design and maintenance of geodetic networks is a complex research process. Such a complex process of planning, design and implementation of a geodetic network requires the optimization of geodetic networks according to several criteria, and among other things, attention must be paid to the organization of geodetic works. To that end, this paper discusses the choice of the number of field teams and methods for faster and more economical control and potential renewal of destroyed points of the geodetic net in the territory in purview of the Real Estate Cadastre Service of Bela Palanka. Seven alternatives and four criterion functions have been defined for solving the specific task. Multicriteria ranking was performed using the MUCOS (MUlticriteria COmpromise Solution) method. Here, two methods with variations in the number of field teams were used to control and revise the geodetic basis. The geodetic net on the territory of the municipality of Bela Palanka includes 13,400 points and all calculations in the paper were performed with regard to this number.

Key words: *design, maintenance, optimization, geodetic networks, MUCOS*

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1. INTRODUCTION

The results of geodetic surveys of the terrain are used in various branches of the economy, as well as for scientific purposes. Thus, survey data are used: for the preparation of spatial plans, economic, statistical, scientific, technical and administrative-legal needs, determining cadastral revenue and other needs of state bodies, institutions, companies, other organizations, citizens and their associations [1]. In order to have data that meet these requirements, it is very important to have quality geodetic networks that are the basis for surveying lower order points, and the basis for collecting the required data. Over time, the points of the geodetic base may become displaced or destroyed, for various reasons, such as: construction, earthquakes, accidents, etc. Namely, after designing and realizing the geodetic net for surveying lower order points (which is done according to the procedure, methods and manner determined in advance, which ensures the designed accuracy), it is necessary to permanently monitor the condition of the geodetic network.

2. METHODOLOGY

2.1. Basic optimization concepts

Optimization is a science whose basics and methods have been known for centuries. However, there was no way for their practical application, primarily due to extensive calculations. The development of optimization as a science was conditioned primarily by the development of computers, which resulted in the fact that optimization practically emerged in the middle of the twentieth century [2]. Optimization is the science that determines the "best" solution to a certain mathematically defined problem [3]. Optimization in the mathematical sense is the search for the extremum of the criterion function under given conditions and constraints.

2.2. Geodetic net for surveying lower order points

One of the basic requirements of today's society is the availability of reliable and accurate data on space, which are important for the functioning of all areas of life. The completeness and exhaustiveness of the information can be achieved on the basis of data collected in the field by various geodetic survey methods (polar, orthogonal, photogrammetry, GPS, ...), which must be organized according to a pre-determined plan and from points of geodetic net. Geodetic networks can have different shapes and purposes, and depending on that, the appropriate name (trigonometric, traverse, polygonometric, elevation, etc.) [4]. The geodetic net for surveying lower order points is composed of: traverse network of the first and second orders, oriented points network as well as additional traverse and linear networks. Depending on the percentage of geodetic points destroyed or non-functional on the territory of one cadastral municipality, it is decided whether to implement a new geodetic net or revise the existing network.

2.3. Methods for restoration and control of a geodetic net

When performing works on control and renewal of geodetic nets, measures of angular and linear parameters or GPS vectors are taken. Depending on that, appropriate measurement methods, terrestrial method and GPS method are used.

2.3.1. Terrestrial method

The measurement of horizontal angles is performed with a classic one-second theodolite, or an electronic theodolite whose resolution of the angular value is 1 ". Lengths are measured on both sides with at least two readings up to a millimeter. Measurement of the height of the instrument and the signal is done up to a centimeter. Data on atmospheric pressure and dry air temperature are taken only at the station for the moment of measurement. In addition to measuring lengths, appropriate zenith distances are also measured.

2.3.2. GPS method

In the reference networks, only phase GPS measurements are performed in static mode, by placing GPS receivers and antennas at traverse points [5]. GPS measurements in the reference network are performed during the day at intervals for which the previous planning determined that they are the most suitable. Atmospheric pressure and air temperature are measured during receiver operation.

2.4. Choice of method and number of field teams

There are some rules to follow when choosing field teams and methods. The number of teams should neither be too great nor too small. Secondly, the number of team members depends on which method is used, and so also the price. Also, when choosing a method of work, one should take into account the equipment that is needed and its price. It is necessary to choose a method whose equipment will be able to be used later when performing works. Among other things, an important factor is the reliability of the method used, because the great importance for performing work within the agreed deadline, depends on the possibility of unobstructed use of equipment and accessories at any time.

2.5. Alternative solutions

Alternative solutions are determined in the form of variant solutions with different numbers of field teams and different work methods. Variant solutions are defined based on the following parameters: works duration time, team members number, equipment, type and number, and method reliability.

The following alternatives are defined:

Seven field teams and GPS method
Five field teams and GPS method
Two field teams and GPS method
Seven field teams and terrestrial method
Five field teams and terrestrial method
Two field teams and terrestrial method
Four field teams, two for GPS method and two for terrestrial method

The group required for work using the GPS method consists of two professionals having high education, and two assistants – rodmen. The equipment needed is: two double frequency GPS receivers with accessories.

The group required for work using the terrestrial method consists of two professionals, and four assistants – rodmen. The equipment needed is: one instrument (total station), tripod, two prisms and two to three appropriate tripods. Daily fee for the geodetic professional with the high education is: 3000,00 din. Daily fee for the geodetic professional with high school education is: 2300,00 din. Daily fee for the rodman is: 1400,00 din. The cost of a total station with tripod + prism with the appropriate tripod: 7500,00e = 885 000,00 din. The cost of double frequency GPS receiver with accessories (antenna and controller): 30 000,00e = 3540000 din.

2.6. **Criterion functions**

The following criterion functions have been adopted for multicriteria optimization:
f_1 - works duration time
f_2 - cost of labor in dinars
f_3 - cost of equipment in dinars
f_4 - reliability of the method for control and revision of the geodetic net.

2.7. **Evaluation of alternatives**

Evaluation of alternatives represents determining values of criteria functions for all alternatives. The geodetic net on the territory of the municipality of Bela Palanka includes 13,400 points and all calculations in the paper were performed with regard to this number.

2.7.1. **Works duration time (f_1)**

The works duration time is expressed in terms of the number of working days (the working day is also obtained by dividing the total working time expressed in hours by eight). Values were obtained based on an estimate of the duration of work for a particular method and the number of field teams

The average time at one station at the total station is 50 min. (when taking into account the work method of, the time of fitting the instrument on the station and repositioning of the rodmen), for the GPS method 30 min. (session duration 20 min. + other). Considering this, the time required for the execution of works by alternatives has been calculated according to the following formula:

$$f_{1_i} = \frac{t \cdot n}{b} \qquad (1)$$

Where:
f_{1_i} - is the number of work days depending on the alternative,
t - time spent on one station for the polar or GPS method expressed in hours,
n - number of points of the geodetic net,
b - number of field teams.
The results are shown in Table 1.

2.7.2. **Cost of labor in dinars (f_2)**

$$f_{2_i} = \left(g_i \cdot c_{g_i} + f_i \cdot c_{f_i}\right) \cdot d_i \qquad (2)$$

Where:

f_{2_i} – is the total cost of labor depending on the alternative,

g_i – number of geodetic professionals,

c_{g_i} – cost of one geodetic professional,

f_i- number of rodmen,

c_{f_i} – cost of one rodman, and

d_i – number of work days required for realization of the alternative.

Results are presented in Table 1.

2.7.3. **Cost of equipment in dinars (f_3)**

$$f_{3_i} = n_i \cdot c_{i_i} \tag{3}$$

Where :

f_{3_i} – is the total cost of the equipment depending on the alternative,

n_i – number of instruments (total stations or GPS receivers),

c_{i_i} – unit cost of equipment in dinars.

Values are provided in Table 1.

2.7.4. **Reliability of the method for control and revision of the geodetic net (f_4)**

Reliability of the method is defined based on the potential of using method at each moment designated for surveying. Implementation of the GPS method requires appropriate conditions for the proper functioning of the equipment. Primarily, optimal arrangement of satellites, correct signal reception, relatively open area around the station, etc. If any of these conditions is not met, the GPS receiver cannot collect data, so the reliability of the system is lower than the terrestrial method whose efficiency depends on a lower number of variables. Numerous values of qualitative criteria are determined on the basis of a linear transformation scale that is generally used in solving multi-attribute decision-making (MAD) models. Results are presented in Table 1.

Table 1. Values of criterion functions

Multicriterial optimization problem	*Quantitative criteria*			*Qualitative criterion*
	f_1-works duration time	*f_2-cost of labour*	*f_3-cost of equipment*	*f_4-quality grade*
Ext	*min*	*min*	*min*	*max*
Alternative, Ai	*(days)*	*(mil. din)*	*(mil.din)*	*(-)*
A1 - GPS (7)	*120*	*7.3920*	*49.560*	*7*
A2 - GPS(5)	*168*	*7.3920*	*35.400*	*7*
A3 - GPS(2)	*419*	*7.3744*	*14.160*	*7*
A4 – Terrestrial TS (7)	*200*	*14.2800*	*6.195*	*9*
A5 - Terrestrial TS(5)	*280*	*14.2800*	*4.425*	*9*
A6 - Terrestrial TS(2)	*698*	*14.2392*	*1.770*	*9*
A7 - Terrestrial TS(2)+ GPS(2)	*262*	*9.9560*	*15.930*	*8*

2.8. Mucos

In this paper, the method MUCOS - Multi-criteria Compromise Ranking or Multi-criteria Compromise Solution (VIKOR – VIšekriterijumsko Kompromisno Rešenje in serbian) was used.

Table 2. Algoritham of MUCOS

Algoritham of MUCOS step by step	
$f_i^* = ext_j f_{ij}$ (i=1,...,n)	*Ideal point definition*
$d_{ij} = \frac{f_i^* - f_{ij}}{f_i^* - f_i^-}$, i=1, ..., n; j=1, ..., J	*Transformation of heterogeneous criteria functions*
ω_i	*Setting weights*
υ	*The value of υ is given in the MUCOS software package itself (υ = 0.5)*
$S_j = \sum_{i=1}^{n} \omega_i d_{ij}$, $R_j = \max_i [\omega_i d_{ij}]$, $Q_j = \upsilon \times QS_j + (1-\upsilon) \times QR_j$	*determination of measures for ranking purposes*
$QS_j = (S_j - S^*)/(S^- - S^*)$ $QR_j = (R_j - R^*)/(R^- - R^*)$	*ranking*
$U1, U2$	*Compromise solution*
$q_1\omega_i \leq \omega_i \leq q_2\omega_i$	*Definition of stability interval*

2.9. Evaluation of quality criterion and weight coefficients of criterion functions

By changing the numerical value that characterizes the reliability of the method for control and revision of the geodetic net when using the GPS method in the range of 5 to 7 and changing the same quantifier for the case when the terrestrial method was used in the range from 8 to 10, i.e. in the range from 7 to 9 for the combination of GPS and terrestrial method, the sensitivity of the compromise solution (A7) to the change of the qualitative criterion (f_4) was tested. Since the structure of the decision maker's preference is not known, various combinations of weight values are given, assuming possible preference structures:

$$\omega_1 = \omega_2 = \omega_3 = \omega_4 = 1$$

$\omega_1 = \omega_4 = 1, \omega_2 = \omega_3 = 2$
$\omega_1 = \omega_4 = 2, \omega_2 = \omega_3 = 1$
$\omega_1 = 4, \omega_2 = 3, \omega_3 = 2, \omega_4 = 1$
$\omega_1 = \omega_2 = 2, \omega_3 = \omega_4 = 1$
$\omega_1 = 1, \omega_2 = 2, \omega_3 = 3, \omega_4 = 4$

3. RESULTS

Ranking was performed for different values of the qualitative criterion and with the weights of the criterion functions from section 2.9.

3.1. Numerical values of the qualitative criterion

GPS-7, terrestrial-9, combinaiton-8 A7, A4, A5, A3, A2, A6, A1 (advantage 37.3%)
GPS-6, terrestrial-9, combination-8 A7, A4, A5, A3, A2, A6, A1 (advantage 48.2%)
GPS-7, terrestrial-9, combination-9 A7, A4, A5, A3, A2, A6, A1 (advantage 63.9%)
GPS-7, terrestrial-10, combination-8 A7, A4, A5, A3, A2, A6, A1 (advantage 26.1%)
GPS-6, terrestrial-8, combination-9 A7, A4, A5, A3, A2, A1, A6 (advantage 72.4%)
GPS-5, terrestrial-9, combination-7 A7, A4, A5, A3, A2, A6, A1 (advantage 37.3%)

Based on the results obtained by the MUCOS program, it was obtained that the alternative A7 is a compromise solution.

3.2. Criteria function weights

For the first combination of weights A7, A4, A5, A3, A2, A6, A1 (advantage 37.3%), compromise solution is alternative A7.

For the second combination of weights A7, A3, A2, A4, A5, A6, A1 (advantage 37.8%), compromise solution is alternative A7.

For the third combination of weights A4, A5, A7, A2, A6, A1, A3 (advantage 6.4% and 27.8%), the solution is a set of compromise solutions {A4, A5}.

For the fourth combination of weights A2, A1, A3, A7, A4, A5, A6 (advantage 14.5% and 8.2% and 19.2%), the solution is a set of compromise solutions {A2, A1, A3}.

For the fifth combination of weights A2, A1, A3, A7, A4, A5, A6 (advantage 3.2% and 8.5% and 6.9%), the solution is a set of compromise solutions {A2, A1, A3, A7}.

For the sixth combination of weightsA7, A4, A5, A6, A3, A2, A1 (advantage 30.6%), compromise solution is alternative A7.

4. DISCUSSION

According to the values obtained by applying the MUCOS method, it can be noticed that different sets of alternatives appear as a compromise solution.

If equal importance is given to all criteria, the analysis of MUCOS results shows that there is a stable compromise solution, so the alternative A7 is proposed for making a final decision.

If more importance is given to costs, in the sense that for the planned works on control and revision of the geodetic net for surveying lower order points, the financial factor has an important role, meaning that the works should be done with as little material costs as possible. In that case, the only compromise solution is an alternative A7.

In case preference is given to the duration of works and reliability, then there is no stable compromise solution and it is suggested that in the next stages of decision-making, variant A4 is considered and A5.

When the greatest importance is given to the duration of works and the least to reliability, there is no single compromise solution, but it is proposed to choose it from a set of compromise solutions A2, A1 and A3, and to define the most favorable solution based on the additional data.

If greater importance is given to the duration of works and the labor cost, there is no single compromise solution, but it is proposed to choose it from a set of compromise solutions A2, A1, A3 and A7.

There is a single solution for assigning the highest weight of reliability and the lowest duration of work, and that is an alternative A7.

Also, the interval in which the numerical value of the qualitative criterion, ie. the reliability of the method for control and renewal of the geodetic net can be changed so that the compromise solution is not changed. For the following ranges of the interval of the qualitative criterion: for GPS method 5-7, terrestrial method 8-10 and combination of GPS and terrestrial method 7-9, it was obtained that the compromise solution is A7 alternative.

The method proposed as a compromise solution for control and revision of the geodetic net for recording details in the municipality of Bela Palanka, and taking into account qualitative and quantitative criteria, is alternative A7 - four field teams, two for the GPS method and two for the terrestrial method.

5. CONCLUSION

Based on all the above, it can be said that Multi-criteria Optimization is applicable and usable for solving more complex problems where the solution depends on a large number of factors, whose impact cannot be realistically considered without the application of an adequate analysis. Regarding geodesy, in addition to the optimization of geodetic networks [6]-[9], which is mathematically defined and for which there are clear guidelines (accuracy, precision, reliability, sensitivity), attention should certainly be paid to optimizing the organization of geodetic works. Creating a project for the organization of geodetic works requires prior study of all conditions under which the work will be performed, then solving optimization tasks in terms of choosing the method of work, instruments and accessories, labor, division of labor, calculation of the duration of each type of work, determining the dynamics of work, setting priorities, spending funds, etc.

Therefore, there is a place and above all a need for the application of Multicriteria Optimization in the organization of geodetic works. Finding the optimal solution when organizing the execution of geodetic works should be an obligation, and multi-criteria optimization is a way to achieve that goal.

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NATURAL AND TECHNOLOGICAL HAZARDS – LIMITING FACTORS IN URBAN AND SPATIAL PLANNING

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Abstract

Natural and technological hazards as extreme phenomena are associated with high levels of damage to natural and urban environments, sometimes associated with life losses. From practice, it is evident that they are a limiting factor in spatial and urban planning, but neglecting them can lead to real disasters. To avoid the negative effects, appropriate urban planning is of primary importance. In that sense, the main goal is to minimize fatalities and reduce the other tangible and intangible losses.

In the frame of the article, we present applied methodology in zonation and modeling of hazards for the area of Macedonian capital Skopje. The analyses are part of one of the studies prepared for the Master plan of the city of Skopje for the period 2022 – 2032.

The terrain suitability for urbanization is related to engineering-geological conditions, ground slope, groundwater level, seismicity, erosion, flood hazards, landslide susceptibility and excavation conditions. The basics of the polynomial interpolation method for extrapolation of selected parameters for zonation are explained.

This study also demonstrates the use of GIS tools for effective data analysis and the possibility of producing various thematic maps using ArcGIS software.

As a result of detailed analyses, besides individual maps of seismic micro zonation, flooding, and erosion, a Final Scoring and Multi-Hazard Maps are prepared, representing the sum of hazard influences over the analyzed area.

In order to achieve efficient communication and to ensure wider consensus between persons and institutions involved in urban and spatial planning, the authors suggest the implementation of the qualitative interaction matrix method. This method can help define roles of all involved parties, in choosing protective systems that will ensure reducing all damages and possible post-recovery costs.

Keywords: *GIS, hazard, polynomial interpolation method, zoning, urban planning, suitability maps, qualitative interaction matrix method*

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1. INTRODUCTION

Well known fact is, that natural and technological hazards as extreme phenomena, are associated with high levels of damage to the natural and urban environment. The importance of this phenomenon's can be underlined, just by mentioning the fact that floods and landslides on average produced yearly damage, of about 50 billion US dollars or 40 000 human lives, and that from 1900—1976, out of a total of 4.8 million were killed in all natural disasters [1].

Having this in mind, it is essential to find a methodology that can help in reducing their influences to an acceptable level. In this sense, in the frame of this article, we are presenting some elements of applied methodology in hazard zonation for the area of the Macedonian capital Skopje. The analyses are part of the studies prepared for the Master plan of the city of Skopje for the period 2022 – 2032 [2].

Such kind of analyses are of primary importance, knowing that Skopje suffers a lot from natural hazards. For example, in an earthquake in 1963, more than 1100 citizens lost their life. Several flood events in 1962, 1979 and 2016 are also important. For example, in August 2016 heavy torrential rain affected the country's capital suburbs, causing tragic loss of 23 lives and an estimated cost of over 30 million EUR. The result was severely damaged infrastructure, affected agricultural land, occurrences of several landslides in the catchment area etc. The Hydrometeorological Service measured 92.9 mm of rain that fell in just a few hours, which is considered an event with a return period of 1,000 years.

From the aspect of technogenic hazards, several factors are also very important. Point and diffuse pollution from some waste disposal areas, cement factory in city area, some heavy industry complexes etc. can have a possible influence on water supply resources, air and soil pollution.

To minimize the impact of natural and technological hazards, one of the steps is to define vulnerable zones in an area to their impact. Here, we are presenting a methodology based mainly on GIS analyses to solve these issues. Using the software ArcGIS, a lot of thematic maps are prepared. Used steps are: detailed analysis of available literature, data from all kinds of geological, engineering-geological, hydrogeological, seismic and other ground investigations, application of specific principles for site zoning and the right selection of various qualitative and quantitative parameters, etc. More than 100 combinations of different maps for erosion protection, landslide hazard, flooding protection, engineering-geological and hydrogeological conditions, bearing capacity maps, etc. are prepared.

The complexity of the process clearly shows that such methodology can be useful as a decision tool and can help to ensure a wider consensus of all involved parties in urban and spatial planning. In this sense, the authors suggest using and implementing of qualitative interaction matrix method for solving problems in urban and spatial planning. The Interaction Matrix Method (IMM) is an approach first introduced in the development of so-called Rock Engineering Systems (RES) by J.A. Hudson [3]. Authors implemented this method also for problems of Applied Hydrogeology, tailing dams and other engineering problems [4] and [5]. The methods are based on demonstrating the links between necessary parameters for some analyzed cases. The entire concept provides coherency when there is need to study the interactions of some elements in a system.

2. METHODOLOGY

The methodology for the determination of influences of natural and technological hazards on the suitability for urbanization is based on several main steps. The first one is to select the main evaluation factors affecting the urbanization of a given area. In this case, the most important factors are considered to be: the Lithological type (LT), Slope Angle (SA), Ground Water Level (GWL), Seismic Intensity (SI) and Excavation Conditions (EC). Details for the methodology can be found in Nedelkovska et al., 2017 [6]. For each of the selected factors, a so-called "rating" has been assigned, depending on their influence on urbanization suitability, and as a result of analyses, the different thematic maps are prepared as separate layers in the GIS environment. In the frame of this article, we suggest following classification of prepared maps:

Maps for general prognosis of conditions for urbanization (Figure 1 and Figure 2).

Maps for design calculations of structures from earthquake, flood, erosion and landslide influences.

Multi-hazard maps.

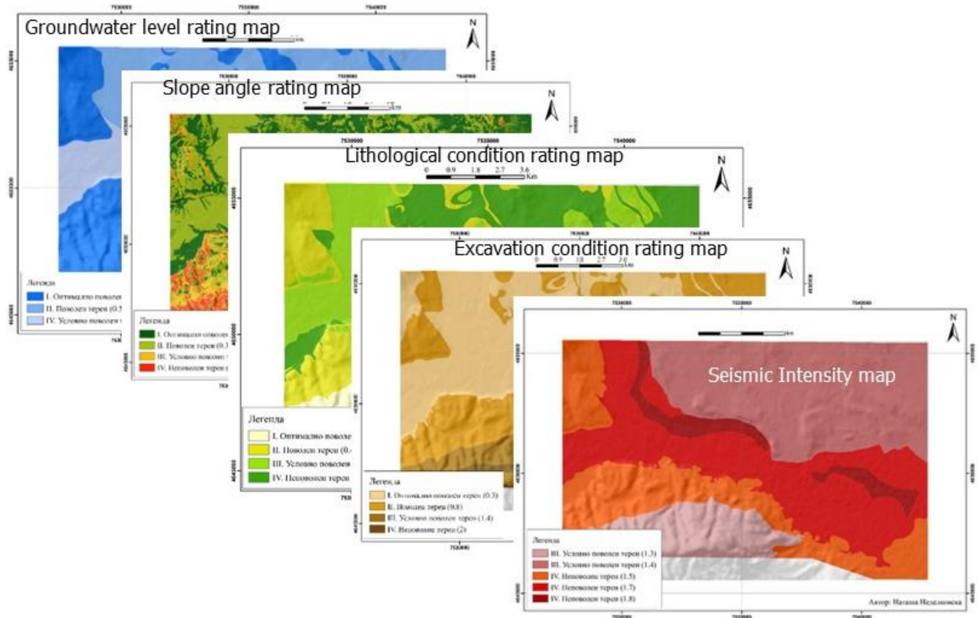

Figure 1. Schematic presentations of thematic rating maps for individual parameters used in the preparation of urbanization suitability map for the Skopje area

The factors are connected to the corresponding ratings in a continuous way, using Polynomial Interpolation Method (PIM). The main idea in developing this method is to find a way to establish analytical correlations between any value of a factor and its rating, which can later serve for easier GIS calculations. In the proposed methodology, all the factors have the same value for the maximum rating (Table 1). The maximum possible Total Urbanization Suitability Rating (TUSR) is 10, where lesser rating means greater suitability.

Table 1. Maximum values of ratings for main evaluation factors

Evaluation factor	*Maximum rating*
LT	*2*
SA	*2*
GWL	*2*
SI	*2*
EC	*2*
Total (TUSR)	*10*

The authors consider that all used factors, more or less, are equally important when determining the urbanization suitability of the terrain, and for each of them, four terrain categories are used, in the following manner: optimally favorable, favorable, conditionally favorable and unfavorable terrain for urbanization. For all cases, correlations are established between values of evaluation factors and their ratings, presented with the following equations [6]:

$$SA - R = 0.0017SA^2 + 0.0145SA - 005 \quad (1)$$
$$GWL - R = 0.001GWL^2 - 0.3073GWL + 2.311 \quad (2)$$
$$SI - R = 0.0131SI^2 - 0.0701SI + 0.077 \quad (3)$$
$$EC - R = -9e^5 ERMR^2 - 0.0286\, ERMR + 0.0117 \quad (4)$$

where: SA-R, GWL-R, SI-R, and EC-R are calculated ratings for any value of the individual evaluation factors.

Important element in analyses is the fact that natural and technological hazards does not recognize municipality borders, so in urban and spatial planning almost in all analyses, the urban areas shall be developed in correlation of contact zones with rural environment, taking in consideration protected zones and possible contaminated areas from technological sources.

3. RESULTS

The main goal of the research was to determine zones that have similar conditions for construction, and to differentiate highly vulnerable zones in terms of natural hazards. Besides a separate thematic map for each factor presented in Figure 1, overlaying of individual thematic maps in ArcGIS, a Final Scoring Map is also prepared (Figure 2). A statistical overview of the data and the presence of each urbanization suitability category in percentage is presented in the left upper corner in Figure 2. Because of the fact that Skopje is a seismically active area and an area prone to floods, it is evident that urbanization suitability maps are only the first approach in the preparation of urban and spatial plans. They cannot be used directly in calculations of structures stability, robustness and serviceability from seismic, flood erosion or landslide protection aspects. For this purpose, specific additional analyses are necessary, and the use of data from special thematic maps is necessary. Some of them are presented in the following figures.

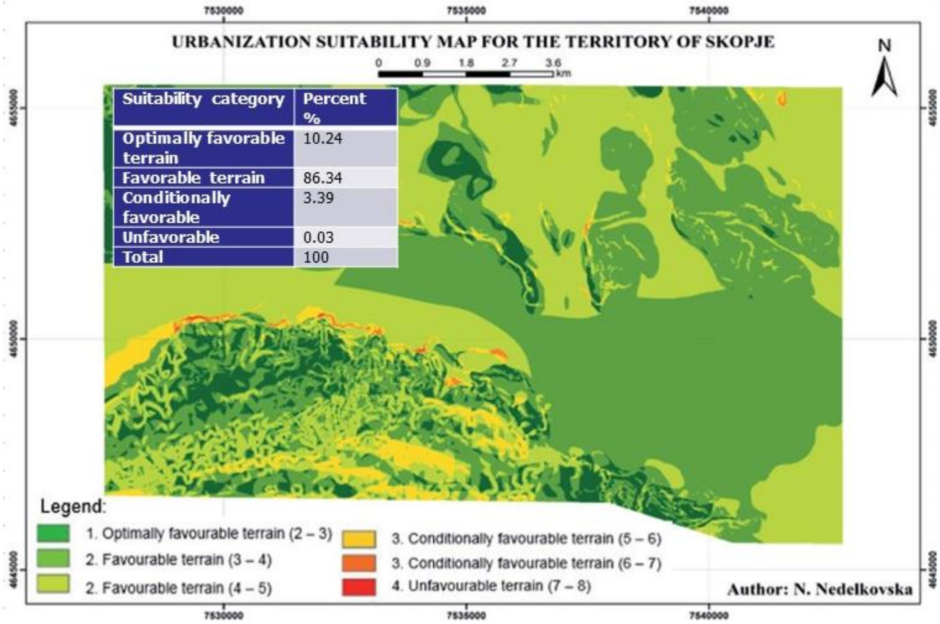

Figure 2. Urbanization suitability map for the territory of Skopje

For example, areas with known active landslide and erosion phenomena are presented in Figure 3.

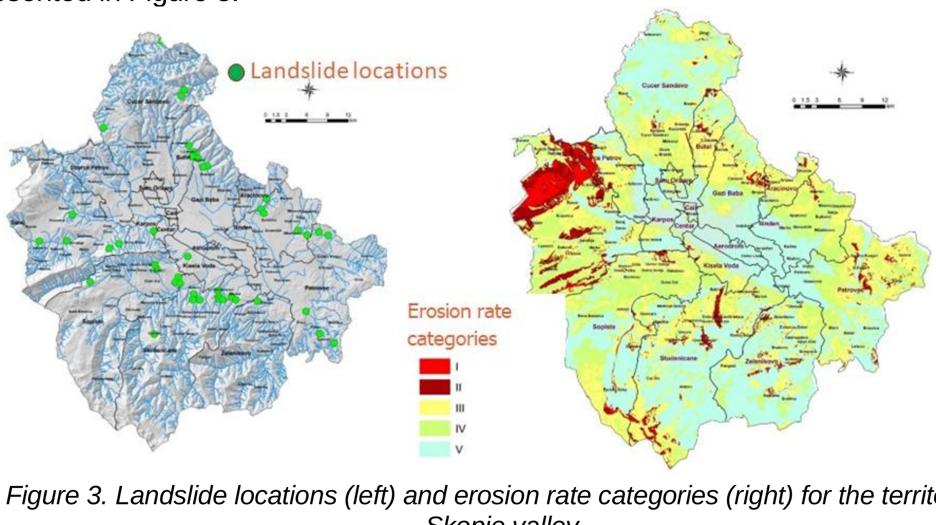

Figure 3. Landslide locations (left) and erosion rate categories (right) for the territory of Skopje valley

Floods are among the natural hazards with the highest risk in Skopje valley, and a lot of attention is given to these phenomena, by developing several scenarios. One of possible scenarios of flooding is presented in Figure 4.

Another limiting factor is the seismicity of the area. Before the catastrophic earthquake in 1963, poor attention has been paid to aseismic designing in the country, but the lessons learned from the earthquake led to intensive geological, geotechnical and seismic investigations and the preparation of seismic micro zonation maps.

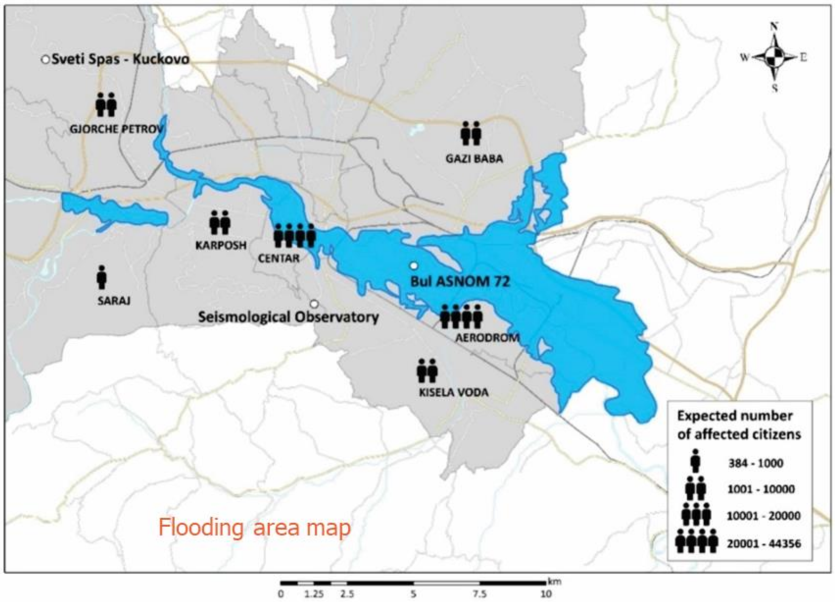

Figure 4. Flooding map of the Skopje area, scenario for a return period of 10 000 years

Using approaches from Eurocode 8, Mirakovski et al., 2011, prepared a series of maps with expected accelerations for different damping factor return periods of 95, 145, 475, 975 and 2475 years respectively [7].

One example is presented in Figure 5.

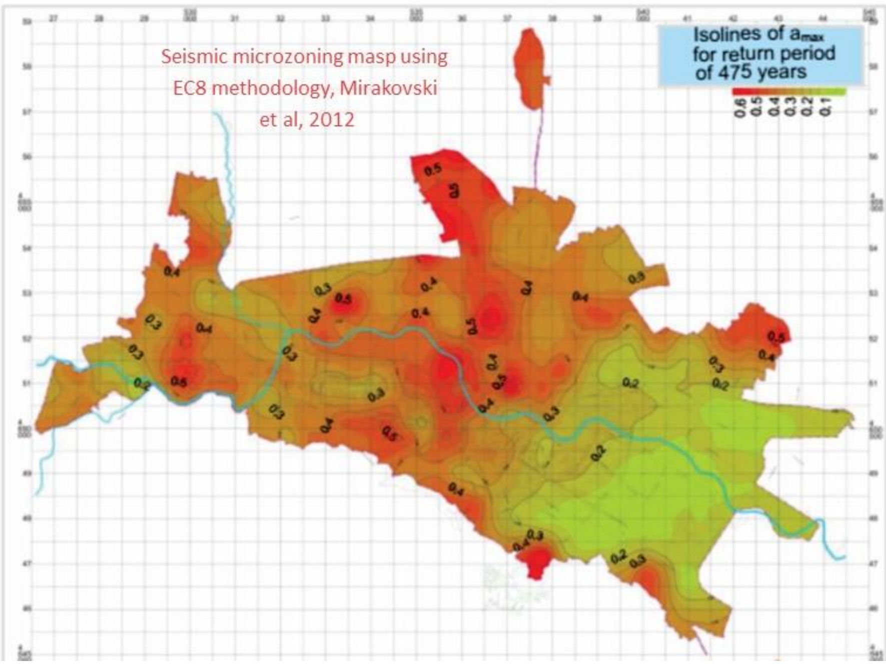

Figure 5. Isolines of peak ground acceleration amax for a return period of 475 years[7]

It is visible that in a large part of the urban area, expected ground accelerations are higher than 0.3g. This certainly leads to the necessity of the application of seismic design rules and codes for all structures.

Another important step is to define overall susceptibility to natural hazards in certain area. Due to the highest frequency of floodings, followed by seismic hazards and soil erosion, one “simple” multi-hazard map is presented in Figure 6. It is obvious, that all urban area and contact zone with sub-urban areas are susceptible to erosion, floods and earthquakes.

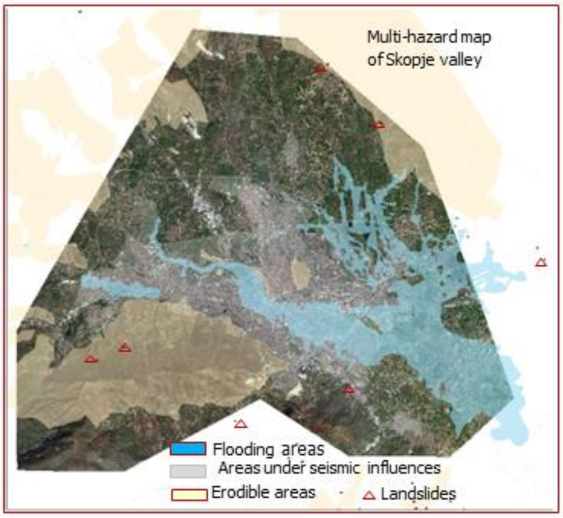

Figure 6 Simplified multi-hazard map of Skopje valley

Another important in planning is to preserve protected areas from influences of several “hot-spots” (Figure 7). Here, groundwater sources as Rasche spring, zone of wells Lepenec and Banjani spring marked in Figure 7 are of primary importance.

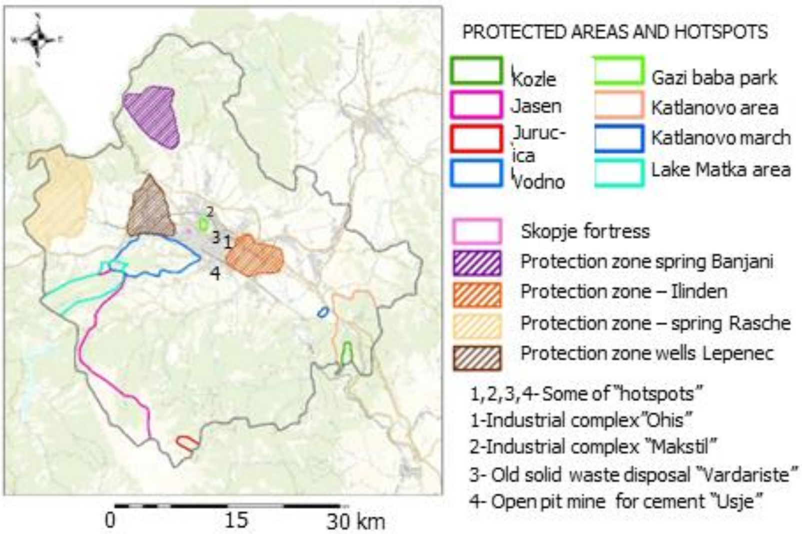

Figure 7. Protected areas in Skopje valley and some of industrial hot spots as a limiting factor for urban development.

4. DISCUSSION

Obtained results show that application of GIS-based analysis has many advantages, because of easy data manipulation, rapid data update and the possibility to produce various new hazard and risk scenarios. This is significant for the local community and all institutions dealing with environmental protection and emergency management.

It is worth mentioning that this cannot be achieved if there is no good coordination and cooperation among all stakeholders in the process of urban and spatial planning. Rational and efficient designing of resilient structures and protective measures for minimizing hazard influences is not possible without knowing in detail the complex geological, hydrogeological, geotechnical, hydrological and other conditions in the environment. This requires constant and systematic investment in environmental protection, design and construction based on the consistent application of design codes, systematic maintenance of buildings and, if necessary, remediation. Responsible authorities dealing with spatial and urban planning are the most important link that must find a way to connect and unite these requirements.

It seems that Interaction Matrix Method (IMM) can help in solving complex mutual interferences between all these elements. Here, we will present one approach to integrating all relevant aspects in the form of a qualitative interaction matrix (Figure 8).

Factor 1 Urban and spatial planners	Interaction 1,2 Urban and spatial planners ask for experts dealing with hazard data for earthquakes, floods, landslides, erosion etc.	Interaction 1,3 Urban and spatial planners ask decision-makers and investors for their plans for spatial development for some period
Interaction 2,1 Experts dealing with hazards present data in front of planners and suggest necessary protective measures	**Factor 2** Experts dealing with natural and technogenic hazards (Geologists, seismologists, Geotechnical engineers etc.)	Interaction 2,3 Experts dealing with hazards present data in front of investors, to present possible limitations and necessary protective measures
Interaction 3,1 Decision makers present in front of urban and spatial planners their needs and expectations, possible time-frame, and investment plans	Interaction 3,2 Decision makers present Terms of References, acceptable level of risk, codes to be followed etc. in front of experts	**Factor 3** Decision makers (State and Municipality Institutions, Investors etc.)

Figure 8 Conceptual qualitative interaction matrix between three basic factors F1, F2, F3 in urban and spatial planning

These factors are involved mutually, in 6 basic kinds of interaction. Defined interactions in a qualitative manner are a good basis for complex analytical and numerical analyses, where the interactions can be defined with all necessary outputs from urban and spatial planning documents. Some of the outputs can be the design of safe and resilient structures, protection of some specific areas, stability of the surrounding geological media, groundwater pollution etc. All this is necessary in order to define investment plans for short and medium time periods. The completed risk assessment will provide the basis for the disaster resilience strategy. It seems, that to achieve goals of Smart Cities, one of the main needs is to establish effective alarm, warning and forecasting Early Warning Systems as *,,the set of capacities needed to generate and disseminate timely and meaningful warning information to enable individuals, communities and organizations threatened by a hazard to prepare and to act appropriately and in sufficient time to reduce the possibility of harm or loss"* [8].

Detailed analyses of this aspects overcome the frame of the article.

5. CONCLUSIONS

The analyses in this article clearly show that for successful spatial and urban planning, it is necessary to get acquainted in detail with the natural and technogenic hazards. Estimating the potential impacts requires analysis of previous events, and incorporating the findings using existing modern modeling methods.

State and Public enterprises dealing with spatial and urban planning and nature protection, in cooperation with the institutions, should be involved in the process of standardization and implementation of the multi-hazard methodologies in monitoring and identification of natural disasters at a local and regional scale.

The complexity of the process clearly shows that such methodology can be useful as a decision tool and can help to ensure a wider consensus of all involved parties in urban and spatial planning.

The main conclusion is that the Interaction Matrix Method is one of the possible approaches and some kind of philosophy for solving complex urban planning and engineering problems. The authors believe that this concept can be used separately for each project, in order to establish a way for defining all influential factors, with the main idea, to achieve the main goal – living in a friendly and safe environment.

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THE INFLUENCE OF GENERATIVE DESIGN ON THE PROCESS OF ARCHITECTURAL SPACE PLANNING

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Abstract

The process of architectural design involves the architect's thoughtful approach to the problem, the means, and the procedures employed during the design phase. The journey from the initial idea to the final project is long and challenging. The inherent difficulty in design lies in the essence of decision-making, where numerous choices need to be made, and any change can have a cascading effect on various other elements, necessitating a thoughtful balance of benefits and compromises. These choices come in various forms, each demanding extensive study or contemplation to arrive at the most suitable option. In this phase, the concept of generative design in architecture is increasingly emerging.

The generative design combines parametric design and artificial intelligence along with data, constraints, and goals provided by the architect, enabling the simultaneous creation of numerous solutions and, at times, even discovering "happy accidents" or unique and unforeseen solutions that would be challenging to uncover using traditional methods. For the selection of the final solution, multi-objective optimization stands out as a powerful tool for decision-making in complex systems where multiple objectives must be taken into account simultaneously.

The objective of this study is to expedite and simplify the architect's work in the process of architectural space planning by implementing the generative design with multi-objective optimization. This will be achieved through a comparative analysis of the process of architectural space planning and generative design, conducted by studying their respective phases, identifying common characteristics, and differences, and exploring possibilities of mutual integration.

Key words: *generative design, multi-objective optimization, space planning, architectural design process, analysis*

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1. INTRODUCTION

Design is a complex activity that requires artistic creativity while also relying on scientific and technological knowledge. Architectural planning, as a creative process, is considered extremely complex due to several reasons:

- Lengthy and demanding path: The journey from the initial idea to the final project in architecture takes time and effort. Architects face making countless decisions, where each change can impact many other elements. Moreover, there are always defined deadlines during each project, and clients often rush, leaving limited time for thoughtful consideration of every possible combination or precise adequacy of each decision [1].
- Considering different aspects with associated parameters, constraints, and goals: Architectural planning involves decision-making regarding numerous aspects such as sustainability, aesthetics, costs, spatial requirements, user needs, etc. [2].
- Duality of subjectivity and objectivity: Architects grapple with balancing subjective and objective factors when making decisions. They must consider client requirements, regulations, and other factors while simultaneously striving for creative solutions.
- The architect's inner world: In the decision-making process, the architect's inner thoughts, knowledge, experience, feelings, affinities, and ambitions play a crucial role, contributing to the architectural planning process and decision-making.

A common characteristic of the aforementioned reasons is that architects make decisions that concern the future. Formulating a design methodology and applying scientific methods can be helpful in defining the design process and aiding decision-making. Many design methods aim to establish analogical connections with scientific methodological procedures, using similar fundamental steps such as problem identification and description, hypothesis setting, research and drawing consequences from hypotheses, finding problem solutions, and formulating guidelines for their application. Design methodology provides tools to help designers efficiently navigate all stages of the architectural planning process, offering a choice of various methods that can be adapted according to their preferences.

Over the past fifty years, particular emphasis has been placed on the development of design methods, especially in architecture. This research has focused on reducing subjectivity in design, more efficient application of scientific knowledge, and productive use of information technology [3]. The goal has been to improve the design process and outcomes, with a specific focus on adding structure to design decision-making. Many methods, such as Analogous, Attribute Listing, TRIZ, Brainstorming, Mind Maps, and Biomimicry, provide designers with useful tools in the idea-generation phase of the design process [4].

In recent decades, new perspectives and approaches with the potential to transform the design process have been developed. One of these approaches is generative design, applied in the early stages of the design process to explore various concepts and expand design horizons. The generative design allows for the simultaneous generation of multiple solutions and the discovery of new, unconventional ideas that might be difficult to access through traditional methods [5].

It relies on parametric design, artificial intelligence, and search algorithms to intelligently adapt and explore different possibilities within the design space.

Expanding the architect's knowledge and creating powerful design alternatives through generative design contribute to saving design time, increasing process flexibility, considering various aspects with associated parameters, constraints, and goals, and adopting a more objective approach to decision-making [6]. However, every architectural project involves conflicting objectives related to, for example, construction costs, investor profits, work quality, and construction time. Defining these factors is crucial when considering design. The primary task of architects is to find the ideal balance between different objectives, as achieving multiple objectives and overcoming conflicting interests can create architecture that benefits both its users and society as a whole. The application of generative design and multi-objective optimization can be crucial in making such decisions, as this mathematical optimization technique aims to find a set of solutions known as the Pareto front, representing a balance between different objectives [7-9]. The advantages of this optimization in architectural planning include simultaneous consideration of multiple objectives, finding compromises, efficient exploration of design space, constraints, and preferences, better-informed decisions, and increased innovation and creativity.

This research analyzes the impact of generative design and multi-objective optimization on the architectural planning process, focusing on the analysis of its phases and the application of generative design with multi-objective optimization. A comparative analysis was conducted to determine the contributions of these approaches to the efficiency of architectural planning and to facilitate the work of architects and their collaborators in the future. The research results point to potential benefits in the creative process, improved decision-making efficiency, and better results in achieving multiple architectural project objectives. This study provides valuable insights into the possibilities of applying generative design and multi-objective optimization in the architectural context and can serve as a guideline for further research and advancement of approaches in the future. Through this research, new perspectives are opened in the field of architectural planning, and the results are expected to contribute to improving the quality of architectural solutions and the overall design process.

2. METHODOLOGY

The research has the following methodology (Figure 1):

- Analyzing architectural design process: determination of all phases in this design process with associated elements by analysis and synthesis;
- Analyzing generative design process with multi-objective optimization: determination of all phases in this design process with associated elements by analysis and synthesis and
- Comparative analysis and determination of possible correlation of these designs.

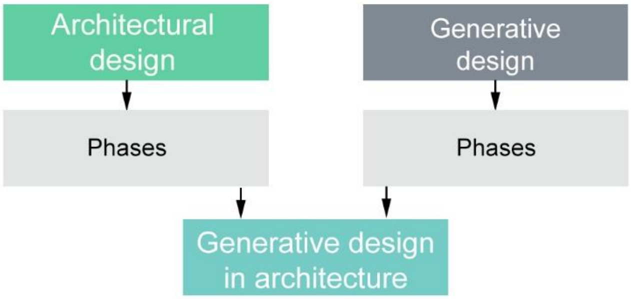

Figure 1. Research methodology, illustration of the author's team

2.1. Phases in the architectural space planning process

Approaches to understanding and organizing the design process itself have evolved over the years. Each of these approaches emphasizes different phases and aspects of the design process, providing diverse perspectives on how designers think and create their solutions.

One of the early models of the design process was proposed by Bruce Archer, emphasizing that the design process should combine intuition and knowledge, and the formalization of the creative process should aim to transform it into a scientifically-based practice [10]. Thus, the design process should be divided into the analytical, creative, and executive phases with different approaches - systematic observation and inductive reasoning in the analytical phase, and subjective and deductive reasoning in the creative phase. These phases are characteristic of the design process in the 1960s.

Architects from The Royal Institute of British Architects (RIBA) presented a design process map with four phases in the publication "Architectural Practice and Management Handbook" [11]: assimilation (collecting and organizing general information and information specifically related to the current problem), general study (examining the nature of the problem, possible solutions, or means of solution), development (elaboration and improvement of one or more temporary solutions isolated during the previous phase), and communication (communication of one or more solutions to people within or outside the design team). The RIBA guide is very candid here, emphasizing that there will be unpredictable jumps and feedback between these four phases.

Academics Markus Tom [12] and Maver Tom [13] have contributed to understanding the architectural design process through the development of complex maps and approaches. They highlight that a complete understanding of the design method requires considering the "sequence of decision-making" and the "design process" or "morphology". The "sequence of decision-making" refers to the steps that a designer takes in the process of analysis, synthesis, evaluation, and decision-making. It is a sequence of activities carried out to understand the issue, generate solutions, evaluate their value, and ultimately select the best solution. The "sequence of decision-making" can be observed as a gradual process that occurs at increasingly detailed levels. It starts with problem analysis and the collection of relevant information. Then it moves to synthesis, where different solutions that meet identified requirements are generated. After that, an evaluation of the generated solutions takes place to choose the one that best fits the set goals. This cycle can be repeated to improve and optimize solutions. On the other hand, the "design process" or "morphology" refers to a broader consideration of the architectural process and approach. This aspect involves contemplating different methods, theories, approaches, and strategies that designers can apply throughout the entire design process. It includes considering various styles, technical aspects, creative techniques, and approaches that can shape the final design.

Darke's map [14] emphasizes the significance of the "primary generator" in the design process. Instead of the traditional approach of analysis-synthesis, Darke suggests that the designer first identifies an important aspect of the problem that will serve as the primary generator of ideas. Based on that generator, the designer develops a rough sketch or conceptual design. Then, the designer analyzes that design to learn more about the problem and discover other possibilities and implications. This approach encourages creativity and originality in the design process, as designers use their assumptions, values, and perspectives as a basis for generating ideas. It can lead to different and innovative solutions for various problems. The assumptions and paradigms of designers play a crucial role in shaping and guiding the design process.

Broadbent's model of the design process [15], which includes assumptions, is a significant contribution to understanding how designers shape their solutions. Assumptions play a crucial role as the starting point for the design process, as they influence how the designer thinks about the problem and approaches its solution. The first phase in this model is setting assumptions, which includes the architect's philosophy, aesthetics, previous experiences, or other factors that shape their approach to design. The assumption provides guidelines and a framework for everything that will follow in the process. After setting the assumption, the designer moves to analysis. This phase involves researching the problem, identifying requirements, and gathering relevant data. The analysis is shaped according to the assumption, meaning it will influence how the designer understands the problem and sets design goals. The next phase is synthesis, where possible solutions that match the established assumption are generated. In this phase, the designer may use analogies and canonical methods as additional tactics for generating ideas. After generating possible solutions, the evaluation phase comes, where each solution is assessed against the set goals and requirements. Evaluation is done in line with the assumption and enables the designer to choose the best solution that fits its framework. This model helps in understanding how creativity, analysis, and evaluation are interconnected and integrated into the design process.

Petrović Ivan [16] identifies two distinct models of the design process, each with its characteristics and approaches. The first model is characterized by a linear project sequence and is used to solve technical problems. This model is often applied in situations where there is a clear and well-defined problem, such as in engineering projects. Petrović's first model consists of problem definition, solution creation, and assessment and selection of solutions. The second model is characterized by a circular project sequence, which better reflects the dynamism and disorder of the design process in a real environment. This model is suitable for situations where the problem is not sufficiently defined or is variable, as is often the case in architectural projects. Petrović's second model includes determining the purpose of the design, setting goals, collecting data for design, creating alternative solutions, and selecting a solution. It is important to note that the second model allows flexibility in decision-making and enables the designer to adapt to changing conditions and new information that arises during the design process.

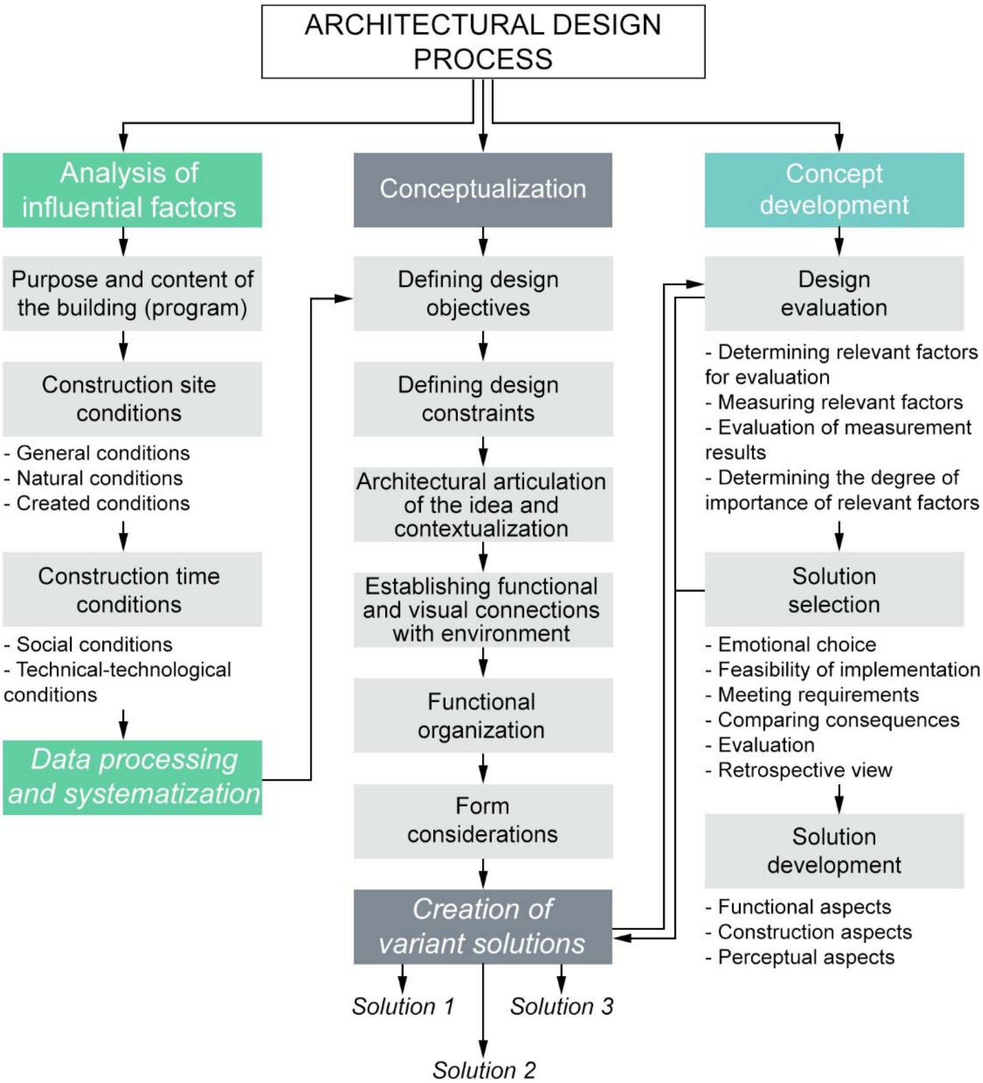

Figure 2. A general model of the architectural space planning process and grouping of activities by phases, according to [17]

According to Nikolić Marko and Brzaković Milan, the design process consists of three main stages: impact analysis, conceptualization, and concept development (Figure 2) [17]. Data collection is a crucial step in understanding the project task and setting guidelines. The architectural concept involves clearly defining project goals and considering limiting factors such as legal regulations and available resources. It is essential to develop alternative solutions to test the validity of initial assumptions and concepts. These alternative solutions should be based on real parameters and consider changes at various levels. The evaluation process allows the designer to assess the achievement of goals and identify potential improvements. Different types of solution choices, such as emotional choice, feasibility, meeting requirements, comparing consequences, and evaluation, are considered during the evaluation. Once the best solution is selected, it is further improved at functional, constructive, and aesthetic levels to meet user needs, aesthetic and technical requirements, as well as legal regulations. The design process integrates with the phase of program definition, and these two stages can occur cyclically and dynamically to adapt to changes and new information. For further research purposes, the authors rely on these stages in the design process.

2.2. Phases in the generative design process

Generative design is not a new theory and has been used since the 1970s as an approach to complex design situations [20]. In the fields of architecture and construction, the need for innovative solutions to design challenges has accelerated the adoption of this approach. Advancements in available technology have contributed to the growth of this design approach, allowing the exploration of many possibilities in a short period.

The phases in generative design may vary depending on the applied technique, but like any computer-aided design, they have precisely defined steps in the process, just with different terminology or multiple steps combined into one. According to Mukkavaara Jani and Sandberg Marcus [5], the generative design process can be divided into solution space, solution set and generator, create models and evaluate solutions, and exploration approach. Similarly, Danil Nagy et al. divide it into design space model, design goals, design space analysis, and design optimization [8].

For further research, the authors use the following phases in the design process according to Gradišar Luka et al. [9] (Figure 3): building a computational model, generating solutions, design evaluation and integration. The first and most crucial step in generative design is formulating a parametric computer model with input parameters, constraints, and objectives, as the quality of the design solutions depends on the completeness and quality of the computer model created by the designer. By using the parametric computer model, the generator automatically explores various combinations of input variables to achieve the specified design objectives through different optimization algorithms. These algorithms work independently on the principle of evolution, where successful members of the population are selected, reproduced, evolved, and improved in each subsequent generation until reaching maximum improvement. It is recommended to run the generator multiple times to obtain a wide range of possible design solutions. The use of such optimization algorithms can lead to the discovery of global extrema, interesting and less obvious solutions that may not arise through traditional methods. Due to the challenge of individually analyzing a large number of solutions, the Pareto front is used to identify optimal solutions or as a reference for comparing other possible solutions in relation to how close they are to the optimal solution. Since there are multiple optimal solutions, additional weight functions can be assigned to each objective depending on their importance, highlighting optimal solutions that perform better in those objectives. After selecting the final design, which ultimately depends on the designer, the integration of the chosen solution follows, involving the merging of different design aspects, such as architectural, structural, mechanical, electrical, and other disciplinary elements, to create a comprehensive and functional solution. The entire process is iterative, and by studying the generated solutions, the built computational model and its behavior can be evaluated. Based on this evaluation, adjustments and improvements are made to the model until an appropriate solution to the design problem is found.

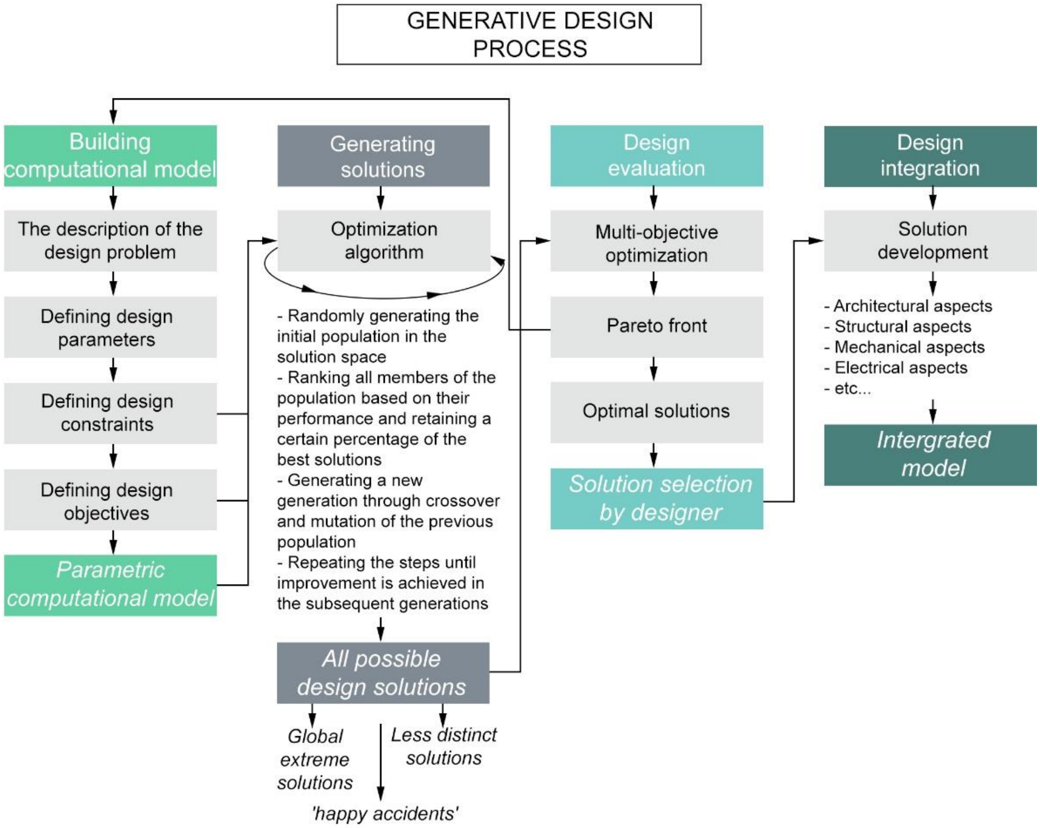

Figure 3. A general model of the generative design process and grouping of activities by phases, according to [9]

2.3. Comparative analysis of architectural space planning and generative design process

A comparative analysis of the architectural design process and generative design is conducted by studying their respective phases and identifying common characteristics, differences, and opportunities for mutual integration to facilitate the design process. Through this analysis, the following conclusions can be drawn:

- The "Analysis of influential factors" phase in the architectural space planning process can be correlated with the "Building computational model" phase in generative design since both involve design parameters such as program, construction site and time conditions. However, the key difference lies in the position of defining constraints and objectives. In architectural space planning, this occurs during the "Conceptualization" phase, while in generative design, it is essential to define these constraints and objectives upfront to create a high-quality parametric computational model.
- Aside from the difference in the position of defining constraints and objectives, the "Conceptualization" phase in architectural space planning

could be likened to the "Generating solutions" phase in generative design, as both aim to create variant solutions. However, in architectural space planning, the architect personally considers constraints, objectives, context, functional organization, and form considerations, and presents several proposed solutions. On the other hand, in generative design, this phase is automated, and the generator within the defined optimization algorithm performs all these tasks without the architect's involvement or decision-making. Another distinction is the time required for solution development and the number of variant solutions. Generative design can produce unpredictable solutions, often referred to as "happy accidents."

- The "Concept development" phase in the architectural space planning process encompasses the "Design evaluation" and "Design integration" phases in generative design. In architectural design, the evaluation of solutions is continuously conducted by the architect based on the given tasks, which can be challenging as multiple predefined objectives need to be satisfied. The choice of solution in this design process is mainly subjective and based on the architect's judgment. However, in generative design, multi-objective optimization is applied to find a set of solutions known as the "Pareto front" or "Pareto set," which represents a balance between different objectives. A solution is considered Pareto optimal if no other solution improves one objective without worsening at least one other objective. In generative design as well, the final result is chosen by the architect, but they select from the Pareto set of optimal solutions.

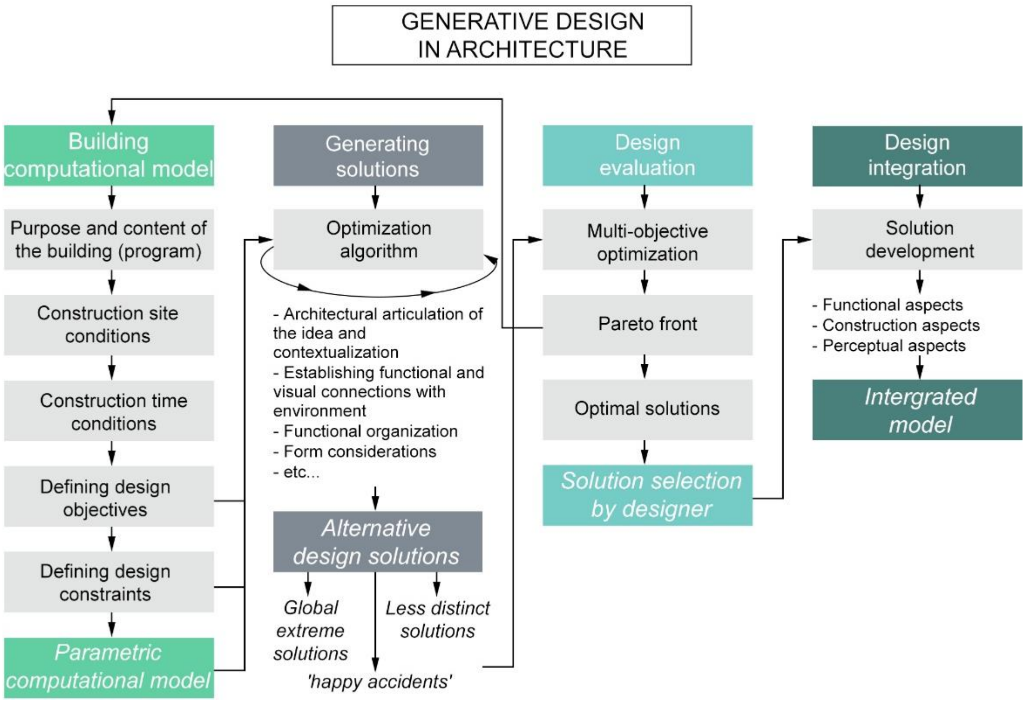

Figure 4. A general model of the generative design process in architecture, illustration by author team

3. RESULTS

The results of the analysis, as a contribution to the impact of generative design on the architectural design process, are presented in the Figure 4 diagram.

4. DISCUSSION

Generative design is the future of architectural planning. This has been recognized by numerous researchers in the field of architecture and other related scientific disciplines, who have started applying it in their research to solve various design problems.

In their work, the author team led by Nagy Danil et al. [8] demonstrates how generative design can be applied to address design problems in urban planning. They optimize two crucial objectives: project profitability for investors and the potential for solar panel energy production placed on the roofs of buildings in a residential area in the Netherlands. The same author team also showcases how generative design can be utilized for the functional organization of a commercial building [7]. The authors employ a computer design model capable of generating unique design solutions and evaluating them based on specific performance criteria. The model is designed to locate all necessary programs and people within the office space, and input parameters can be adjusted to create different layouts that meet specific design criteria. Additionally, the authors use a multi-objective genetic algorithm to search the high-dimensional space of all possible designs and find the best solutions to optimize the design space and discover the most performative solutions, avoiding locally high-performing areas that may not be the best overall.

In another research presented by the author team of Gradišar Luka et al. [9], the generative design was used to create shading solutions for a building with a large surface area of glass. The generative design process involved three key components: design scheme, means of generating different variations, and a mechanism for selecting the desirable output. The generative design system was capable of producing various shading options, assessing their efficiency through energy consumption simulation software, and applying a genetic algorithm to search for new, even better solutions – all in one iteration. The designer continuously modified the model and constraints based on the results until a sustainable and optimal design solution was found. This approach not only resulted in a set of shading solutions with embedded knowledge but also created a model where problem definition knowledge became quite explicit. Another study by Mukkavaara Jani and Sandberg Marcus [5] used generative design to develop a residential block in northern Sweden, with a focus on energy performance considerations.

Generative design can also be applied to the design of public facilities, as they often require complex functional organization. For example, the study by Tomić et al. proposed an algorithm for generating kindergarten plans with the aim of providing all necessary daily activities while promoting physical activity among children [20]. They used room spaces for each activity, along with connections between them, following kindergarten guidelines. The adaptability function was designed to increase these connections between activity spaces, and through iterations, optimal solutions were obtained, featuring the longest path of children's movements.

5. CONCLUSION

Generative design can significantly enhance the conventional process of architectural space planning. Through this approach, architects can develop solutions that are innovative and more efficient, often surpassing human capacities for manually creating such solutions. Generative design, coupled with multi-objective optimization, enables the simultaneous consideration of all design objectives, facilitating the analysis of a large number of alternatives to find the most optimal solution. By using computational models and generative solvers, the process becomes automated, saving time and enabling faster evaluation of different design options.

One of the main advantages of employing this approach is the reduced subjectivity in making critical decisions during the process of architectural space planning, relying instead on established facts. It is important to note that generative design does not replace the human factor in design but rather complements it. Architects still play a pivotal role in defining the problem, constructing the computational model, and evaluating the results. This approach represents a fusion of human creativity and the capabilities of generative design algorithms.

The application of generative design is currently relevant in the field of architecture. This innovative approach to solving design challenges opens new possibilities and perspectives, making further research essential to explore the potential applications of this approach to novel and unique design problems.

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CURRENT TRENDS IN MULTIFAMILY HOUSING IN NIS, SERBIA

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Abstract

Turbulent post-communist period at the end of the twentieth century and the transition from planned to market based economies created a specific context in which multi-family housing in Serbia is being created. The impoverishment of the population, reduced selectivity of users, and the emergence of private investors whose interests are defined by the market demands and the pursuit of profit characterize this context.

Niš, as the third largest city in Serbia, represents an adequate spatial framework for researching modern multi-family housing in this region. An analysis was conducted on a representative sample of multi-family residential buildings that were designed in recent years. The topic of the analysis was primarily compliance with current legislative. The aim of the research is to identify negative trends and the causes of such negative phenomena. After that, it is necessary to define recommendations for improving the current state and multi-family housing quality.

Key words: Multifamily Housing, Transition, Post-communist

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1. INTRODUCTION

The period of the late 20th and early 21st century in Serbia is characterized by a social transition from a communist to a capitalist system, as well as an economic transition from a planned to a market economy. Political instability and conflicts have significantly hindered this transitional process and are the main reason for the region's lag behind other Central and Eastern European countries.

The impact of these processes on housing has been explored by numerous authors. During the socialist period, there was a large number of documents in EX Yugoslavia regulating the architectural aspect of residential construction. All the mentioned regulations were focused on achieving a higher level of comfort and utility value for residential units in the context of planned social construction, where rationality and cost minimization were often among the most important requirements.

"The transition period of the 1990s was characterized by the absence of regulations governing residential construction. The political regime of former communists had an interest in supporting an ideological mix of social justice and market (entrepreneurial) values, in housing as in society. While the first led to the preservation of some institutional arrangements from the previous regime and an imaginative housing policy concerned with justice and equality of outcomes, the second one led to the postponement of explicit regulations and institutional reforms, as it was important to ensure that the market would benefit primarily the political elite or those closely connected with it" [1]. This period can be experienced as a kind of triumph of the market over regulation [2]. As the countries of the Sotheast European region were in transition from communist towards market housing policy - all elements of the previous regulations were dissolved, while the introduction of the new market regulation was very slow in some of the countries. [3]

This greatly affected the quality of residential construction during that period. Multi-apartment housing in urban areas has deteriorated due to lack of effective legal, organizational and financial measures for its management [4]. The socialist concept of the welfare state was transformed in a very short time in a neoliberal economic concept, with deregulation of the housing legislation [5].

After more than twenty years of legal vacuum in that segment, in 2012, the „Rule Book on Conditions and Norms for the Design of Residential Buildings and Apartments" was adopted. Two additional revisions of this regulation have been carried out, and the currently valid version is from 2015. [6]

Although the social and economic context has completely changed in the meantime, certain common tendencies can be identified in residential construction in these two periods. This primarily relates to the effort to minimize costs, which is common to planned residential construction in the socialist period and contemporary market-driven residential construction. However, the motives behind this are not the same. During the socialist period, there was a desire to create conditions for providing housing and a better quality of life for a wider population by mass construction of affordable housing, where cost reduction was a priority. In the contemporary market context, the primary motives are the profit of investors and the purchasing power of the population. The aim of reducing construction costs is fully compatible with these requirements. In that sense, reducing the price of a unit by minimizing its size while maintaining an acceptable level of comfort and utility value is a desirable design model in both periods.

The current regulation addresses parameters that define minimum surface areas of apartments or individual rooms, minimum widths of individual rooms, or other functional requirements that influence the organization of the apartment.

In this entire context, certain negative trends in the qualitative development of housing on an urban and architectural level are evident. In addition to the obvious decline in the quality of construction itself, numerous problems can be identified in urban planning and architectural design, which have pronounced negative consequences.

2. METHODOLOGY

Nis, as the third-largest city in Serbia, has been chosen as a representative sample for researching these processes. Three examples of multi-family residential buildings have been selected, reflecting current trends and serving as case studies for analysis. The analysis focused on compliance with current regulations, primarily in terms of spatial parameters, such as the dimensions and areas of apartments and rooms. Minimal values of these parameters, according to Rule Book on Conditions and Norms for the Design of Residential Buildings and Apartments are shown in tables 1 and 2.

Table 1.Parameters for analysis – minimum width and areas of rooms

	Minimum width	*Minimum area of rooms*
Living room	*320cm for studio 340cm for one and one and a half bedroom apartments 360cm for two and two and a half bedroom apartments 380cm for three and three and a half bedroom apartments*	*16m^2*
One person bedroom	*210cm*	*7m^2*
Two person bedrooms	*240cm*	*11m^2*
Master bedroom	*280cm*	*11m^2*
Kitchen	*170cm*	*4m^2*
Dining	*220cm*	*4m^2*
Bathroom	*160cm*	*3m^2*
Minimum area of apartment	*50%*	*0%*

Table 2. Parameters for analysis – minimum areas of apartments

Type of apartment	*Minimum area of apartment*
Studio	*30m^2*
Junior one bedroom	*40m^2*
One bedroom apartment	*48m^2*

One and a half bedroom apartments	*56m²*
Two bedroom apartment	*64m²*
Two and a half bedroom apartment	*77m²*
Three bedroom apartment	*86m²*
Three and a half bedroom apartment	*97m²*

Through this analysis, the trends of deviation from the regulation were identified, which served as a basis for the analysis of the regulation itself and its possible shortcomings. The ultimate goal was to form recommendations for the correction of the regulation and its improvement and harmonization with the real situation on the market.

3. ANALYSIS AND RESULTS

Three case studies were conducted. Buildings in the central city area, of different authors and sizes, were selected for these studies. Basic data on the selected buildings are given in table 3.

Table 3. Basic data on the selected buildings

	Vojvode Tankosica Street No. 16	*Corner of Svetosavska and Jeronimova Streets*	*Jovana Skerlića Street, No. 21*
Designers	*P. Dencic and M. Krstic (A.De.Pe.)*	*Djordje Kitic and Dusan Nikolic (Alterno INC)*	*Zoran Nikolic and Miroljub Stankovic (Kontrastudio)*
Number of storeys	*Ground Floor and Six Floors*	*Ground Floor and Three Floors*	*Ground Floor and Four Floors*
Number of apartments	*48*	*12*	*16*

3.1. Vojvode Tankosica Street No. 16

The residential building at Vojvode Tankosica Street No. 16 is an example of a architectural design that has achieved a satisfactory level of functional organization of apartments, which has been successful in the market, even though it may not fully comply with the existing regulations. (Figure 1)

On the typical floor, there are eight apartments, consisting of one-bedroom and two-bedroom units. The apartment sizes are relatively small, in accordance with market demands. Most of the apartments have sizes below the minimum requirements defined by the regulations. The compliance of apartment sizes with the minimum required sizes defined by the regulations is only 12.50%.

Figure 1. Residential building in Vojvode Tankosica Street, design by P. Dencic and M. Krstic

Table 4. Vojvode Tankosica Street No. 16 - Overview of apartments sizes and compliance with regulations

	Vojvode Tankosica Street No. 16	
Number of apartments	*48*	
Number of apartments on typical floor	*8*	
Type of apartment	*Area (m^2)*	*compliance with minimal area*
One and a half bedroom apartment	*56,52*	-
Junior one bedroom	*37,75*	-
One and a half bedroom apartment	*53,71*	-
Junior one bedroom	*35,31*	-
One and a half bedroom apartment	*63,80*	+
Junior one bedroom	*32,59*	-
One and a half bedroom apartment	*49,86*	-
Average apartment size	*45,41*	

3.2. Corner of Svetosavska and Jeronimova Streets

The residential building located at the corner of Svetosavska and Jeronimova streets is designed with four apartments per staircase (Figure 2). The apartments are mostly two-bedroom, with only one of them being one-bedroom. The sizes of all the apartments are below the minimum requirement set by the regulations but reflect the demands of the market. The size of the one-bedroom apartment is 32.67m2, while the sizes of the two-bedroom apartments range from 42.59m2 to 52.77m2. Despite being below the minimum size, they are relatively functional. By integrating the living room and circulation spaces, the available area is utilized in an optimal way. In this case, compliance of apartment sizes with the minimum required sizes defined by the regulations is 0%, none of the apartments complies with regulations. But it can be said that these apartments are functional and in line with market requirements.

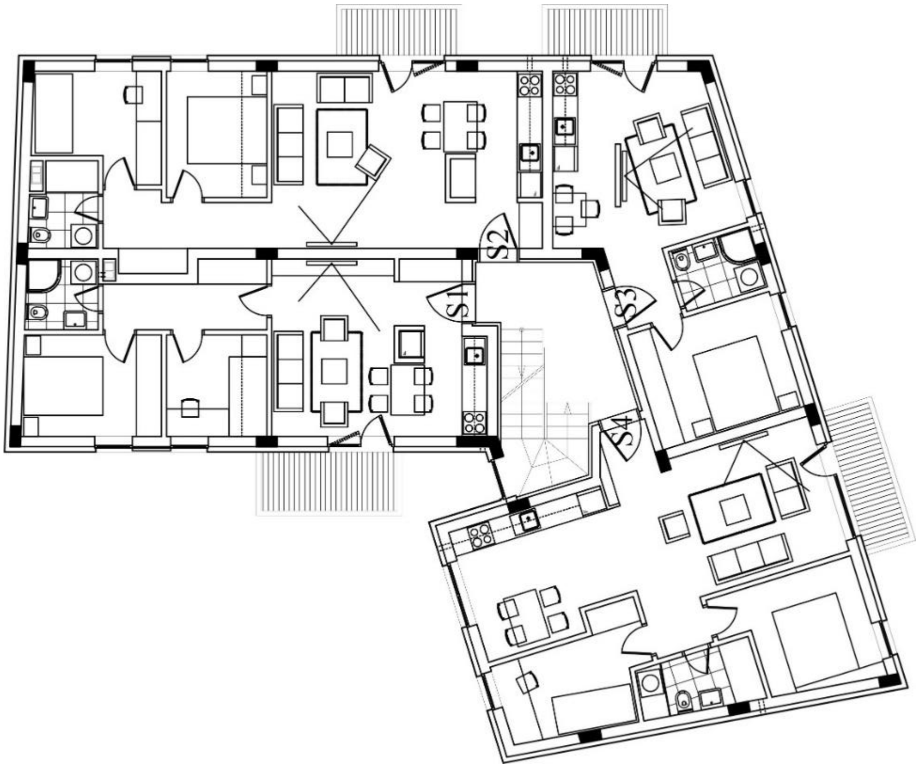

Figure 2. Residential building at the corner of Svetosavska and Jeronimova Streets, design by Alterno INC

Table 5. Corner of Svetosavska and Jeronimova Streets - Overview of apartments sizes and compliance with regulations

	Corner of Svetosavska and Jeronimova Streets	
Number of apartments	*12*	
Number of apartments on typical floor	*4*	
Type of apartment	*Area (m^2)*	*compliance with minimal area*

One and a half bedroom apartment	*42,59*	-
One and a half bedroom apartment	*50,66*	-
One bedroom apartment	*32,67*	-
One and a half bedroom apartment	*52,77*	-
Average apartment size	*44,67*	

3.3. Jovana Skerlića Street, No. 21

Another example, very successful in circumvention of the applicable regulations is a residential building located at Jovana Skerlića Street, No. 21 (Figure 3). With this building, the design possibilities were significantly limited due to unfavourable urban planning regulations and parameters.

It is designed in a discontinuous row, where the western side of the building is attached to the neighbouring plot, while the eastern side is detached. The typical floor contains four apartments, two smaller ones on the western side adjacent to the neighbour, and two larger ones on the eastern side. In this case, the designers were compelled to adhere to the typology defined by the planning document, although it was not adequately considered in this part of the city (a continuous row would have been a much more logical solution). Due to the narrow width of the plot and the eastern orientation towards the neighbouring plot, it was not utilized to its fullest potential. If this orientation were utilized for lighting the residential spaces on the protruding part of the structure, it would have required a distance from the neighbouring building (which is on the boundary) equal to half the height of the taller building. If the residential spaces do not open on that side, a distance equal to a quarter of the height would suffice. Therefore, one room in the southeastern apartment is defined as a wardrobe, and it is described that blinds will be installed on its window. This allows the window of the "auxiliary" space to open on that side.

Figure 3. Residential building in Jovana Skerlica Street, design by Kontra Studio

The layout of that apartment, which will actually be used as a two-bedroom apartment, is presented as a one-bedroom apartment, thus avoiding the obligation to include a separate toilet in addition to the bathroom. This obligation is also avoided in the northeastern apartment, where one bedroom is declared as a dining room. After the technical acceptance, the residents will be able to use the mentioned rooms according to their preference and furnish them as they wish, so it can be expected that the "wardrobe" and "dining room" will be used as bedrooms or children's rooms. It can also be expected that even the one-bedroom apartments will be used by at least two occupants. In this building, the apartments were analysed in accordance with the real way of use, not with the one shown in the project.

Table 6. Jovana Skerlića Street, No. 21 - Overview of apartments sizes and compliance with regulations

	Jovana Skerlića Street, No. 21	
Number of apartments	*16*	
Number of apartments on typical floor	*4*	
Type of apartment	*Area (m^2)*	*compliance with minimal area*
Junior one bedroom	*47,20*	+
One and a half bedroom apartment	*60,80*	+
One and a half bedroom apartment	*61,50*	+
Junior one bedroom	*43,30*	+
Average apartment size	*53,20*	

4. DISCUSSION

The results of the analysis of compliance with the minimum dimensions defined by the regulation are shown in table 7.

It can be concluded that essential compliance with the regulation, regarding minimum dimensions, in the analysed examples, except Jovana Skerlića Street, No. 21 is at a very low level. But this example is also in collision with regulations when it comes to the contents of the apartment and urban planning regulations.

The question arises as to what are the causes of this phenomenon and whether it is truly negative. Market demands and the purchasing power of buyers dictate the need to minimize the surface area of apartments in relation to their structure and to fit as many rooms as possible into a smaller area. This is a reality that must be accepted. The regulations on the conditions and norms for designing residential buildings and apartments clearly define overly strict conditions that are circumvented by such innovative approaches by designers.

The correction of regulations should be based on two principles. The first principle is to inform users about the achieved quality of the apartment. The second principle is to respect market conditions and reduce the minimum required dimensions. These two principles define the need for a fundamental change in regulations.

Table 7. Results of the analysis of compliance with the minimum dimensions

	Vojvode Tankosica Street No. 16	*Corner of Svetosavska and Jeronimova Streets*	*Jovana Skerlića Street, No. 21*
Minimum width	*59.18%*	*50%*	*75%*
Minimum area of rooms	*62.85%*	*39.13%*	*83,33%*
Minimum area of apartment	*12.50%*	*0%*	*100%*

The experiences of foreign regulations show that in developed countries, there are not overly strict limitations when it comes to minimum spatial requirements that an apartment should meet. However, the quality of residential construction is often regulated by the market itself, often in a positive way. Potential apartment buyers who have the financial means to afford a quality apartment typically seek out such apartments and are highly selective in their choices.

The economic situation in Serbia often limits the possibilities for buyers to afford adequate apartments. They are often forced, based on the material resources they have, to secure any type of apartment that would meet their basic needs at the very least.

To form a sustainable regulation, it is necessary to consider market demands and adopt a more flexible approach when it comes to certain minimum parameters for lower-quality apartments, while also introducing categorization of apartments.

The current practice often involves bypassing and not applying the minimum surface areas and dimensions prescribed by the regulations because they are not suitable for market demands. By taking market requirements into account and adjusting certain minimum parameters for lower-quality apartments, a more sustainable regulation can be developed. Introducing categorization of apartments can further enhance the flexibility of the regulations and allow for better alignment with market needs.

5. CONCLUSIONS

It is evident that there are numerous issues with the implementation of the current rule book and significant resistance from the market towards certain provisions. That is a consequence of the non-compliance between the regulation and the actual capabilities of the buyers and market demands.

Some authors emphasize the shortcomings of the existing regulations. “Primarily, it is doubtful is the situation in Serbia ready for so detailed regulation document such as the Act on conditions and normative for the design of housing buildings and units. Perhaps the division between more and less important elements of the acts should be made. The first ones would be obligatory and second ones would be recommendable till the moment when the situation in the country will be ready for accept them.” [7].

It can be concluded that the correction of the regulation and its adjustment with the real state of the market is necessary, in order to improve the quality of multi-family housing design. The current regulation tries to forcefully impose criteria and level of housing for which the market and purchasing power of users are not ready. It is necessary to take into account the real situation and make corrections to the legislation, which would lower the minimum criteria, but also carry out a qualitative classification of apartments, in order to inform buyers about their real level of quality.

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ASSESSMENT OF THE IMPACT OF THE IMMEDIATE ENVIRONMENT ON THE NATURAL LIGHT COMFORT IN THE BUILDING

Jelena Savić[1], Dragan Kostić[2], Dušan Ranđelović[3], Natalija Kostić[4]

Abstract

The infiltration of sunlight into a building's interior is one of the fundamental factors that ensures ambient comfort, which implies a pleasant and healthy stay in the building. The amount of light that reaches a closed space depends on several factors, such as the building's orientation, position, size, and arrangement of openings. The paper analyzes the impact of the planned newly designed building for collective housing on the neighboring existing building for individual housing, considering its number of floors, orientation, and position on the port. The starting point for the analysis lies in the current state of the construction activity, which is characterized by unregulated planning and deviation from the criteria defined by the General Urban Plan. With the help of graphic displays and tools for object modeling, it will be shown how such a condition on the ground can affect natural lighting, and in addition to sociological aspects, energy saving, and people's health.

Key words: *light comfort, building, location, environment*

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1. INTRODUCTION

One of the initial goals of urban planning is to ensure a favorable microclimate of cities, settlements and individual blocks, which would consider the influences that condition it. In order to have buildings on construction plots that, after construction, will meet all the criteria for a healthy and normal stay of people, it is necessary to make maximum use of the entire potential of the location, and to exclude or minimize those negative impacts. We can influence the quantity and quality of daylight in buildings already in the design phase, starting from urban regulations, building typology, architectural design, disposition and proportion of openings, taking into account other important criteria for a given location.

The positive influence of daylight on the psychological and physiological state of the user has been scientifically proven. In recent years, special attention has been paid to the influence of daylight on the mood, will, energy, productivity and health of people in closed spaces. Adequate natural lighting is also important due to other objective factors, such as energy savings, which includes savings related to room lighting, as well as savings related to heating, cooling, and ventilation of interior parts of buildings. The basis for obtaining the best results, when talking about natural light comfort in residential and public buildings, is comprehensive urban planning, natural and created factors [1]. Natural factors include climatic conditions, topographical characteristics of the location and configuration, while the group of created factors includes: orientation of buildings, mutual position of buildings, their architectural form and vegetation. Based on these factors, the paper analyzed the natural lighting of an individual residential building, when there is a building for multi-family housing with a higher floor on the neighboring plot. Non-compliance with building rules, as well as deviations from these regulations, lead to the creation of an environment that does not meet the basic criteria of comfort in the observed micro-location.

2. METHODOLOGY

The methodology used for this research is based on the mechanisms of analysis, comparison and synthesis. The analysis is based on the collection of information that is known, as well as information and criteria that are defined by technical rules and construction regulations. The approach of direct comparison of collected and systematized essential information is the basic instrument of analysis. The synthesis includes the collected and analyzed information, compared with the solutions provided by the legal and technical regulation. It is a method that, based on partial conclusions, leads to a comprehensive solution, taking into account all influencing factors.

As a result, following the research workflow and the aim of this study, the structure of the paper is divided into two main sections: an analysis carried out with the help of technical regulation criteria and another analysis, carried out by looking at the existing and newly designed state with the help of insolation analysis software.

3. BASIC DATA ANALYSIS

The location of the existing building is in Pirot, at CP (cadastral parcels)-1831 City of Pirot. The area of the plot land is 334m^2, and according to Geodetic Information System (GIS) on the plot land there is Building 1 (Family residential building) with an area of 96m^2, Building 2 (Ancillary building) with an area of 28m^2, Building 3 (Ancillary building) with an area of 18m^2 and Building 4 (Auxiliary building) with an area of 2m^2. The buildings Building 1 and Building 2 are functionally connected and represent a single residential unit and are the subject of further analysis (Fig.1).

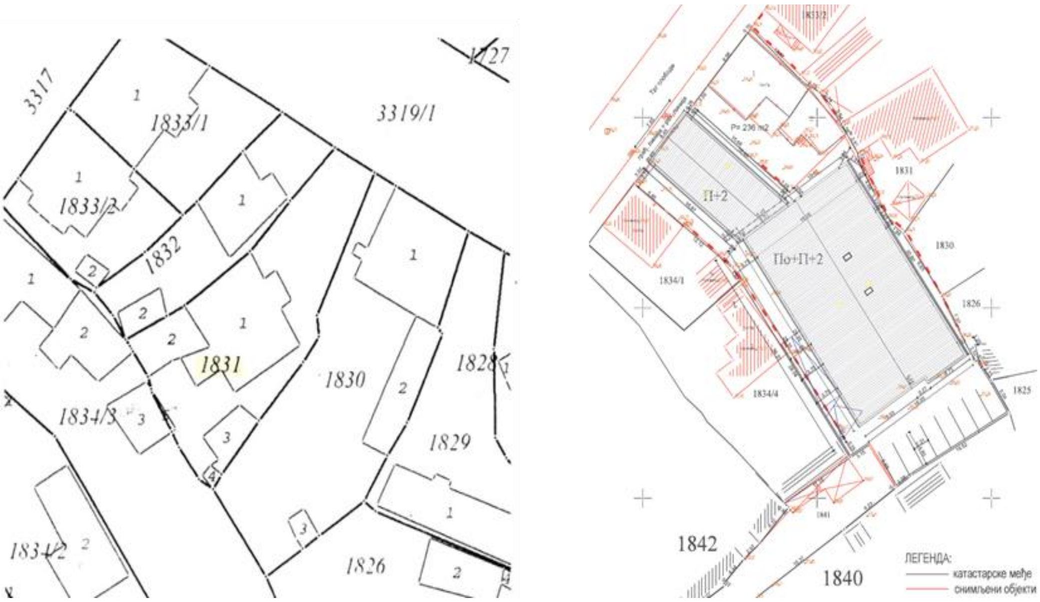

Figure 1 Copy of the plan CP 1831 (left) and the situational plan with the newly designed building (right)

The longitudinal axis of Buildings 1 and 2 (Fig.1) is placed in relation to the north at an angle of 57°, i.e. in a direction that is approximately north-east / south-west. The number of floors of the existing building is Gr+Loft, with a classic multi-pitched roof and tile covering. The height of the building Building 1 at CP-1831 City of Pirot is given in Table 1, and it was taken from the Main design based on which the reconstruction of the building was carried out and by an on-site measurement (Tab.1).

Table 1. Height of building Building 1 and Building 2 at CP-1831

	Number of storeys		Height of cornice		Height of ridge	
	Designed	Implemented	Designed	Implemented	Designed	implemented
Reconstruction of the existing residential building	Gr+Loft	Gr+Loft	4,65	4,65	7,17	7,17
Reconstruction of the existing auxiliary building into a residential building	Gr+Loft	Gr+Loft	4,66	4,66	6,40	6,40

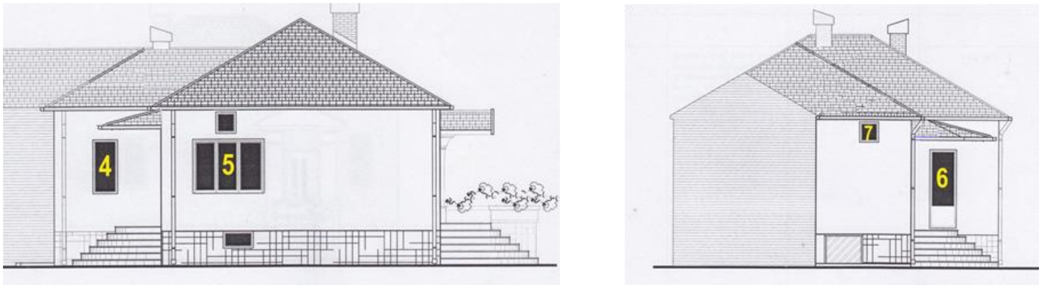

Figure 2 a) South-eastern facade of Building 1 at CP-1831 b) South-western facade of Building 1 at CP-1831

The newly planned residential and commercial building is planned for CP-1834/2, CP-1834/3 and CP-1841 in Pirot. The parcels have not yet been consolidated - the pre-parceling by urban compaction of the previous parcels (CP-1834/2, CP-1834/3 and CP-1841) with a total area of 1693 m^2 has not been carried out. The plot CP-1832/3 is adjacent to the plot on which the existing lower building is located and borders it. The newly planned building is designed with floors Gr+2F and Bs+Gr+2F has different floor levels: in the part where there is a basement Bs+Gr+2F up to a height of 14.11 m, while in the commercial-residential part without a basement, the number of floors is Gr+2F up to height 10.82 m. The height of the newly planned building is given in Table 2, taken from the Main Volume of the PBP (project for building permit) [2].

Table 2. Height of the newly planned building

		Number of storeys	Height of cornice (m)	Height of ridge (m)
1	Office residential	Bs+Gr+2F	9,94	14,11
2	Residential	Gr+2F	8,85	10,82

The newly planned building is closest to the existing building in its northeastern part, which is given in table 3.

Table 3. Distance of the newly planned building from the existing building

	Distance of the newly planned building from the existing building	*Distance of the newly planned building from the border of the plots land*
The shortest distance from Building 1	*5,80м*	*1,06м*
The shortest distance from Building 2	*1,54м*	*1,06м*
The shortest distance from Building 3	*2,32м*	*1,06м*
The shortest distance from Building 4	*1,06*	*1,06м*
Maximum distance from the border of the plot land	*-*	*1,53м*

The structure of Building 1 and the Newly Planned Building would be at a distance of 1.53 m, then 5.98 m and 8.71 m due to the spread of the foundation of Building 1 at CP-1831 (Figure 3).

Facade openings on Building 1 oriented to the south-east and south-west, especially on the ground floor, may be threatened by the newly planned building in terms of reduced comfort due to the reduction of sunlight (insolation) and the reduction of natural light in the residential premises, as well as the opposite openings.

Windows on the structure of Building 1 on the ground floor in the living room (Window 5: 2.13/1.53 m), in the kitchen (Window 4: 0.73/1.49 m) in the dining room (Window 3: 1.79/1.40 m), the brightness of which can be disputed, have a south-east orientation, which is considered a very favorable position in terms of construction and architecture. The glazed door of the living room on the ground floor of Building 1 (Window 6: 0.7/2.20m) is on the south-west facade, which is also considered a very favorable orientation from the aspect of insolation and natural lighting.

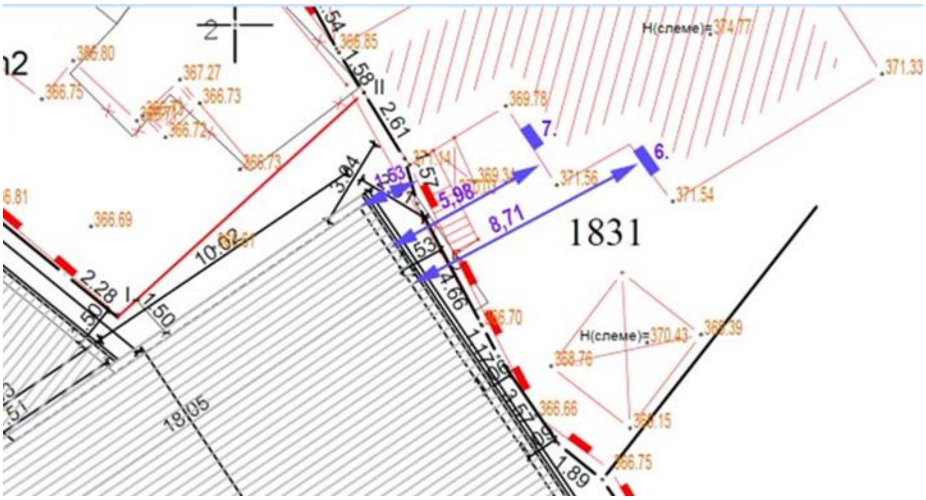

Figure 3 Planned mutual sharing of buildings (source of information Main Volume of PGD for Newly Planned Residential and Commercial Building)

According to the General Regulation Plan "Pirot-Center" (Official Gazette of the City of Niš 60/14, 70/14, 72/18, 24/19 and 71/22), the Location Conditions for the Newly Planned Building at CP-1834/2, CP -1834/3 and CP-1841 [3]. According to the issued Location Conditions for the urban complex P16 the rules of arrangement and construction are prescribed. In this act of the City Administration of Pirot, it is specified for the location of the building a minimum of 1.0 m from the dividing line CP-1831, CP-1830 and CP-1826... By searching publicly available databases, on the website of the City of Pirot [2], [3] was inspected (Official Gazette of the City of Niš 71/22).

“Book 1, Page 54: For the construction of buildings in the zone - Central urban and business zones - which are built individually or in a continuous series on individual construction plots, the following construction rules apply, which also refer to the distance between buildings.

The mutual distance of new free-standing buildings, of any type of construction, from an existing building of the same type and class is 3m. This distance does not apply to atrial, semi-atrial, and continuous array objects. The specified distance does not refer to the distance from auxiliary facilities and premises. For buildings built by different owners, the distance between them is less than 3m, in the case of reconstruction, opposite openings of residential premises (rooms and living rooms) cannot be designed on the adjacent sides.

The distance of a new building from another building is determined by applying the general rule that reads: the mutual distance between free-standing multi-story buildings and buildings that are built in an interrupted sequence is at least half the height of the taller building. The distance can be reduced to a quarter if the buildings on the opposite side facades do not contain opposite openings on the living quarters (as well as studios and business premises). This distance cannot be less than 3m if one of the walls contains openings for daylight. In addition to the conditions from the previous paragraph, a multi-story freestanding building cannot block the direct sunlight of another building for more than half of the duration of the direct sunlight.

If the business building also contains premises for residential purposes, it must provide free space on its plot, facing south, with a width of 2.50 m for unobstructed insolation of the residential part. A residential building must be placed on its own plot so that its southern side is exposed to the sun unhindered, this right cannot be exercised to the detriment of the neighboring plot."

4. INSOLATION

Today, for the analysis of insolation of objects, several different software are available that can easily and precisely determine the movement of the sun, the position and the movement of shadows during the bright part of the day. The software most often used for these analyzes are: Autodesk Ecotect Analysis, ArchiCAD, Rhinoceros, Ladybug Solar Research Analytics ant etc.

Sunlight-insolation of the critical south-east and south-west facades of the existing building was analyzed by the projection of the shadows cast by the Newly Planned Residential and Business Building on the facade plane of Building 1 and Building 2 at CP-1831. Through a detailed analysis of the projections of the spatial angles of incident solar rays for the position of the sun in the sky in the characteristic positions of the sun in the firmament (summer solstice, spring and autumn equinox, and winter solstice), and according to the data of the Belgrade Observatory and the Yearbook of Our Sky, SANU 1961 edition, as well as on based on mega data from publicly available astronomical observations.

4.1. Insolation before the planned construction of the Newly Planned Residential and Commercial Building Bs+Gr+2F

Before the construction of the newly planned building, the south-eastern and south-western facades of Building 1 and Building 2 on CP-1831 will be partially shaded due to the position of the buildings themselves in the space.

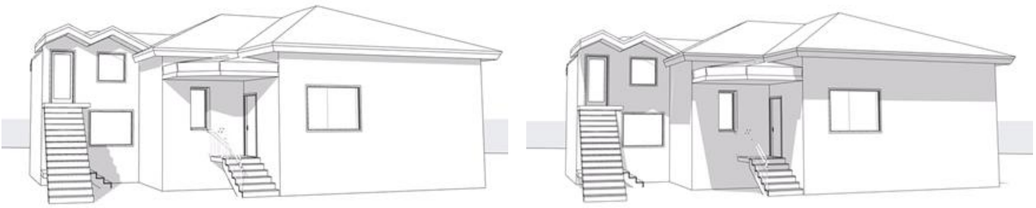

Figure 4. Sun exposure of the south-east and south-west facades of the building at 11:35 a.m.(winter solstice December 22) left and (summer solstice June 22) right (computer-assisted simulations by ArchiCAD software)

Sunlight on the south-eastern and south-western facades of Building 1 and Building 2 on CP-1831 occurred in the summer period (summer solstice on June 22) and in the winter period (winter solstice on December 22) in the morning hours, while in the later periods of the day complete shading occurs (Fig. 4). Figure 5 shows the facade openings with their numbering, and the following tables show the duration of sunlight in characteristic annual periods (spring and autumn equinox, summer long day and winter short day) for the case when there is no newly planned residential and business building (Po+ 2) and for the case when that facility exists as planned according to the Building Permit.

Figure 5 South-East facade of Building 1 and Building 2 at CP-1831 Pirot City, with facade opening marks that were analyzed and data on inclination and azimuth angles of solar radiation incidence

4.2. Insolation for the case when a newly designed residential-business building Bs+Gr+2F would be built

By modeling and simulating the movement of the Sun based on the data on the incident angles of the sun's rays for characteristic annual periods, if the newly planned residential and commercial building were to be built, additional shading of the south-east and south-west facades of the building Building 1 and Building 2 at CP-1831 of Pirot City.

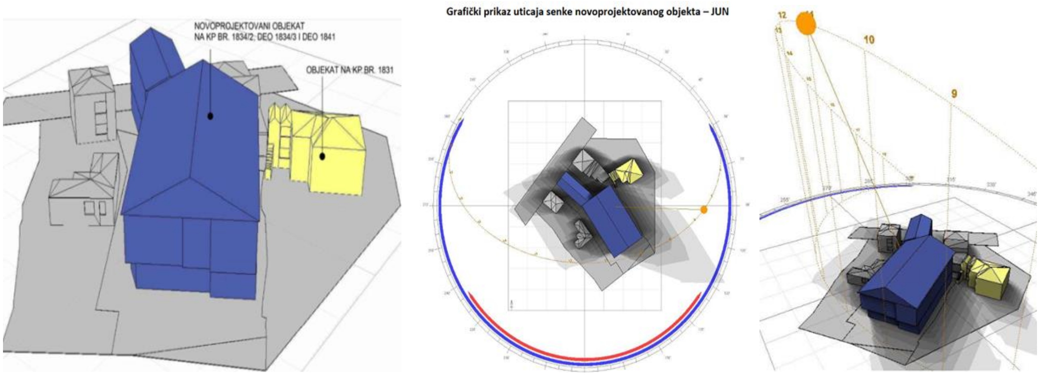

Figure 6. Graphic representation of the impact of the shadow of the newly designed object - JUN (Autodesk Ecotect Analysis)

Models of insolation and shadow projection are given in Figure 5 and Figure 6, animations of the influence of insolation were created and periods were analyzed in which the facade openings on Building 1 and Building 2 at CP-1831 City of Pirot were shaded, which is shown tabularly in Tables 4 to 9.

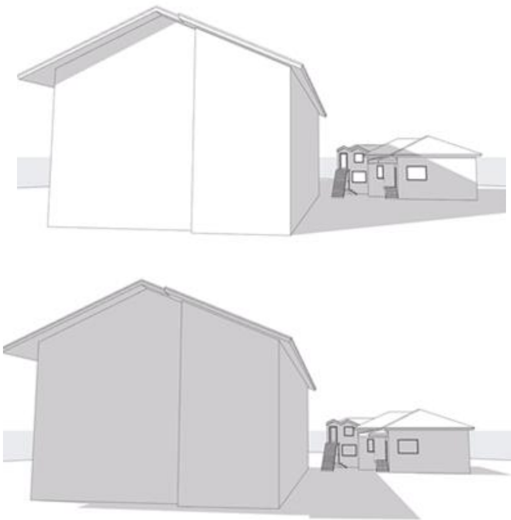

Figure 7. Analyzed periods in which facade openings on the existing building were shaded (winter solstice December 22, around 1 p.m - up) and (summer solstice June 22, after 1 p.m - down) (computer-assisted simulations by ArchiCAD software)

Table 4 Duration of shading of facade opening 5

Window 5	Duration of bright part of the day	Duration of sun exposure per day before construction of the defendant's	The duration of the own shadow before the construction of the newly planned	Number of hours of sunshine per day after the construction of the newly planned	The number of days	Total duration of insolation for the indicated period		Sun exposure after construction of the building according to the number of hours
						Obscured by a structure	After the construction of the building	
1	2	3	4	5	6	7=3*6	8=5*6	9=8/7
Vernal equinox	12h 12' 734'	509'	213'	489'	92	46828'	44988'	96.07
Summer solstice	15h 23' 923'	400'	523'	400'	92	36800'	36800'	100%
Autumnal equinox	12h 11' 731'	439'	360'	439'	91	39949'	39949'	100%
Winter solstice	8h 59' 539'	539'	0	257'	90	48510'	23130'	47.68%
IN TOTAL					365	2868h 7'	2414h 27'	84,18%

Table 5 Duration of shading of facade opening 4

Window 5	Duration of bright part of the day	Duration of sun exposure per day before construction of the defendant's	The duration of the own shadow before the construction of the newly planned	Number of hours of sunshine per day after the construction of the newly planned	The number of days	Total duration of insolation for the indicated period		Sun exposure after construction of the building according to the number of hours
						Obscured by an object	After the construction of the building	
1	2	3	4	5	6	7=3*6	8=5*6	9=8/7
Vernal equinox	12h 12′ 734'	65′	669'	0′	92	5980'	0'	0%
Summer solstice	15h 23′ 923'	0′	923'	0′	92	0'	0'	0 %
Autumnal equinox	12h 11′ 731'	69′	360'	0′	91	6279′	0′	0%
Winter solstice	8h 59′ 539'	179′+ 360'(50 %)	0	78′+ 150' (50%)	90	16110′	7020'	43,57%
IN TOTAL					**365**	**28369′** 472h 49′	**7020′** 117h	**24.75%**

Table 6 Duration of shading of facade opening 3

Window 5	*Duration of bright part of the day*	*Duration of sun exposure per day before construction of the defendant's*	*The duration of the own shadow before the construction of the newly planned*	*Number of hours of sunshine per day after the construction of the newly planned*	*The number of days*	*Total duration of sunbathing for the indicated period* — *Obscured by an object*	*Total duration of sunbathing for the indicated period* — *After the construction of the building*	*Sun exposure after construction of the building according to the number of hours*
1	*2*	*3*	*4*	*5*	*6*	*7=3*6*	*8=5*6*	*9=8/7*
Vernal equinox	12h 12′ *734'*	220′	283'	120′	92	20240'	11040'	54.55%
Summer solstice	15h 23′ *923'*	180′	241'	180′	92	16560'	16560'	100%
Autumnal equinox	12h 11′ *731'*	160′	611'	129′	91	14560′	11739'	80.63%
Winter solstice	8h 59′ *539'*	124′	103'+255' (50%)	64′	90	11160′	5760'	51.61%
IN TOTAL					**365**	**62520'**	**45099 '**	**72,14%**

The sun exposure of the endangered south-east and south-west walls of the observed existing building would reduce the direct sunlight of Window 4 and Door 1 and Door 6, i.e. the average annual insolation is reduced by more than half of the duration of possible direct insolation compared to the previous situation with ground-floor buildings in the environment, which is not in accordance with the provisions of Article 18 of the Rulebook on general conditions on parceling and construction and the content, conditions and procedure of issuing an act on urban planning conditions for facilities for which the construction permit is issued by the municipal, i.e. city administration, which was published in the Official Gazette of the RS No. 75/03, as well as the Rulebook on the general rules of urban regulation and subdivision [5], and it also contradicts the provisions of GRP "Pirot-Center" rules of arrangement and construction [6].

An analysis of the reduction in sunlight exposure of the endangered facade openings of the south-east wall and the south-west wall of the building in case there were no obstacles blocking the building shows that in that ideal case according to the possible number of sunny hours on the same facade openings.

The insolation ratio for the sheltered object 1 and object 2 shows the reduction of insolation for that ideal case for each opening, ie. the average annual insolation is reduced by more than half the duration of possible direct insolation for Window 4 and Door 1 and Door 6.

5. DISCUSSION OF THE FINDINGS

Based on the conducted analyzes and comparative comparisons, the following conclusions can be drawn for certain critical places in the existing facility.

- Sunlight of the south-east and south-west facades, i.e. facade openings, would be reduced. The insolation of facade openings: window 4, door 1 and door 6 would be 24.75% - 49.55% - 34.42%, which is less than the permitted insolation according to the current Rulebook [5] and GRP [6] (the reduction is more than half, i.e. amounts to 75.25% - 50.45% - 65.58%) and was carried out in relation to the state before the construction of the building, taking into account the initial - reference state of the position in the area of sunlight penetration during the year. It can be considered that the conditions of the aforementioned rulebook and the conditions of position and arrangement defined by the PGR in terms of sun exposure have not been met.

[0] The northern facade of the Newly Planned Building contains openings on residential and business premises that are opposite the openings of Window No. 7 and Door 6 of the building on CP-1831, and the distance is less than prescribed (half the height of the newly planned building)

[1] The location conditions are also deficient in terms of the defined distances, that is, smaller distances from neighboring buildings and neighboring plots are given compared to the prescribed development conditions from general regulation plan "Pirot" [6].

6. CONCLUSION

Contemporary trends in architectural planning and design of settlements and buildings show that the provision of thermally comfortable and health-friendly living conditions are the basis for proper and normal living and functioning in a certain location. Climate as one of the main characteristics of the location, with its elements such as temperature, wind, solar radiation, i.e. insolation, affects the healthy and pleasant stay of people in the facilities. The correct use of all these characteristics and parameters of a certain location can significantly contribute to the quality of life, energy savings and the creation of optimal living conditions. In the case of newly planned buildings and settlements, in accordance with climatic conditions, prescribed and defined recommendations and building rules should be applied in order to create environments that are comfortable, healthy and that meet the other needs of modern housing. The correct disposition of the building on the plot, the well-prescribed height, as well as the appropriate distance between the buildings, are the main parameters for the creation of other basic conditions for a healthy environment. This implies the creation of a good microclimate, adequate ventilation, and sufficient and well-used insolation.

Modern tools, software for the analysis of insolation and other climatic parameters, should be used for every planning and design of a new building. In this way, all mistakes and poor solutions would be avoided, which can further result in poor conditions for the life and stay of people.

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ARCHITECTURAL GRAPHICS - ANCIENT ORIGINS

Vladan Nikolić[1], Olivera Nikolić[2], Jasmina Tamburić[3], Sanja Spasić Đorđević[4], Ana Momčilović Petronijević[5]

Abstract

A Man has always drawn, in South Africa a part of a Paleolithic cave drawing was found that is about 73,000 years old. Building a shelter was one of the most important activities of prehistoric man, and with it came the first architectural drawing. Architectural graphics have a long history that can be traced back to ancient civilizations. The historical development of architectural representation can be considered on several interconnected levels. These are the development of ways of presenting space, the development of tools and media (accessories and materials), the improvement of graphic techniques, the articulation of a specific visual expression, as well as the temporal (historical) context. Only a complete picture reveals the character of architectural representation in different historical periods. Numerous preserved artifacts confirm the existence of awareness and the need for architectural visualization since the earliest period of human civilization. It was assumed that architectural graphics date back to the ancient century, but certain archaeological discoveries have called this into question. This work sublimates available knowledge into a unique retrospective of the creation of architectural graphics.

Key words: *architectural graphics, ancient origins, architectural history*

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1. INTRODUCTION

Architecture is multidisciplinary, spread among art, craftswork, science, engineering and numerous socio-psychological aspects. The articulation of architectural solutions follows and generates the development of human civilization. A man has always drawn, in South Africa a part of a Paleolithic cave drawing was found that is about 73,000 years old [1]. Building a shelter was one of the most important activities of prehistoric man, and with it came the first architectural drawing. Numerous preserved artifacts testify to the development of architectural visualization. Based on them, it is possible to see the development of architectural visualization during the old century and to create a complete picture of the field of architecture, which is not sufficiently systematized.

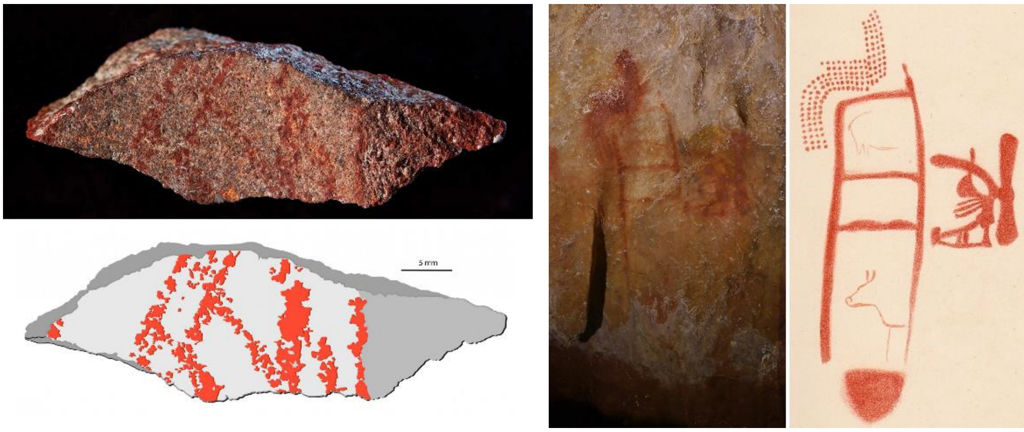

Figure 1. Fragment of a drawing from the Blombos Cave in South Africa (currently the oldest human drawing found from the Paleolithic period, about 73000 years old) / picture: Craig Foster, illustration: D'Errico / Henshilwood / Nature/ reconstruction of Neanderthal drawings from the Paleolithic period about 64000 years old, La Pasiega cave in Spain /C.D Standish, A.W.G. Pike, D.L. Hoffmann/

Visual communications is a term that broadly describes the use of design, formal and textual elements in a specific period of time and space context, so that the created message has a synergistic effect that exceeds the possibilities of conveying ideas by each of the elements individually. Architectural graphics are part of visual communications and have the function of being a means of expression, documentation, research, communication, that is, to develop the ability of architect's visual imagination. As a complex activity, it is based on the application of certain formal rules and a high degree of inventiveness. Architectural graphics is the art and skill of visualizing architectural ideas, using appropriate tools and media, different graphic techniques and certain rules. It represents a visual language without which architecture would be silent and random [2].

2. HISTORICAL DEVELOPMENT

The historical development of architectural representation can be considered on several interconnected levels. These are the development of ways of presenting space, the development of tools and media, the improvement of graphic techniques, the articulation of a specific visual expression, as well as the historical context. Only a complete picture reveals the character of architectural representation through different periods in history.

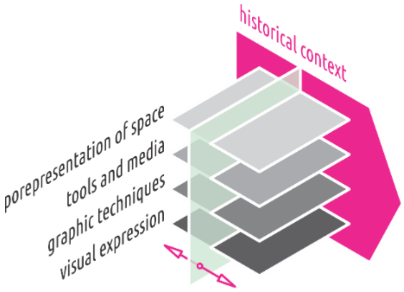

Figure 2. Research of the architectural representation - development factors

Spatial display systems were developed until modern times. In the old century, there were no systematically based ways of depicting space. They were often based on canons and religious interpretations.

Tools and media were just beginning to develop in the old century. The period of more intensive development began in the Renaissance period. Because of it, the possibilities of creating high-quality visualizations were very limited. Also available graphic techniques were in direct connection with the level of development of tools and media in particular period of time.

Historical context is also an important component in researching the development of architectural graphics. This primarily refers to the previously mentioned religious aspects of the depiction of space. Various canons and dogmatic interpretations determined the character of architectural representations, sometimes even more than all other influential factors.

2.1. **Prehistory**

Numerous preserved artifacts confirm the existence of awareness and the need for architectural visualization since the earliest period of human civilization. It was assumed that architectural graphics date back to the ancient century, but certain archaeological discoveries have questioned it. A drawing of plan of a prehistoric Neolithic settlement was found at the Çatal Hoyuk site in Turkey [3], dating to around 6200 BC. It is also possible to hypothesize that man has been using architectural representation for much longer, given that cave drawings have been found that are believed to represent prehistoric huts and shelters [4]. Despite the large number of known artifacts, it is difficult to systematize the development, but it is certainly possible to look at the knowledge and skills inherited from the civilizations of the ancient century.

Figure 3. „Tectiforms“ - Prehistoric schematic drawings of shelters and huts from the Fon de Gomme cave in France /taken from the literature [5]/

Figure 4. Reconstruction of a Neolithic drawing of the settlement plan of Çatal Höyük (above) created on the territory of present-day Turkey around 6200 BC. and the virtual reconstruction of the same settlement (below) /visualization in the picture below: Dan Lewandowski/

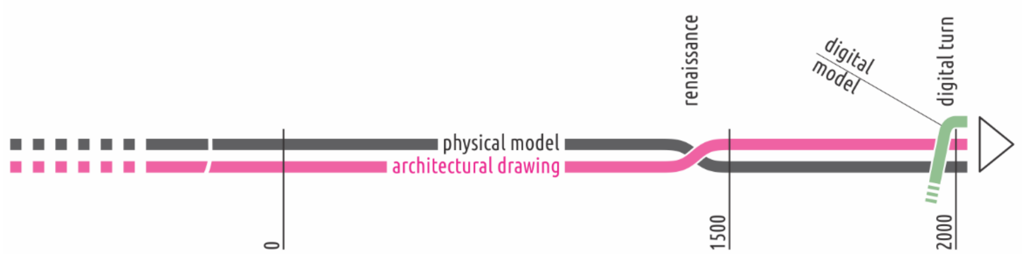

Figure 5. Dominant methods of architectural representation throughout history

As architectural structures became more complex, the need arose for their representation in the form of technical drawings and physical models (models). Until the Renaissance, the physical model was the dominant way of representation in architectural design, and only after that, the drawing took the primary place [6].

2.2. Ancient history

The oldest architectural drawings that are found, date back to the 25th century BC. Builders in the ancient states of Mesopotamia used clay tiles on which they engraved architectural drawings. They represent plans of settlements and the foundations of buildings, on which the purposes and dimensions of the rooms are often written, similar to the modern concept of architectural drawings. The base of the temple carved on a slab that is part of a statue of Gudea, from the ruler of the city of Lagos, dates from the 22nd century BC [6]. Plans of the Sumerian city of Nippur on clay tablets have been created around 1500 and around 1200 BC.

Figure 6. Plan of the Sumerian city of Nippur created around 1500 BC. /source: bookaddicts.org/ (above), Sumerian house plan from the city of Lagash, Akkadian period, 24th century (bottom middle), Sumerian house plan from the city of Uma, Ur III period, 21st century BC (bottom left) / Near East Museum, Berlin and Louvre Museum, Paris/ and Nippur Map Tablet created around 1500 B.C. (bottom right)

In ancient Egypt, architectural drawings were made on papyrus, parchment, ceramics, or thin limestone slabs. The discovery of a technical drawing known as the Turin Papyrus is particularly significant. It was created around 1150 BC. and it's a detailed drawing of the base of the tomb of Ramesses IV. Depending on the material they represent, the lines are drawn in several colors [4]. The Egyptians established a connection between layout and elevation drawing, as early as in the 14th century B.C. s [7]. Clay and wooden models - dioramas of Egyptian houses, temples and crafts shops dating back to the 20th century BC have been found in Egyptian tombs. Although they had a ritual purpose, they can also be considered a form of architectural visualization.

Figure 7. Turin papyrus - the basis of the tomb of Ramesses IV on papyrus created around 1150 BC /source: web.philo.ulg.ac.be/

Figure 8. Plan of the tomb of Ramesses IX on a stone slab, around 1120 BC ostracon: fragment of a jar bearing plan of a temple and hieratic text

Figure 9. Egyptian dioramas, 20th century BC./ source: metmuseum.org/

There is not much information about the way of architectural representation during the Aegean civilizations before Hellenic Greece. A number of artifacts have been found such as frescoes with architectural motifs dating from the 20th century BC [8], miniatures of Minoan house facades on faience tiles from the 17th century BC. They were found in the Palace of Knossos and were probably decorations of luxurious wooden furniture [9]. Clay models of Minoan houses were created in the same period. A fresco from Konossos, created around 1500 BC, shows the holding of ceremonial games with a drawing of a palace. A fresco created between 2000 and 1500 BC was found on the island of Thera (today's Santorini). It shows a fleet of ships with drawings of cities on the coast [10].

Figure 10. Facades of Minoan houses on faience tiles /Archaeological Museum in Heraklion/

Architectural drawings from ancient Greece have not been preserved. The terms ichnographia and orthographia were used for drawings that correspond to modern drawings of the basis and appearance [6]. Drawings of temples on Greek vases represent the first three-dimensional representations of objects (scenographia) on which some of the much later systematized rules of linear perspective were applied. It is known that before construction, in addition to drawings, wax models were made with details of ornaments (tipos) or models (paradeigma) [10], as evidenced by the texts of Herodotus from the 5th century BC.

A small number of architectural drawings have been preserved from the period of the Roman Empire, and these are carved stone slabs and architectural visualizations made on frescoes. The Great Plan of the City of Rome (Forma Urbis Romae), also known as the Severus Marble Plan, was created between 203 and 211 AD. It was carved on marble tablets placed on the wall of the Peace Palace in Rome. Only parts of the plan have been preserved. The walls of Roman villas were decorated with frescoes whose primary role was to alleviate the claustrophobic feeling in rooms built without windows. From the aspect of architectural visualization, the second phase of the Pompeian style in Roman wall and decorative painting from the 1st century BC, called the architectural style, is significant [11]. The motifs on the frescoes are different architectural structures with views of the landscapes that extend from them. Certain rules of linear perspective drawing were used, but there is no evidence that these rules were systematized. The graphic and geometrical qualities distinguish the frescoes from the Villa of Augustus in Rome, where the quality of perspective constructions is at the level of linear perspective from the Renaissance period, 1500 years later [2, 12].

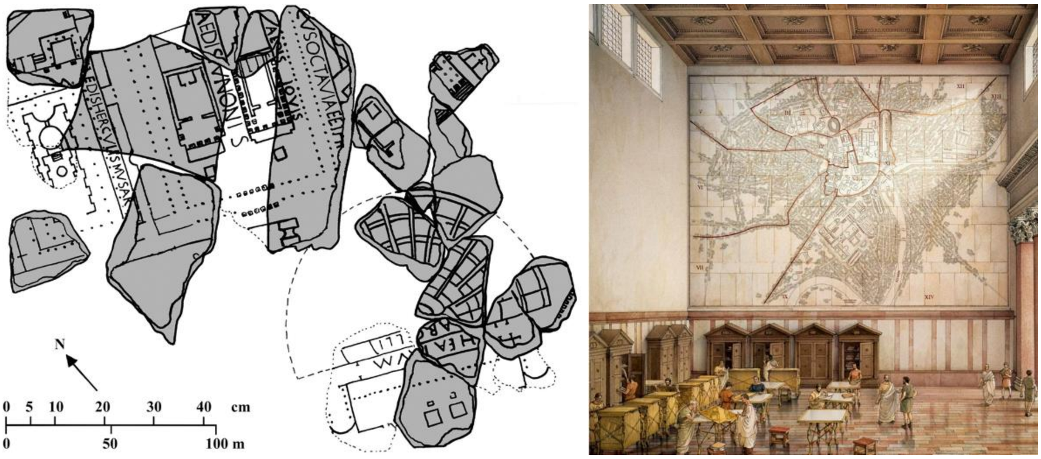

Figure 11. Part of the preserved fragments of the Great Plan of Rome on marble slabs, created between 203 and 211 / drawing: Maggie L. Popkin/ and illustration: hall of the Palace of Peace in Rome with a plan /atlasofancientrome.com/

In the ancient world and later during the Middle Ages, Euclid's books Optics and Elements (written in the 3rd century BC) were the basis for understanding spatial perception and architectural representation. Of special importance is Vitruvius's Ten Books on Architecture, written between 30 and 15 BC. They collected the knowledge and experiences of numerous builders and authors from the ancient period, including those related to architectural representation [13]. Also in the context of the architectural articulation of space, the book on urbanism that was written around 450 BC should be mentioned. written by Hippodamus of Miletus.

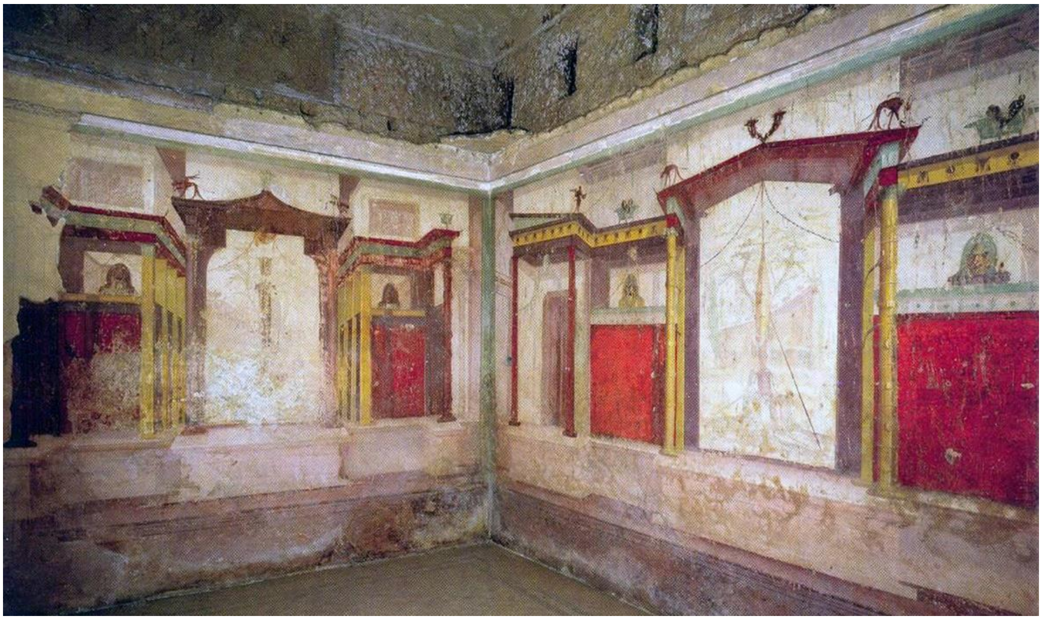

Figure 12. Frescoes from the Villa of Augustus in Rome, 1st century BC.

3. CONCLUSION

Architectural drawing is the basic expressive means of architectural practice and has a complex role to represent, study and document. The fund of knowledge in the field of architectural graphics, created in the old century, received its systematic articulation only after the Middle Ages. Until the Renaissance, architectural drawing did not have clear guidelines and rules of production. Models represented the basic way of thinking and planning the construction of significant buildings.

The ways of showing space in architectural representations in the old century were not systematically based, or they were canonized. From the earliest periods of civilization there has been an awareness of orthogonal projections. This is confirmed by numerous preserved artifacts of Mesopotamian civilizations. In some cases, the Egyptians managed to establish a connection between disposition and elevation. The first attempts to depict space in perspective appeared in ancient Greece in the form of decorative drawings on pottery. In ancient Rome, the first successful perspective representations of architectural objects were created, but even then only for decorative purposes. Axonometric representation of space was unknown in ancient civilizations in Europe, North Africa and the Middle East.

The materials (media) on which architectural drawings were made in the old century were diverse. Mesopotamian civilizations used clay tiles on which they carved the foundations of settlements, temples and houses. In Egypt, they used papyrus and animal skins, and designs on the construction site were drawn on pottery or carved on stone slabs. The Greeks and Romans relied more on making models and textual descriptions.

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EVALUATING URBAN VOIDS IN URBAN VILLAGES: A STUDY OF URBAN VOIDS IN HUMAYUNPUR VILLAGE

Anupma Goel[1]

Abstract

Urbanization has resulted in increasing proportion of the population living in cities. Hence this creates not just shortage of residential spaces but open recreational spaces, as well. In this case it is important to up-cycle the existing spaces. Herein Urban Voids act as a 'Green infrastructure" providing the space functionality, security and Imageability. Urban Voids exist even in planned areas so is there any potential of voids in unplanned areas like Urban villages? And if yes can these voids give identity to that urban village?

This research looks into the identification and classification of urban voids in an urban village i.e., Humayunpur in New-Delhi, India, and exploring if these voids hold the potential of acting as a catalyst for placemaking of the village. Use of solid theoretical background and functional case studies are attained to conceptualize the unpacking of the potentials of Urban voids in Urban villages.

Key words: *Urban Void, Urban Village, Design Intervention, high density, urban renewal, Introspection*

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1. INTRODUCTION

The guidelines known as the Urban Regional Development Plans Formulation and Implementation (URDPFI) guidelines of 2014 proposed an allocation of 10 to 12 square meters of open space per individual within a city.[However, due to the significant growth and expansion resulting from population increase and urbanization, metropolises are now encountering challenges related to the scarcity of urban spaces and resources, particularly in densely populated areas such as urban villages. In the case of Delhi, which encompasses 135 urban villages, there is a lack of comprehensive development proposals specifically designed for these regions.[1]

In order to address this situation, both macro and micro approaches to urban renewal are being considered. However, macro-scale efforts have proven largely ineffective due to their impractical clean slate approach, often lacking meaningful connections to the existing urban context. On the other hand, micro-scale revitalization efforts take into account the social context and aim to revitalize the local economy. Therefore, future development initiatives should prioritize concentrating efforts within the existing urban fabric. This is where the crucial elements known as "Urban Voids" come into play, playing a significant role in the process.[3]

Aim: To explore placemaking catalyst of identified Urban Voids in Urban Villages

Objective: In order to up-cycle an urban void, this research defines the following primary objectives:

A. To study Urban Voids and its Typologies
B. To understand Urban Villages and Causes of formation of Urban Voids in Urban Villages
C. To identify voids in Humayunpur (Live urban village project)
D. To evaluate strategies for revitalization of Voids by comparing case studies
E. To offer Recommendations and Conclusion

2. METHODOLOGY

STEP 1: Conceptual understanding:

- Gain a comprehensive understanding of the concept of urban villages and urban voids.
- Review relevant literature, scholarly articles, and academic resources to establish a theoretical framework.

STEP 2: Previous Studies:

- Conduct a thorough literature review of previous studies focusing on urban voids within urban villages and their role in placemaking.
- Analyze case studies and research papers that explore similar scenarios to gain insights into the strategies employed and their outcomes.

STEP 3: Real-life Example:

- Select a specific urban village as a case study for in-depth analysis.
- Conduct on-site visits and surveys to identify urban voids within the chosen urban village.
- Collect data on the characteristics, size, location, and surrounding context of the identified urban voids.

STEP 4: **Analysis and Evaluation:**

- Analyze the identified urban voids based on their potential for placemaking and their impact on the surrounding environment.
- Evaluate the existing conditions, including social dynamics, built environment, and accessibility, to understand the challenges and opportunities for activating the urban voids.

STEP 5: Recommendations:

- Utilize insights from previous studies and case studies to develop practical recommendations for reactivating the urban voids.
- Consider the specific context of the chosen urban village while formulating recommendations.
- Provide detailed design recommendations, urban interventions, and strategies to transform the identified urban voids into vibrant, functional spaces that enhance placemaking.

STEP 6: Conclusion:

- Summarize the findings from the analysis and evaluation of urban voids in urban villages.
- Highlight the significance of urban voids in placemaking and their potential for creating vibrant public spaces.
- Emphasize the importance of integrating recommendations derived from previous studies and real-life examples into future urban development and design initiatives.

3. CONCEPTUAL FRAMEWORK

3.1. Defining urban voids

Table 1. Definition of urban voids by different authors, Author

Author	*Term Used*
Roger Trancik, 1986 [6]	Lost Spaces - "Urban voids are **undesirable urban areas** that are in **need of redesign**, anti-space, making no positive contribution to the surroundings or users. They are ill-defined, without measurable boundaries and **fail to connect elements in a coherent way''**
Michael Greenberg,1990; Perera & Amin, 1996 Greenbergetal, 2000 [3]	*(TOADS) 'Temporarily Obsolete Abandoned Derelict Sites'*
Accordino & Johnson, 2000[10]	'Vacant land'
Pagano & Bowman, 2000	Vacant land refers to many different types of **unutilized and underutilized parcels** with abandoned buildings and structures
Cybriwsky, 1999[10]	'Planned wasteland' or 'new urban desert'
Groth & Corjin, 2005; Akkerman & Cornfield, 2010	'Fortuitous urban void' spaces beyond the conventional mainstream planned space which are more likely to be in **marginal and residual condition**
De Solà-Morales, 2013 [2]	Terrain Vague - 'Terrain', a stretch of land of an urban nature which is strange compared to the productive nature of the city. **'Vague'** which means **absence** also creates an expectation where invisible questions of identity are hidden

Urban Voids refer to prevalent spaces situated between the public and private domains within the built environment that are either underutilized or left unused. These spaces possess an inherent character and can manifest in various forms, such as abandoned lands, derelict sites, vacant plots, brownfields, dilapidated areas, and similar obsolete territories.

3.1.1. Typology of Voids

They are classified as following by Erick Villagomez [2]:

1. **Void spaces:** large under-utilized sites surrounding buildings
2. **Spaces below:** spaces below infrastructural elements such as elevated railway lines, motorway, flyover etc
3. **spaces between:** the results after urban demolition
4. **Spaces around:** the results of new development under old contexts when new position buildings create intermediary zones between the public streets and private interior space of the buildings.
5. **redundant infrastructure:** infrastructures which are not in use anymore.
6. **Rooftops:** underused rooftop spaces of buildings
7. **Wedges:** the results of intersections of conflicting urban grids or infrastructural lines.
8. **Oversized infrastructure:** overestimated spaces for traffic.

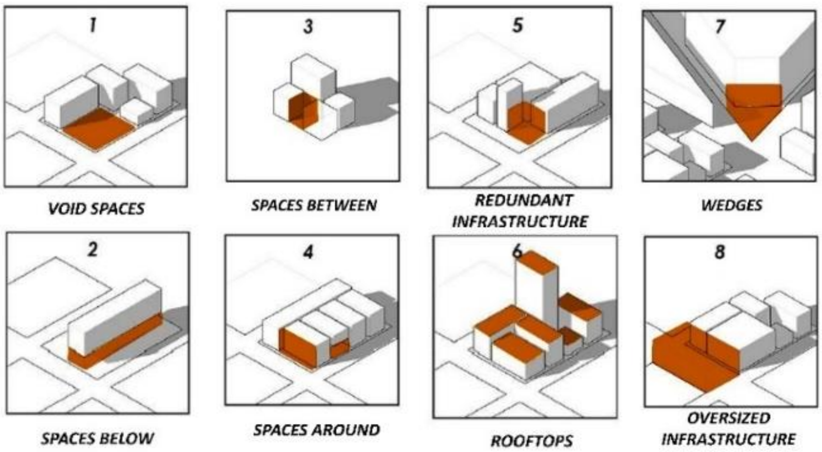

Figure 1. Void Typology According to Erick Villagomez, Author

Urban Voids can also be classified in a broader category on the basis of their formation that are, planning, functional and geographical context.

3.1.2. Factors which have impact on Urban voids

(Suggested by Roger Trancik in his book ‘Finding lost Spaces’,1986) [6]

1. **Increasing Dependency on automobile**

In contemporary times, a city's identity and progress are often measured by its accessibility through automobile connectivity to various destinations. Consequently, there has been a surge in the creation of extensive road networks and a significant demand for expansive parking areas to accommodate these vehicles. However, this infrastructure requirement inadvertently leads to the emergence of nondescript spaces, commonly known as roads, and inadvertently creates a physical separation among neighborhoods. As a consequence, the level of interaction among local residents diminishes, resulting in a sense of detachment and alienation.

2. **Attitude of Urban designers towards Open spaces**

The Modern Movement lacks sufficient consideration for the vibrant life that exists between buildings, leading to the creation of mechanical and impersonal environments. Instead of being integrated into a cohesive system, buildings tend to function as individual objects.

3. **Division of city on the basis of zoning and land use**

In order to maximize land utilization and accommodate the growing population, high-rise towers are constructed, and land uses are segregated. However, this approach often leads to the creation of unresponsive living environments, where the connection between the community and the built environment is lost.

4. **Unwillingness of the stakeholder**

In order to fulfill individual needs, collective spaces are often transformed into private spheres, guided by the principle of "Form follows profit."

5. **Abandonment of a building**

As land use evolves and industries relocate, there is a trend of leaving behind abandoned properties, including restricted military assets, vacant commercial spaces, and residential properties. These properties are often demolished once they have served their initial purpose or reached the end of their lifespan.

3.2. Defining urban villages

Urban Villages are densely populated areas within an urban environment, characterized by a heterogeneous mix of residents resulting from spontaneous and incremental development. These villages are demarcated by a boundary known as Lal Dora, which separates the residential area from agricultural land. The area within Lal Dora is exempt from the municipal zoning laws but falls under the jurisdiction of the Delhi Development Authority for development purposes. Within Lal Dora, buildings are constructed as per the immediate requirements, often leading to haphazard construction of structures up to 5-6 floors without proper setbacks.[5]

The urban villages in Delhi have served as a refuge for the city, providing a buffer against the pressures of population growth, as there were no proper planning provisions in place. One notable aspect common to most urban villages is their ability to accommodate a diverse cross-section of society, including young workers, low-level office staff, students, and low-income families.

3.2.1. Causes of formation of Urban Voids in Urban Villages

The objective is to identify emerged problems in current Urban tissue, it is important to explore scale and origin of each problem that cause the formation of urban voids. Following are the major reasons:

- **Urbanization and Spatial growth**

With the rapid growth of India's economy, rural settlements have experienced a significant influx of migrants from rural to urban areas, surpassing initial projections. Due to the unplanned and hasty development of urban Indian cities, a considerable number of vacant, underutilized, and irregularly shaped land parcels have emerged. These parcels now constitute approximately 10-15% of the city's total area. This uncontrolled expansion has resulted in the alarming phenomenon of peri-urban development, which has had transformational impacts on urban land management, economic structure, environment, and socio-cultural life.

This trend highlights the prevailing inclination of cities to expand outward rather than optimizing spaces within the existing urban fabric. Furthermore, legal issues have arisen, including unauthorized encroachments on public areas and the proliferation of illegal constructions.

- **Inter authoritative legal issues**

Due to their significant population diversity, urban villages often experience political conflicts and inter-authority issues among various stakeholders, particularly concerning speculative lands and legal matters. Examples of such issues include unauthorized encroachments on public areas and the proliferation of illegal constructions.

- **Lack of awareness, belongingness and negligence** towards the community amongst the villagers, let urban voids form and keep existing.

4. CASE BASED STUDY

4.1. Strategies for revitalization of voids

To Observe existing examples of reutilization of urban voids for the recommendation of Urban voids in the urban village; Humayunpur. The Investigation, evaluation and placement of case studies is under the selection criteria of the typology of voids to be mostly found in Humayunpur.

Table 2. Comparison between case studies, Author

Image before:	*Case Study 1: The place of a Giant* 	*Case Study 2: Zhulang Huagai* 	*Case Study 3: Champa Gali* 
Image after:			
Location:	*Saint-Étienne, France [2]*	*Shenzhen, China [2]*	*Khasra 258, Lane, Number 3, Said-ul-Ajaib village, New Delhi, Delhi 110030 [7]*
Involvement:	*Collectif Etc, Community, Artists, Activists, Students*	*Cooper Union, NADAAA*	*Community of young artists, Beautify Earth Project, Mokuzai Studio, Artists, graphic designers, interior designers, architects, carpenters, metal fabricators*

Previous Use:	*Land was a location of former petrol station then an industrial wasteland but then was used as a Parking lot (Previous State)*	*Parking*	*Cow shed and furniture shops*
Present Use:	*Public space*	*Mixed use*	*A passage way with Cafes around*
Area:	*670 m.sq.*	*110 m.sq.*	*100 m.sq.*
Completed In:	*2011 (4-week construction)*	*2017*	*2016*
Typology of Voids	*Wedges*	*Redundant infrastructure*	*Spaces Between*
Concept:	*Resemble the future housing plan on ground and its section on adjoining building*	*model to promote the rejuvenation of the ancient city with cultural activities*	*To bring back life to the streets by painting the world in colour*
Strategy:	*Workshops (DIY kinds) of:* *Landscape & Gardening* *Carpentry to build urban furniture* *Graphic Design* *Public Art* *Strategic zig zag Pathways* *Modularity in use of space* *Online blog to spread awareness*	*linear wall of the site which act as a datum that gives the open space a shape.* *Public Art* *Shading devices* *Urban furniture*	*Collaboration with different stakeholders* *minimalistic designs* *40 murals* *designed 15 cafes with themes* *Installation of art to make the street worth visiting* *Use of Pebble stones to finish the pathway*
Space Programme:	*Wall art* *Children Park* *Food Market* *Community garden* *Workshops* *Music Night*	*Market* *Shops* *Public Square* *Exhibition* *Installation* *Festival*	*Programs surrounding the Gali:* *Cafes* *Design Studios* *Reading Room* *Handicraft shop* *Music venue*
Impact:	*Engagement of different age groups and occupation to local people* *Exchange of knowledge*	*Active and safe space that serves as vibrant public space for the villagers.*	*Creating culturally aesthetic chic place*
Evaluation:	*Most important stakeholder for the change is the residents living around that space*	*Small tactical intervention like installing a shade can add so many dimensions and contribute to building public life.*	*Highlighting and developing the identities of the place. A balance of marketing mix provides a re-image of the place.*

The case studies presented in this paper illustrate the findings and highlight the concept of regenerative design. This approach focuses on repurposing underused spaces through an eco-design framework and promoting public participation to generate or reactivate open spaces.

4.2. Identification of voids in humayunpur

Humayunpur, situated in South-east Delhi, is an urban village characterized by dense settlements and a heterogeneous urban population. It emerged as a result of sporadic piecemeal development in New Delhi, India. The village's unique identity is shaped by its diverse ethnicity, particularly influenced by northeast migrants within a predominantly Jat-dominated community. Additionally, Humayunpur offers an opportunity to explore the culinary delights from the northeastern states of India. The selection of this village as a case study is driven by its rich historical background, dating back to the medieval period, as well as its manageable size, which facilitates a comprehensive study of the village and its associated voids.

Figure 2. Mind map, sketched in the process of identifying Voids, Author

Figure 3. Types of Urban Voids identified in Humayunpur Village, Author

4.3. Recommendations

After evaluating pertinent case studies that illustrate the effects of various design approaches, the most feasible strategies for reactivating residual spaces have been identified. Based on these findings, design recommendations have been formulated specifically for the observed urban voids in Humayunpur village[9].

Table 3. Recommendations for the specific 3 typologies of voids discovered in Humayunpur, Author

Voids Typology	*Recommendations*	*Impacts*
Void Type 1: Wedges (chowks)	*Design of Flexible, Modular spaces Creating Sitting arrangement around the tree placed centrally/ in that void Re-designing the boundary walls adjacent/ enclosing the voids Provide alternative to the parking issue Space for informal vendors Weekly markets, events, exhibitions, hatt functions Providing interactive urban furniture and designing parklets, seating spaces for informal activities Shading illustrations Creating strategic pathways for Forceful pedestrian movement Using Public Art with vibrant colours, materials and interactive art installations, making the space attractive and eye catching*	*Attract people and create awareness Act as a boon for gathering keeping the eyes to the street Active and safe space that serves as vibrant public space for the villagers. Amalgamation of different cultures Indulging Quality of life Simulation of Public Life*
Void Type 2: Spaces Between	*Providing solution and awareness for the waste dumping Focussing more on green infrastructure Use of vibrant wall art to make the space safer and active Providing recreational spaces by temporary sports facilities like table tennis and swing Designing of boundary wall Promote small local Business owners situated in the village by creating marketing mix strategies A source of formal and informal education by open classrooms, art workshops and awareness camps*	*Enhance integration, safety, reduce crime and effect change to the urban environment Exchange of knowledge Creating commercial and recreational facilities enables greater human interaction.*
Void Type 3: Redundant Infrastructure	*Recreational farming or gardening on community level Temporary playing area for kids Re-designing of its boundary walls to make the space more interactive*	*Engagement of different age groups and occupation to local people*

5. CONCLUSION

Based on the aforementioned study, it becomes evident that urban voids can be effectively transformed to enhance their value by considering the involvement of all stakeholders associated with the void and its surrounding context. To provide public spaces in densely populated urban environments where open spaces are limited, urban designers should actively identify these voids, integrate them into the urban network, and activate them using diverse urban design strategies and tactics.

By activating the ecosystem of urban voids, the surrounding context can experience a catalytic effect. These void spaces have the potential to become incubators of public life, fostering social interaction and creating a vibrant, accessible public realm. Moreover, they can contribute to the creation of new public or communal spaces within a predominantly privatized city. In the case of the urban village of Humayunpur, the identified voids hold the potential to stimulate placemaking by facilitating various activities, promoting connectivity, enhancing sociability, ensuring comfort, and improving the overall image and user experience.

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  - površina parcele oko 200 ha
  - Nacionalni stadion sa 52.000 sedišta
  - kompleks EXPO 2027
  - stambeni prostor
  - komercijalni sadržaji
  - linijska infrastruktura u funkciji kompleksa (gradski bulevari, saobraćajna petlja, parking, linije gasovoda, toplovoda, vodovoda)
  - savremene tehnologije
  - održivi i energetski efikasni objekti

Najznačajniji projekti:

- Naselje Stepa Stepanović, Voždovac, Beograd
  - 42 ha naselja
  - 434.000 m^2 stambeno-poslovnog prostora
  - 4.616 stanova
  - 3.300 parking mesta
  - 9,5km novi saobraćajnica

- Stambeno–poslovni kompleks PETICA, Novi Beograd
  - 308 luksuznih stanova
  - 60.000m^2 stambeno- poslovnog prostora
  - atraktivni penthouse stanovi sa panoramskim pogledom
  - moderan poslovni prostor

- Naselje Zemunske kapije, Beograd
  - 200.000m2 stambeno-poslovnig prostora
  - 1.440 stanova
  - komercijalni sadžaji, zelene površine, dečja igrališta

- Centrala Poreske uprave Srbije
  - 27.500m^2 modernog poslovnog prostora
  - atraktivna arhitektonska rešenja
  - zeleni krov
  - energetski efikasan objekat

- Stanovi za pripadnike snaga bezbednosti
  - Više od 7.000 stambenih jedinica izgrađenih od 2019. godine u Beogradu, Novom Sadu, Sremskoj Mitrovici, Kragujevcu, Kraljevu, Nišu i Vranju

- Granični prelazi Horgoš, Batrovci, Preševo

Građevinska direkcija Srbije

- 19.000 stanova
- 1.800.000 m^2 stambeno-poslovnog prostora
- Stanogradnja
- Upravljanje i nadzor
- Upravljanje velikim državnim projektima
- Izgradnja i rekonstrukcija graničnih prelaza
- Rekonstrukcije i adaptacije objekata
- Sanacija posledica elementarnih nepogoda

Građevinska direkcija Srbije d.o.o.
Jurija Gagarina 76
11073 Novi Beograd
www.gds.rs

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