UNIVERSITY "UNION - NIKOLA TESLA"

Nikola Tesla

THE SECOND INTERNATIONAL CONFERENCE ON SUSTAINABLE ENVIRONMENT AND TECHNOLOGIES

PROCEEDINGS

23-24 SEPTEMBER 2022
CARA DUŠANA 62-64, BELGRADE, SERBIA

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ANALYZING AND ASSESSING ECOLOGICAL TRANSITION IN BUILDING SUSTAINABLE CITIES

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Abstract

The concept of sustainability has often been included in the buzzwords list, such as smart cities or big data. The practical aim of sustainable development is the possibility to guarantee a better life quality for an enduring period. This concept is too weak to ensure conservation in space and time, avoiding altering current environmental conditions. Recently, many economic resources have been allocated for the green deal and ecological transition at the national and European levels. To improve the quality of investments in the environmental field, it is fundamental to adopt analytical methods to support the construction of possible scenarios. This contribution will illustrate, on one side, several experiences of inappropriate use of renewable energy sources, with high impacts and low energy production, and on the other side, analytical methods able to simulate possible scenarios for improving the decision quality environmental field.

Key words: Sustainable Development, Renewable Energy Sources, Green Deal, Ecological Transition

INTRODUCTION

The idea of sustainable development may appear vague, fuzzy, and evasive (Pearce et al. 1989). The term "sustainability" is frequently mentioned alongside terms like "smart city" or "big data" in lists of trendy terms. The ability to provide improved life quality over the long term is the practical goal of sustainable development. This term has often been used as a slogan, even for environmentally invasive interventions. This idea is inadequate to preserve time and space without affecting the environment as it is now.

Urban planning's primary objectives are the ability to guarantee social balance, biodiversity protection, and natural resource carrying capacity, as well as the possibility of ensuring a high quality of life for all inhabitants. Two key elements, in particular, are highlighted in the sustainable development definition: intergenerational and intragenerational equity. The first focuses on the necessity to manage current resources to meet the requirements of future generations, while the second seeks to minimize inequalities in how resources are distributed among people at the same time. The third aspect is time because sustainability requires planning for the future and should be included in models since it includes taking care of the next generations.

At the national and European levels, many financial resources have recently been dedicated to the green deal and ecological conversion.

In addition to these funding sources, due to the rising cost of fossil energy sources caused by the economic recovery after the COVID-19 recession and further increased by the war in Ukraine, other financial resources have been allocated to accelerate the transition to renewable energy sources.

The main problem is that all these resources must be used and accounted for in a very tight timeframe by 2026. Consequently, it will not be possible to make proper and deep evaluations. It is essential that these resources will be used in the best possible way allowing real benefits for the environment.

The complex nature of a decision-making process related to territorial transformations leads to the need for particular assessments, not just in terms of the suggested interventions' feasibility from a technical, economic, financial, etc., but adopting evaluations that go beyond the traditional approach also capable of analyzing their effects on political, social, economic, and cultural systems as well as the development of multidimensional evaluation techniques. It is fundamental to consider that not all forms of capital (natural, human, social, and economic) can be replaced by one another. Hence it is vital to set certain restrictions on how easily they can be replaced (Pearce and Turner 1990).

The knowledge created by Ian McHarg (1969) is the first effort to base environmental planning on more impartial techniques. He theorized that the real world might be classified as a layer cake, with each layer standing for a sectoral study (e.g., hydrology, geology, vegetation, transport, etc.). The fundamentals of overlay mapping are represented by this metaphor. These principles were first exclusively implemented manually, with the degree of darkness generated by layer transparency being viewed as a drawback. This handcrafted data structur-

ing method, in the subsequent years, has been adopted by Geographic Information Systems, delivering rigorous and high-quality studies.

Today, GIS has been used extensively in research in the field of environmental planning. A comprehensive overview of research fields of GIScience methodologies' applications to sustainable spatial planning was produced by Campagna (2005). Using spatial simulation models to forecast phenomena' evolution is an essential step after the simple application of geographic information to support environmental planning. The growth in quality and quantity of data sets improved the possibility of basing the decision-making process on spatial information. In the same way, the capability to base decision-making on expectations of future scenarios is made possible by using geostatistics, spatial simulation, and, more generally, geocomputation methodologies.

THE ASSESSMENT OF RENEWABLE ENERGY SOURCES (RES) ON LAND TAKE

To address the worldwide issues of climate change and carbon emissions, renewable energy sources (RES) are an essential element of the solution. Renewable energy sources are increasingly promoted by programs and policies at various levels, creating a problem for regional planners and decision-makers to control territorial fragmentation and landscape change to develop a workable, sustainable solution. If, on one side, the use of renewable energy sources is guiding territorial development toward a low-carbon economy and sustainability principles, on the other side, RES plants can be considered as new forms of territorial settlements and consequently produce anthropic actions, in most cases, not sustainable at all.

The development of clean energy technology is often the focus of policy proposals to accomplish a complete energy transition, but the (not secondary) impact of these policies on the territory, natural ecosystems, and the landscape, in general, is often neglected. It is essential to consider RES development as a significant concern for existing urban and territorial planning. Consequently, the measures currently employed to quantify urban expansion have to be used to assess renewable energy sources' impacts.

Defining the induced phenomena to assess the environmental effects of RES is essential. Land Take is the amount of agriculture, forest, semi-natural/natural land, wetland, or water taken by urban and other artificial land development (EC, 2016). The Corine Land Cover (CLC) database's assessments of the "artificial cover" class, with its related resolution and typological challenges, has been

adopted as the current basis for the Land Take Indicator (minimum mappable unit 25 ha).

Urban sprawl spreads urban developments with disordered growth across the undeveloped area surrounding a city with low population densities (Galster et al. 2001; Hasse and Lathrop 2003; Romano and Zullo 2014).

Residents of new neighborhoods have seen temporary benefits due to urban sprawl, satisfying their desire to live in reasonably priced single-family homes with a garden and greater solitude.

The environmental effects resulting from the transformation of agricultural land into built or simply waterproofed areas that are no longer suitable for food production. This has changed the landscape and caused a severe decline in the quality of the water and air, as well as the loss of the more significant part of the ecological functions of the soil, reduction of the resilience of ecosystems, and higher energy consumption. Longer commute times, reliance on automobiles, traffic jams, and the spatial segregation of social classes produce huge impacts on society.

The urban fragmentation phenomenon, which entails reducing expansive natural habitat areas into smaller ones (fragments) that are typically isolated from the original, is another significant factor (Jaeger 2000; De Montis et al. 2017]. Urban fragmentation, in this particular instance, is connected to physical changes in urban areas and their ensuing dispersion in space (You 2015).

The "sprinkling effect," which divides the environment into several frequently far apart sections, is especially detrimental to rural areas. "A little quantity spread in droplets or scattered particles" is the definition of the sprinkling phenomenon (Romano et al., 2017; Saganeiti et al., 2018). Manganelli et al. (2020) analyzed the social cost of urban sprinkling.

Urban sprinkling is more related to low demographic and housing density than the urban sprawl phenomenon. Sprinkling has a very dispersed distribution.

Soil sealing is defined as a soil covering due to urbanization and infrastructure construction so that the soil can no longer perform most of its functions. Based on high-resolution HRL Imperviousness data, the Soil Sealing Indicator directly assesses imperviousness.

The division of the landscape into smaller fragments caused by mobility and transportation infrastructure is another factor to take into account. This directly impacts the use of land and ecosystem services and can result in the loss of

natural habitats and the death or isolation of animal and plant species (Geneletti 2003; Kabisch et al. 2016).

Although there is not a consensus on what constitutes an efficient settlement (Deilmann et al., 2018), the topic needs to be investigated in light of the anticipated global urbanization (United Nations, Department of Economic and Social Affairs, Population, 2017) and to link the planning discipline to the complex idea of sustainability (New Urban Agenda, 2016; United Nations, 2015).

The need to support the connections between urban, peri-urban, and rural regions on an economic, social, and environmental level is mentioned explicitly in Sustainable Development Goal 11 (SDG 11).

Saganeiti et al. (2020) analyzed the sprinkling effect of RES in the Basilicata Region (figure 1).

They compared the percentage of Wind turbines and solar panels installed in the Basilicata region in connection to the national context to fully comprehend the intensity and the ways of spreading transformation dynamics linked with RES facilities. Currently, the Italian region with the most significant number of wind farms on the national territory is Basilicata (25%), followed by Apulia (21%). At the same time, the Basilicata region produces a very low percentage of energy, only 10%, while the Apulia region is 25%. One of the most important results of this research is comparing urban growth and sprinkling produced by RES farms.

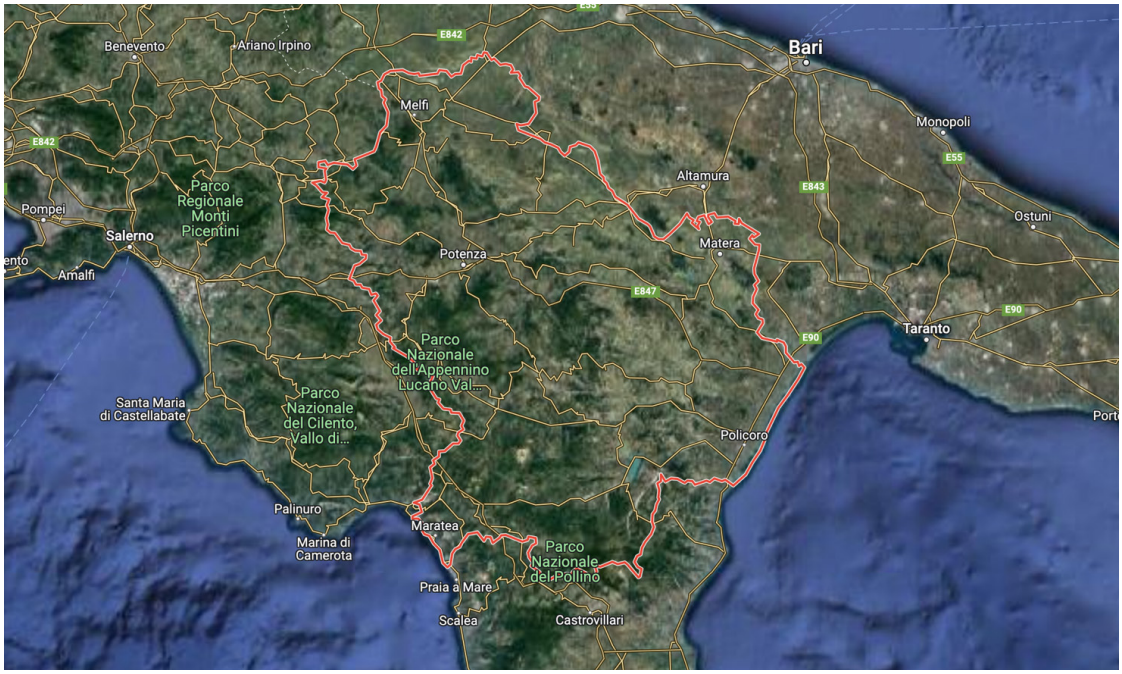

Figure 1. Basilicata Region Location

Figure 2 highlights that before 2008 the sprinkling produced by new buildings was 92%, while due to wind farms was only 7,52 %. Considering the interval between 2008 and 2013, the situation changed slightly, 77,52% for new buildings and 22,479 for wind farms. In the period between 2013 and 2017, the trend was completely inverted. The sprinkling produced by new buildings was 30,19%, while the sprinkling generated by wind farms reached 69,80%.

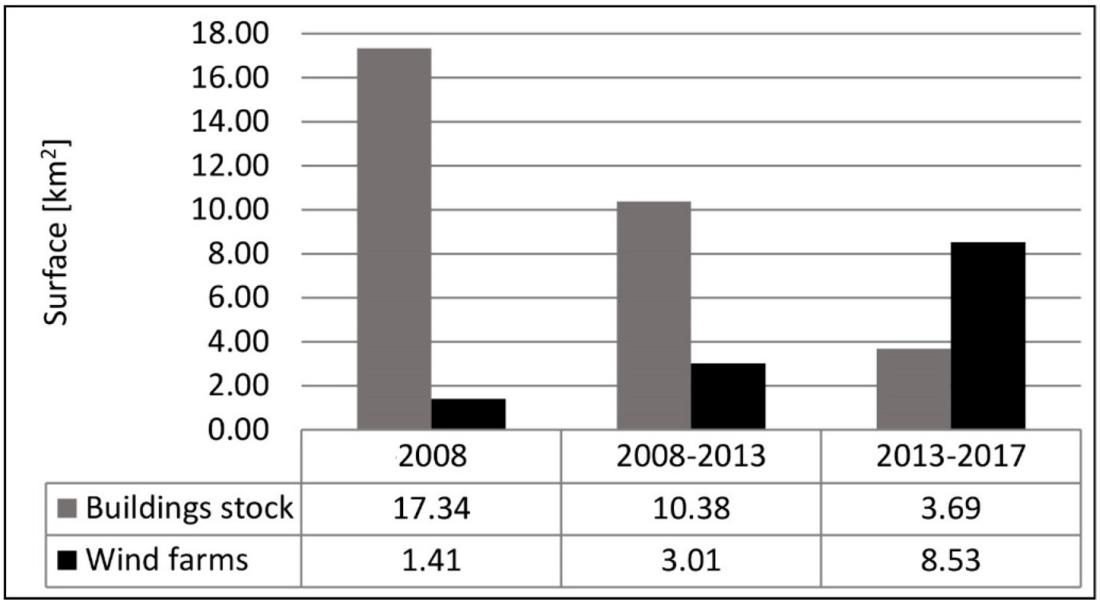

Figure 2. Sprinkling produced by new buildings and RES farms (Saganeiti et al., 2020).

This research highlights that while the spread of new forms of anthropic elements has increased (the RES farms), the evolution of the classic anthropic settlement components (residences, industries, and infrastructures) has slowed. This research analyzed a crucial issue: how to balance the need for natural assets and the achievement of the Res energy production target.

The real problem is that the current urban planning tools RES plants are not considered part of the territorial transformation. As a result, there was no official territorial plan or provision regarding the spatial deployment of RES plants. This is also due to the outdated Italian planning regulatory system lacking the ability to manage contemporary issues presented by social, technological, and environmental innovations that cause significant spatial alterations (Scorza et al., 2021, Romano et al., 2018). The traditional planning framework seems to have no provision for territorial transformation activities.

Lack of organized and trustworthy information about a given RES plant (location, technical features, operational details, etc.) makes it difficult to define an adequate impact assessment procedure for the ex-ante evaluation of RES projects. This is an example of the structural deficiencies in the laws and policies that regulate territorial government at various scales. Assume there is no trustworthy system in place to track land modification processes. Then, decision-makers

lack the knowledge necessary to create a territorial growth scenario for new anthropization like renewable energy.

THE IMPACT OF RENEWABLE ENERGY SOURCES (RES) ON ECO-SYSTEM SERVICES (ES)

Wind energy is an indispensable resource for tackling the threat of climate change and securing energy supplies. However, these aspects must be reconciled with the need to reduce negative spatial impacts drastically. The widespread installation of wind power plants is often accompanied by a lack of or inadequate spatial planning and a lack of an adequate impact monitoring system to support land control and management processes. Since the landscape is considered to be the result of interactions over the centuries between natural and human activities, which have transformed natural and human-managed ecosystems to adapt them to the needs of society, it is recognized that the spread of low-carbon energy production facilities could have a considerable impact on ecosystems and some associated services. Wind farms constitute an important form of landscape transformation that affects the environment at different spatial and temporal scales.

Wind farms and the related impacts on the landscape, environment, and fauna are vital, especially considering the principal contradiction associated with the concept of sustainability of renewable energy sources.

The Millennium Ecosystem Assessment (MEA, 2005) defines ecosystem services as ecosystem benefits. They represent both goods (food, water, raw materials, building materials) and the set of functions that contribute to a given ecological process: absorption of pollutants, protection against erosion and flooding, regulation of surface water run-off and drought, maintenance of water quality, disease control, soil formation, etc.

Four main categories can be distinguished:

- provisioning services, which concern the availability and supply of resources;
- regulating services that take place in the regulation or mitigation of processes and events;
- supporting services, which cover the activities required to perform all ecosystem functions (e.g., oxygen production, regulation of the nutrient and water cycles, habitat conservation, and maintenance of biodiversity);

- cultural services that contribute to man's recreational and spiritual well-being.

These services have a direct and indirect utility for human beings, so it is essential to integrate the ecosystem services concept and assess the effects of different land-use choices on them within the framework of land management and planning policies.

It is fundamental to analyze the critical issue of the relationship between Renewable Energy Sources (RES) and Ecosystem Services (ES).

Muzzillo et al. (2020) analyzed these impacts in an internal area of the Basilicata region (figure 3).

The study area (about 300 km²) includes five municipalities in the province of Potenza, where the phenomenon of installation of RES plants is widespread. In this area, there are wind power plant installations (identified on the map by the red colored point elements) of dimensions and power varying between 20 kW to 1000 kW.

A spatial approach has been used for evaluating territorial transformations through the toolbox provided by InVEST (Integrated Valuation of ES and Tradeoffs) developed by Stanford University within the "Natural Capital Project."

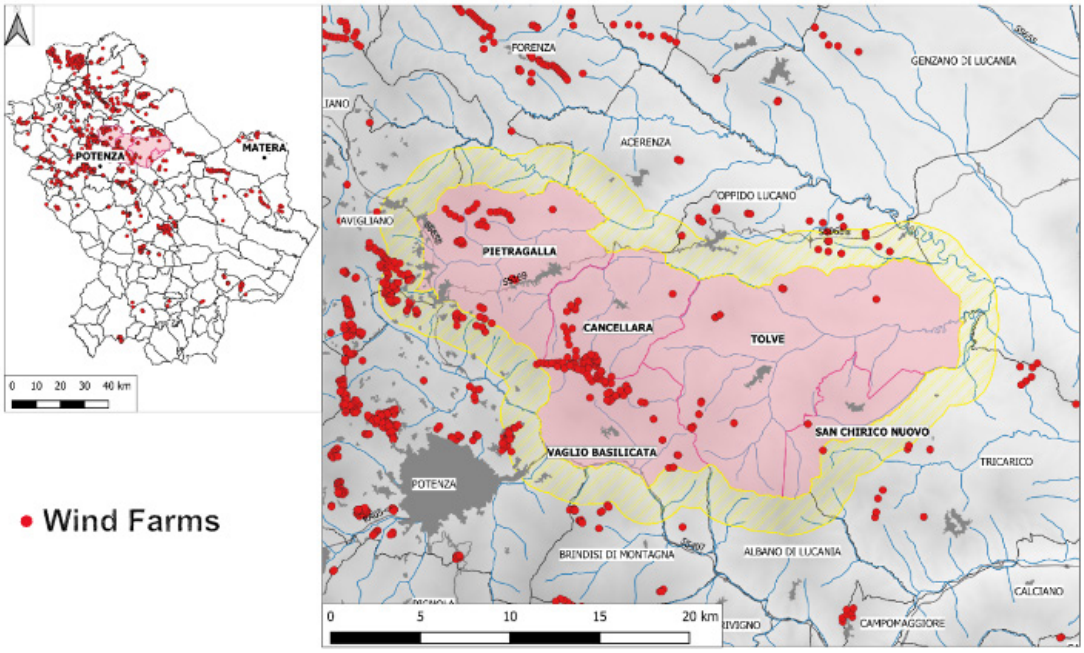

Figure 3. Spatial overview of the study area.

The correct application of the model requires an evaluation of board effects. Therefore, the elaborations were carried out considering an area with an extension more significant than the administrative areas of the five municipalities defined through an external buffer of 2 km, in yellow in figure 3.

Instead, the "Habitat Quality" module uses the ecosystem service model to evaluate the degree of biodiversity and related degradation risks. Habitat has been considered an environment favorable for the presence of various plant and animal creatures.

The Habitat Quality model combines information on land cover and threats to biodiversity to produce a map of habitat quality and one of degradation due to the distribution and intensity of threats (Wu et al., 2015; Polasky et al., 2011).

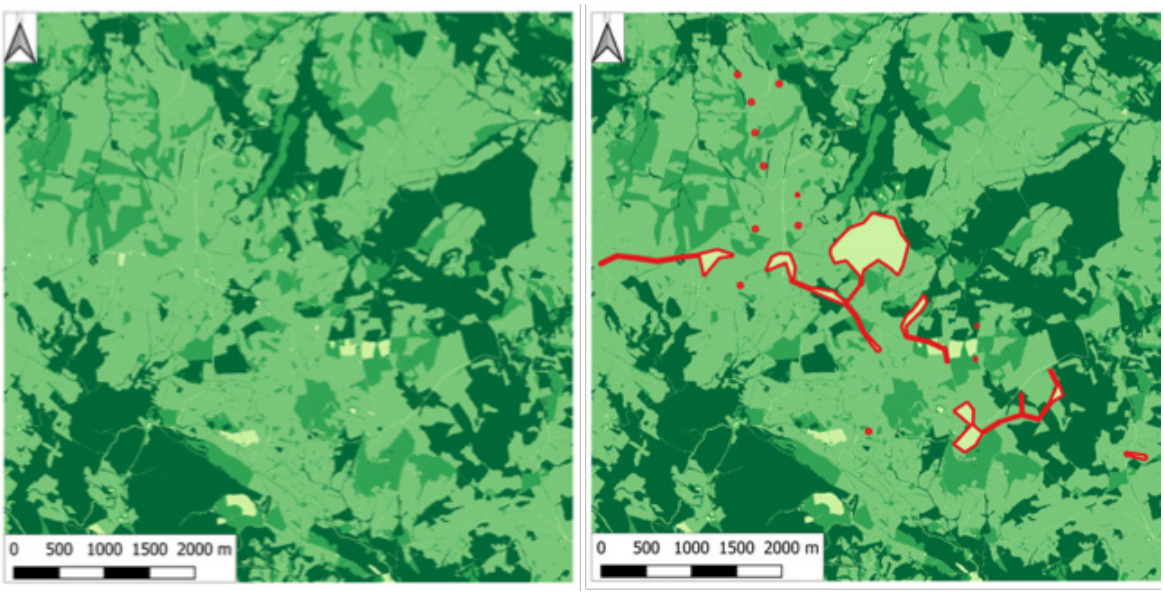

Figure 4. Habitat Quality Map at 2013 left and 2018 right.

Analyzing the Results of the "Habitat Quality" model (figure 4), it is possible to observe the change in Habitat quality after the installation of wind farms from 2013 to 2018.

The quality is more excellent in correspondence of forests along the rivers (which show a more marked green on the map) and lesser (identified by more light colors) in the most anthropized areas.

Wind turbines have been located in those areas highlighted in red from 2013 to 2018. After the installation of the aerogenerators, there is a decrease in habitat quality in the areas immediately surrounding the wind farms.

Differenza Habitat Degradation (2018-2013)

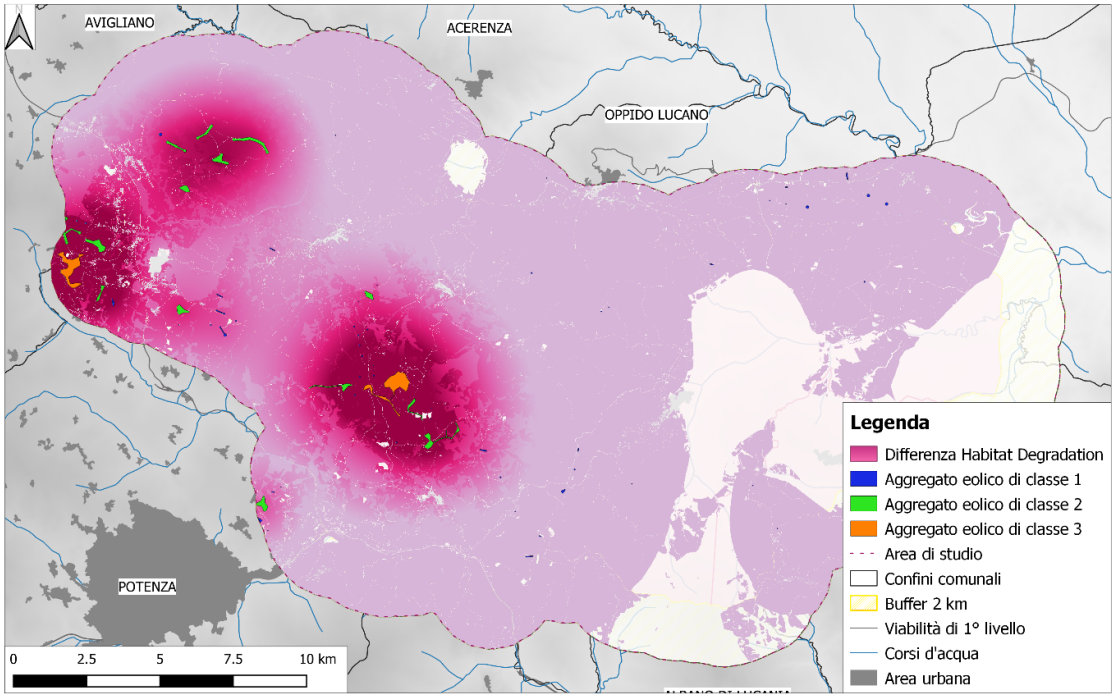

Figure 5. Habitat Degradation Map at 2013 left and 2018 right.

The level of degradation of the 2013 and 2018 output maps was analyzed similarly (figure 5).

A habitat quality difference map between 2018 and 12013 has been realized in this case.

This variation also emerges from the map showing the difference between the Habitat Degradation 2018 and 2013 raster maps. The alteration occurs in the areas immediately surrounding those classified as "wind power," especially where there is a greater density of wind aggregates than classes 2 and 3, therefore those of higher size and power.

ECOLOGICAL TRANSITION AND SUSTAINABLE CITIES

An important concept emerges from what has been argued: the ecological transition is not strictly related to solving the energy problem. Energy conversion to renewable sources is essential, but it cannot be pursued at the expense of other environmental components. Consequently, changing the approach to planning and developing urban policies is fundamental.

Plans are typically the outcome of protracted deliberations that culminate in a lengthy list of stringent rules. Thus, enforcing such norms is the fundamental goal of this planning strategy.

Outdated plans, disconnected from the current time or based on antiquated legislation, frequently represent an obstacle to developing tools necessary to address contemporary issues. As a result, the primary planning objectives are far from offering a genuine response to the everyday transformation demands. This approach is based on vintage planning (Romano et al. 2018) or ghost planning (Scorza et al. 2020), as highlighted in figure 6.

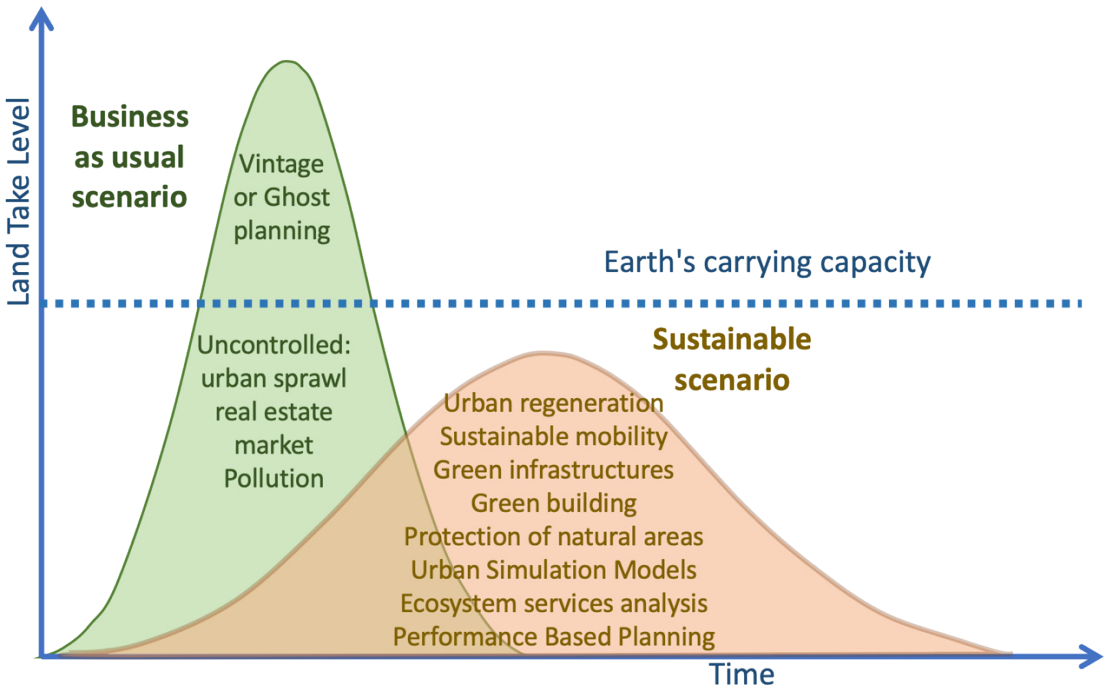

Figure 6. Flattening curve of Earth's carrying capacity based on comparing two possible scenarios: business-as-usual and sustainable.

Different outcomes could be obtained. A city where the real estate market is out of control causes urban sprawl; due to Airbnb, some areas of the city are only devoted to tourists; these car-dependent cities have severe pollution issues. In this scenario, more resources are consumed than the world can support. In 2022, after two years of covid, Overshoot Day occurred again in late July. As a result, during the next five months, humans consumed resources that the planet was unable to supply. An alternative is a simulation-based technique for evaluating the effects of transformations, which enables planners to consider various land use scenarios and select the most appropriate transformations. This planning strategy also accounts for potential losses of ecosystem services in simulations (Geneletti 2016; Gobattoni et al. 2016; Pelorosso et al. 2017; Picchi et al. 2019; Scorza et al. 2020).

The expression "performance-based planning" was employed by several authors (Botequilha -Leitão and Díaz-Varela 2020; Baker et al. 2006; Frew et al. 2016; Marwedel 1998; Janin Rivolin 2008; Pappalardo and La Rosa 2020; La Rosa and Pappalardo 2020; Geneletti et al 2017). This term can be considered an umbrella to include all spatial simulation models and tools to create possible scenarios. Given data availability, all models based on Neural Network, Multiagent Systems, Cellular automata, Space Syntax, and Geodesign (Steinitz 2012; Cocco et al. 2020; Cocco et al. 2019) can include various factors in complete simulations. As a result, objectives for protecting natural resources will be more effectively implemented. Also, 15 minutes city could be an excellent solution to reducing Land Take, traffic jams, and pollution.

The 15 minutes city concept (Moreno et al., 2021) promotes cycling and walking and suggests sustainable urban area development based on proximity to reduce needless travel in polluting and energy-consuming ways dramatically. This theory states that one's residence should ideally be 15 minutes away by walking or cycling from their place of employment, stores, health care, education, wellness, and entertainment. The perspective has shifted: instead of focusing on how to get from one distant location to another as quickly as possible in the past, today's challenge is to bring these locations closer together to minimize the amount of time people must spend traveling to meet their basic needs. Instead of creating massive commercial tertiary structures in the suburbs of cities that must be accessed by automobile or congested public transportation, it encourages people to enjoy the streets "on their doorstep" and restores the vibrancy of neighborhoods. The significant advantages start with a redistribution of one's essential time due to a sharp decrease in the number of hours lost in lengthy commutes, traffic, and line-ups in cities. Moreover, by implementing urban policies

that emphasize 15 minutes city, urban renewal, sustainable transportation, and the development of green infrastructure, it could be possible to realize a more sustainable scenario that will flatten the earth's carrying capacity curve.

CONCLUSION

Since the Industrial Revolution, cities have become less sustainable, and it may be argued that town mobility is the primary cause of this problem. The use of cars in cities has altered the dynamics of urban planning and contributed to the growth of urban sprawl, which has other adverse effects on biodiversity and quality of life as well as on the time factor, which is frequently lost in traffic to reach different parts of the city. Numerous city models have been proposed over the past few centuries, many of which depend on vehicles and attempt to reorganize the various functions by "zoning" areas. All these attempts produced the contemporary unsustainable city.

The result has been achieved following the 'rational-comprehensive' approach of the plans, which attempted all aspects of plan structure and development in a coercive and detailed way, not flexible at all (Camagni 1992). Today the risk is that in pursuing the ecological transition, the attention will be concentrated on renewable energy sources in a deterministic way, forgetting the other environmental components often damaged by the installation of these plants. The considerable investments in the environmental sector can significantly damage the landscape and ecosystems. It is fundamental to adopt analytical methods to build possible scenarios and alternatives in supporting decision-makers to improve the quality of investments in the environmental field.

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FLOOR vibration serviceability problem: 21ST-CENTURY SOLUTION FOR FOR CLIMATE EMERGENCY

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Abstract

Historically, structural engineers designing buildings tended to deal with many structural design uncertainties by throwing in the past relatively cheap construction materials at them, as no better approach existed. The climate emergency means that such a practice must stop immediately requiring a radically different innovative design approach to meeting increasingly stringent floor vibration requirements. This paper identified numerous uncertainties related to floor vibration serviceability: location of partitions, walking corridors, number and activity of office occupants, future tenant's vibration serviceability needs, etc. The perception of the floor partitions generally being helpful and reducing the floor's vibration response was shown to be wrong in the paper – partitions, surprisingly, do increase response in the unpartitioned areas of the whole while reducing them in the partitioned areas. Therefore, a widespread practice of not modelling partitions is generally not on a 'safe' side as far as floor resonant vibrations are concerned. With the need to stop wasting materials and so much uncertainty about the floor vibration performance that can easily render floor vibration design predictions unreliable and useless, the new CALMFLOOR® active mass damping technology that has just been launched in the UK (United Kingdom) is potentially a *game-changer*. CALMFLOOR® can completely replace additional materials and making significant structural modifications (including shortening of the precious spans) just for the purpose of controlling exceedingly small floor resonant vibrations, that are also strongly perceptible by human occupants of the floor. CALMFLOOR® offers unprecedented levels of flexibility when managing floor vibrations as it is an off-the shelf mass produced technology that can be deployed at short notice and only at floor vibration 'hotspots' after the handover of the building and the tenant and their needs are known.

Key words: floor vibration serviceability, active mass damper, partitions

INTRODUCTION

The present climate emergency requires serious and fast re-thinking of how the construction sector operates worldwide. Construction and operation of buildings, and construction industry in general currently generate 39% of 42GtCO_2e of all annual emissions in the world. Of these 28% is pertinent to buildings (construction and operation) and 11% to the rest of the construction industry. A good estimate (Orr et al, 2021) is that 10% of all worldwide annual emissions i.e., a staggering 4.2GtCO_2e is due to – structural engineering decision making. This should be viewed in the context of the enormous size of the construction sector worldwide which creates and maintains the whole of the human-built environment and provides millions of jobs generating 13% of the world's Gross Domestic Product (GDP) (Orr et al, 2021). However, in the process of doing this, the construction very clearly also - destroys the environment.

The UN Environment and International Energy Agency (2021) estimates that the total building floor area will double by 2060 by 230bn m^2 of new floors. This is equivalent to adding one Paris to the planet *every week* for the next 38 years! This last fact emphasises the importance of building floors on the consumption of the CO_2e worldwide. On average, one m^2 of a typical building floor in a multi-storey building will require 250kgCO_2e. Therefore, to create 230bn m^2 of floors in the next 38 years a total of 57.5GtCO_2e is needed which is more than what the entire world consumes in a single year. On average, this is about 1.5GtCO_2e per year which is just over a third of the above mentioned 4.2GtCO_2e for which structural engineers around the world are responsible. This is about 3% of the total CO_2e emissions annually generated by the entire world – just to build the floors in buildings needed for the growing human population demanding more quality space.

Therefore, as floors are omnipresent and by far the most frequent type of civil engineering structure, which is everywhere, the key question is: how are modern floors in buildings designed? Considering the huge floor area which needs to be built globally, any however small waste in the embodied carbon per m^2 of the floor should be identified as it could yield to enormous waste on a global scale. Such identified waste should be tackled and eliminated through immediate change of the design or construction practice.

There are many types and classifications of building floors. Classifications exist based on construction materials (concrete, composite, timber, etc.), construction method (in-situ cast, pre-cast, modular), ownership (private, commer-

cial, mixed), type of utilisation (office, assembly structures, condominiums, retail, laboratories, schools, hospitals, gyms, etc.), and so on.

Out of all these, the commercial and assembly floors (offices, retail, airports, etc.) are particularly important as they normally consume above average CO_2e while making a considerable proportion of all floors. For example, just in the UK every year over 1 million of m^2 of new office floors is built. The function and commercial viability of such floors dictate that they tend to be open plan, long-span and increasingly lightweight. Consequently, such floors have low natural frequencies, low damping and low mass which in turn means that they are increasingly prone to vibrations caused by footfall dynamic forces due to omnipresent walking of the human occupants of such floors.

Vibration performance of low-frequency building floors responding to human-induced footfall dynamic loading, typically walking, is worldwide by far the most widely considered vibration serviceability requirement. It has rightly become a governing design criterion since it is by far the most frequent cause of the growing number of reported problems with excessive vibrations of floors what are otherwise sound structurally considering other design criteria such as strength and fire resistance. Not surprisingly, over the last 10 years, I published with my researchers and collaborators dozens of technical and scientific papers dealing with vibration serviceability of civil engineering structures, chiefly under human-induced dynamic loading, such as walking on floors. The opening sentence of such papers typically reads:

> *"With the advent of stronger and lighter construction materials and advancements in construction technology, vibration serviceability has become a governing design criterion for lightweight and slender civil engineering structures occupied and dynamically excited by humans."*

The *governing design criterion* term mentioned above means that, vibrations rather than strength considerations determine the size and shape of office floor structures. This, in turn, dictates the carbon footprint of the floor structure, which is typically accounting for 60% of the total weight of multi-storey buildings.

So, how are then the low-frequency floors designed today to avoid them vibrating excessively?

PROBLEM WITH DAMPING AND MASS

For low-frequency floors, all design guidelines around the world (Willford and Young, 2006; Murray et al, 2016) invariably assume that human walking can

cause a floor to vibrate excessively in resonance. In resonance, the calculated floor acceleration response is inversely proportional to the modal damping ratio and modal mass (Willford and Young, 2006). The latter is very much directly proportional to the physical mass.

So, it is no surprise that the crucial question when checking floor vibration performance is: what is the damping ratio? This is accompanied by a usual scramble for any shred of published or other evidence to assume a higher damping ratio and reduce the calculated response. If the damping ratio of a resonating mode can be increased from, say, 1.5% to 2.5%, the calculated vibration response will be reduced by a whopping 40%! A previously failing floor now passes with flying colours.

Interestingly, similar questions are not usually asked about the other equally important modelling parameter when calculating the resonant response – modal mass. Modal mass values are generated by a formula or computer modelling, so it is perceived to be more 'reliable' and less questionable. Modal mass comes from a calculation whereas the modal damping ratio gets assumed based on design guidelines and experience. So, there is a perception that the modal damping value is more 'flexible' to interpret and assume than its modal mass counterpart when it comes to calculating the resonant response.

However, those who – like me – spent their professional lives not only modelling but also – whenever possible – testing full-scale floors (and comparing the two sets of data) know that modal damping ratio and modal mass are together also the two most unreliable floor vibration modelling parameters. Moreover, they are quite difficult to measure and correlate with their counterparts used in the calculations. Hence, every time I use the assumed value of modal damping ratio and the calculated value of modal mass to get the floor's resonant response, I am worried about how different they could be in reality after the floor is constructed. Yet, as nothing better is available, we all keep using them in a calculation procedure that is overly sensitive to their values.

How much does good floor vibration cost?

As previously mentioned, and quite surprisingly, in the case of omnipresent open plan and long-span floors, it is not the *strength* (i.e., the threat of structural failure) but *vibration* (i.e., the threat of excessive dynamic motion) which dictates the size and shape of such structures nowadays. When I talk about this to laypeople, they are often perplexed that anything other than serious structural failure and threat to life can dictate the use of literally millions of tonnes of

construction materials and associated embodied carbon. Very often, in situations like this, I get asked a simple question: *how much more material and embodied carbon is then needed just to have satisfactory floor vibrations*?

Here is an example illustrating the answer to this important question.

Doubling floor weight to control only tiny floor vibrations

The contour plot in Figure 1 shows the plot of the so-called *response factors* (Willford and Young, 2006) due to walking over a 42m long and 27m wide (1,134m^2) floor plate consisting of nine floor panels, each spanning 14m and being 9m wide. So,

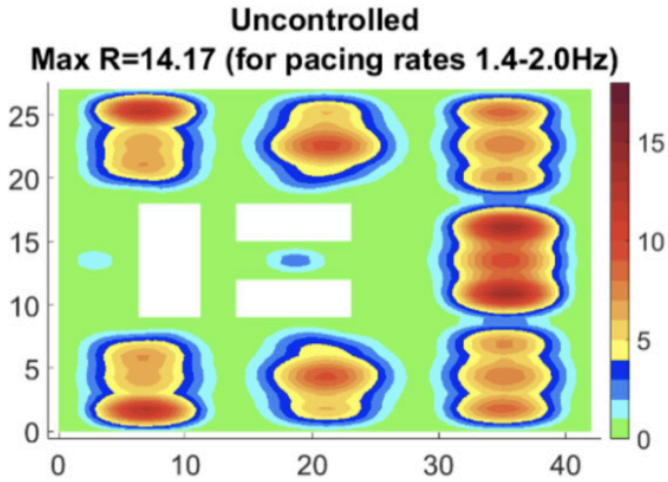

Figure 1: Uncontrolled floor designed for minimum weight satisfying all design criteria apart from vibration serviceability.

it is a typical long-span composite steel-concrete floor which can be found in many modern commercial buildings in the UK and internationally. The floor, featuring the usual 14m long secondary beams to minimise the number of beam-to-beam connections, was optimised to have minimum weight and structural depth while satisfying all design criteria (strength, deflection, fire resistance, thermal comfort, and sound insulation) apart from the vertical floor vibrations. However, the maximum vertical vibrations allowed were set to response factor R<4, as appropriate for an office in accordance with the relevant, respected and widely used international standard ISO 10137 (International Standardisation Organisation, 2007)). In the UK that would be a criterion required for a 'quiet office'. The floor's 130mm deep lightweight concrete deck, beams, and columns had an admirably low mass of 231kg/m^2 and equally very reasonable embodied energy of only 201kgCO_2e. However, as Figure 1 shows, 25% of the floor area

(warm coloured) had R>4 with the maximum R>14. The floor clearly failed the vibration serviceability check.

The usual structural modifications followed to improve the floor's vibration performance by increasing the sizes of the structural elements of the floor, while keeping the spans intact. After many iterations, again a floor structure with minimum weight and depth emerged, but this time satisfying the R<4 criterion over 99% of its area. However, the mass of that structurally modified floor almost doubled to 452kg/m2 with the total floor depth being 260mm greater and embodied carbon 30% greater just for the floor structure. The obvious consequences on the whole life cycle cost of the building, including the increases in the cost of foundations, construction, and decommissioning were not considered. Needless to say, with so much greater floor depth, a typical multi-storey commercial building featuring floors like this and with a normally limited height in an urban environment, would lose one entire usable floor level every dozen or so floors. So, the cost of structural modifications to meet the R<4 floor vibration serviceability requirements is obviously colossal and very much unacceptable. What then?

4<R<8 can and did create excessively lively floors

One often seen in practice approach is to relax the floor vibration serviceability requirement and go for R<6 or R<8. However, over the years I dealt with quite a few problematic floors with unhappy floor tenants and demonstrably with 4<R<8, which the tenants did not like. Others have reported issues with such floors as well. I have to say here that, scientifically, there is not much proper science and peer-reviewed evidence that would justify R>4 for offices. Hence, R<8 for offices seems to be driven by the obviously extremely high environmental and financial cost of meeting R<4 mentioned above. However, this fact is somewhat muted with 4<R<8 becoming a de-facto norm with an expectation that the floor will behave well. Nevertheless, 4<R<8 could attract a considerable number of complaints under certain conditions. Unfortunately, those conditions are currently not clear and require further scientific research. I wrote a paper that tried to present some available evidence about vibration problems with 'code compliant' building floors, the history of the 4<R<8 criterion and presented it at the SECED 2019 conference (Pavic, 2019).

Having all this in mind, what is then the way forward when: a) meeting R<4 criterion is prohibitively expensive, and b) not meeting R<4 can easily create an unduly lively floor attracting complaints and which is difficult to let and fix?

Figure 2 shows the contour plot of R-factors for the same, previously mentioned, unmodified lightweight floor structure featuring full-height non-structural partitions (outlined in pink). These partitions are typically present in every office, but their stiffness is normally neglected. This even though there is a growing body of published peer-reviewed evidence that non-structural partitions can completely change the dynamics of the floor rendering bare floor calculations potentially useless. This is very much the experience of anybody who witnessed a normally lively bare composite floor transforming into a well-behaving floor in the partitioned areas. Following recommendations from some recent peer-reviewed publications (Devin et al., 2015; Murray et al., 2016), the vertical stiffness of the outlined partitions was modelled using simple vertical springs.

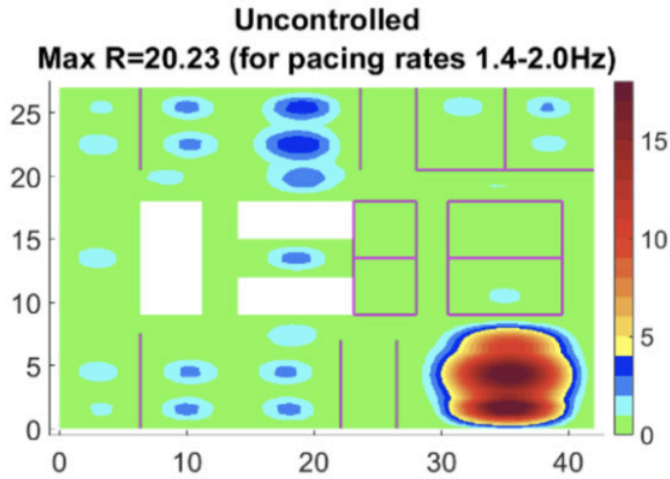

Figure 2: The original lightweight composite floor not satisfying vibration serviceability, but with floor partitions modelled.

The partitions very much suppressed vibrations in the partitioned areas, as expected. But, the partitions also *amplified vibrations in the not-partitioned open-plan part of the floor*, boosting the maximum R-factor to over 20. Although the experience is also that not-partitioned areas of the floor are known to be lively, such a significant amplification of vibration is a surprising result.

When comparing contour plots in Figures 1 and 2, the response factors in the unpartitioned area of the floor (bottom right corner) are almost 50% greater than when calculated neglecting the presence of the partitions. This means that the common belief that neglecting partitions is a 'safe' assumption may well not be correct. This may concern many colleagues as it definitely concerned me.

Other problems

This is not the only source of considerable uncertainty in the calculations of floor resonant vibrations under footfall loading. I tested an open plan floor in service with as many as 120 people working where, as usual, the calculation formulae assume that only a single person is walking and causing resonance, no matter how statistically (un)likely that is! Everybody knows occupants in such offices frequently walk simultaneously and very close to each other, very possibly causing greater responses than an individual walker. The footbridge design guidelines moved on from a single person walking model to groups and crowds walking simultaneously. They also introduced the likelihood of the pacing frequencies matching the natural frequency many years ago. However, the floor design guides are still sticking with the approach from 30-40 years ago despite the obvious unwarranted assumptions. The logic has been that one wrong assumption (resonance due to footfall is regularly achieved, overpredicting responses) will be cancelled by another wrong assumption (multiple pedestrians are neglected, underpredicting responses) and it will be OK in the end. Pass-fail criteria suitable for ultimate limit state calculations still prevail in floor vibration serviceability assessment where a more nuanced and informed probability-based approach of what is likely to happen in day-to-day operation is preferable.

Finally, the climate emergency means that it cannot be business as usual anymore, whereby the structural engineering profession throws vast amounts of construction materials and embodied energy at managing design risk and uncertainties relating to floor vibration serviceability. Increasing the mass and/or stiffness of the floor just to control tiny footfall-induced vibration of low-frequency floors is not a viable design option anymore.

BIG QUESTION

So, knowing all of this, the big question is: why do we keep designing up-front omnipresent low-frequency floor structures using uncertain structural parameters and unreliable loading models given the evidence that our approach does not always work and is definitely not fit for purpose in a climate emergency? In partitioned areas of the floor the responses are easily considerably lower than calculated and in the unpartitioned areas they can easily be much higher! Adding mass and stiffness to control low-frequency floor resonance is also plain wrong when damping is by far the most effective way of doing that. Every textbook on structural dynamics is telling us that increasing damping and not

mass and/or stiffness should be used to reduce resonant vibrations. So, here is a thought: how about we stop doing all of that?

The really big question then is: shall we start designing floor structures for everything except vibration serviceability?

In this rather radical change of the approach to designing building floors, we optimise the floor structure for the minimum embodied energy while meeting strength, deflection, concrete cracking, fire, sound and thermal comfort criteria (and wherever else, just not the footfall-induced vibration criterion). We do not consider footfall vibrations at all when deciding spans and sizing structural elements. After all, what is the point designing the low-frequency floor structure for vibration serviceability when we know that:

- Significantly more (up to 100%) materials will be needed to achieve a code-compliant vibration serviceability design. This will severely impact material utilisation and destroy the green credentials of the building design knowing that more than 60% of the total multi-storey building mass above the ground and corresponding embodied energy is in floors, as previously mentioned.
- Even when we do design a floor structure for acceptable vibration serviceability, the uncertain damping, inappropriate footfall loading model and effect of partitions will render the design calculations meaningless when compared with what is really happening on the real floor after it is constructed.

Granted, neglecting floor vibration serviceability in structural design will result in a very slender floor which will certainly be bouncy on its own under footfall dynamic loading, as shown in Figure 1. We will have a safe and sustainable, but not fit for purpose floor. What then?

Well, then the floor will be constructed and partitions and other non-structural elements (installations, facade, furniture, etc.) will come in. That will certainly improve the floor vibration performance in many partitioned areas, so much so that they will often become quite satisfactory but difficult to predict upfront. This is known to anybody who witnessed fitting out of an empty and rather lively floor and its transformation into a solid floor in the partitioned areas. The large non-partitioned areas of the floor are likely to remain lively requiring vibration control. However, this is likely to be just a fraction of the total floor area which would otherwise have required structural modification throughout, and the many millions of tonnes of steel and concrete wasted annually worldwide.

SOLUTION FOR 21ST CENTURY: SOPHISTICATED VIBRATION ANALYSIS COUPLED WITH NEW CALMFLOOR® PRODUCT

Figure 3: The 67kg CALMFLOOR AMD attached to a steel I-beam supporting a composite steel-concrete deck. Courtesy of FSD Active Ltd.

Throwing enormous amounts of steel and concrete at the problem goes against all the principles of lean design which is woefully wasteful for today's climate emergency state in which we all are and the urgent need to reduce embodied energy in construction.

There is a clear need for a new and better way to reduce vibrations in floors. After multi-£m investment in years of research and development, a UK-based start-up company FSD Active Ltd has just brought first to market a novel Active Mass Damper (AMD) to solve the problem of the lively low-frequency floor for good (Figure 3). This device is a potential game changer which enables design of very slender floor structures with no construction material underutilised and wasted or spans unduly shortened just to meet the stringent floor vibration serviceability criteria. All this, while ensuring an outstanding vibration performance of long-span, open-plan, low-frequency commercial floors that is practically impossible to achieve by any other reasonable means on the commercial marked, such as the tuned mass or constrained layer dampers.

By generating an active force proportional to the measured velocity of the floor structure to which CALMFLOOR® is attached, the innovative technology provides a huge amount of additional damping, typically providing more than 10% damping ratio in all modes of floor vibration it is controlling. This is far

beyond anything existing or seen on the market to date. When factored in at the design stage of a new building, this autonomous mechatronics device could replace tens to hundreds of tonnes of traditional construction materials, such as steel and concrete. This is due to increasing damping by 10 or more times which is equivalent to increasing the floor mass by the same amount, which is practically impossible. The CALMFLOOR technology makes it for the first time very possible now.

CALMFLOOR® AMD makes use of the simple yet underappreciated fact that walking-induced forces are incredibly small compared with all other forces these structures are subject to. And yet, despite this, the few microns of oscillatory displacement they cause are not only perceptible to humans but annoying and even sickness-inducing. The CALMFLOOR® system continuously monitors such tiny floor vertical vibrations and cancels them in a manner like noise-cancelling headphones, but on a huge scale.

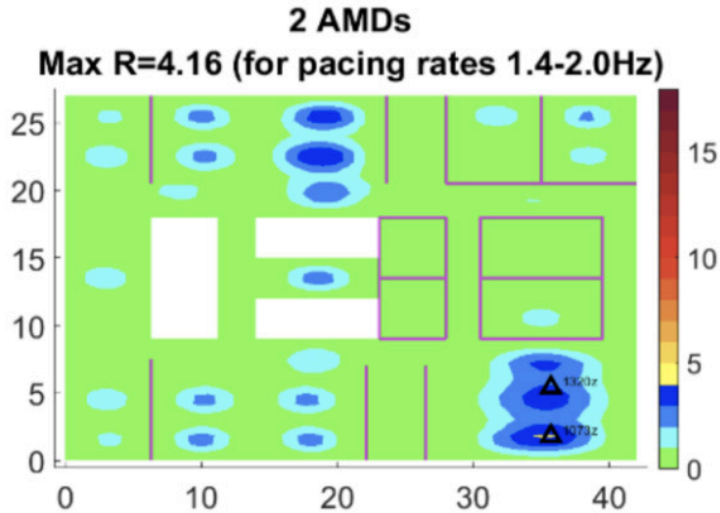

Figure 4: The original long-span composite floor featuring full-height partitions and two CALMFLOOR® units reducing the maximum R-factor from highly problematic 20.2 to satisfactory 4.2 in the problematic unpartitioned area of the floor.

The contour plot in Figure 4 shows R-factors for the structurally *unmodified*, original lightweight floor, featuring partitions and effects of only two CALMFLOOR® active mass dampers in the problematic unpartitioned area previously

mentioned and shown in Figure 2. The floor plate has satisfactory R<4 performance over the whole of its area without any structural modifications or the need to relax the vibration criterion potentially creating an unduly lively floor to save on materials. The small carbon footprint of the two CALMFLOOR® AMDs (Active Mass Dampers) (relative to the mentioned structural modification) and their competitive costs mean that realistic and objective environmental and financial costs of the CALMFLOOR® solution are many times lower than those of the structural modification to achieve the coveted R<4.

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The usual argument against an approach that involves explicit modelling of the partitions is that it is normally not clear where the partitions are going to be until the tenant moves in. The counterargument is that eventually the floor partitions will be erected and then it will be clear where the unpartitioned areas are. The 67kg CALMFLOOR® units can then be installed there causing no disruption. That can be done very easily and with the full cooperation of the tenant after they move in. This huge level of flexibility is the *key transformative feature* of CALMFLOOR®: it is new off-the-shelf technology (all CALMFLOOR® units are identical and suitable for mass production) that is dead easy to install. This is in stark contracts with other post-occupancy solutions to control floor vibrations such as:

- the structural modification, or
- installation of at least an order of magnitude heavier tuned mass dampers (TMDs) which are likely to perform less well and cost very much the same or more than the CALMFLOOR® active mass dampers.

So, combining the sophisticated modelling of partitions with CALMFLOOR® units in the remaining unpartitioned floor areas is an innovative design

approach that enables keeping long and very lightweight spans which also have excellent vibration performance impossible to achieve today by any other means.

CONCLUSIONS

Historically, structural engineers designing buildings tended to deal with many structural design uncertainties by throwing in the past relatively cheap construction materials at them, as no better approach existed. The climate emergency means that such a practice must stop immediately requiring a radically different innovative design approach to meeting increasingly stringent floor vibration requirements.

This paper identified numerous uncertainties related to floor vibration serviceability: location of partitions, walking corridors, number and activity of office occupants, future tenant's vibration serviceability needs, etc. The perception of the floor partitions generally being helpful and reducing the floor's vibration response was shown to be wrong in the paper – partitions, surprisingly, do increase response in the unpartitioned areas of the whole while reducing them in the partitioned areas. Therefore, a common practice of not modelling partitions is generally not on a 'safe' side as far as floor resonant vibrations are concerned.

With the need to stop wasting materials and so much uncertainty about the floor vibration performance that can easily render floor vibration design predictions unreliable and useless, the new CALMFLOOR® active mass damping technology that has just been launched in the UK is potentially a *game-changer*. CALMFLOOR® can completely replace additional materials and making significant structural modifications (including shortening of the precious spans) just for the purpose of controlling exceedingly small floor resonant vibrations, that are also strongly perceptible by human occupants of the floor. CALMFLOOR® offers unprecedented levels of flexibility when managing floor vibrations as it is an off-the shelf mass produced technology that can be deployed at short notice and only at floor vibration 'hotspots' after the handover of the building and the tenant and their needs are know. Compare that with the wasteful structural modifications which need to be done everywhere before the unknown tenant comes in.

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CONTRIBUTION OF NATIONAL URBAN FORUM IN SERBIA TO WORLD URBAN FORUM

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Abstract

The World Urban Forum held for the first time in 2002 had eleven sessions of the global urban forum until 2022. Based on the model of the global urban forum, national urban forums are taking place prior to the global one. Serbia is among the pioneer countries which are using this model recommended by the United Nations Human Settlements Programme in order to improve communication among national stakeholders in the area of urban development and to prepare them for the participation in the global urban forum. The experience of Serbia is shared in this paper on how the interaction of the global and national urban forum can open the way to improvement of urban development activities in one country harmonized with global recommendations. The results might be more visible in future since the first national urban forum using the recommendations from the global level was organized in Serbia in 2022 and its contribution to the World Urban Forum is still fresh and new. Further development should be observed and monitored in order to evaluate this practice and to estimate how the initial efforts are shaping future activities.

Key words: urban development, public spaces, World Urban Forum, National Urban forum

INTRODUCTION

World Urban Forum (WUF) is the premier global conference on urbanization convened by the United Nations Human Settlements Programme (UN-Habitat) held every two years since 2002. The first session of the World Urban Forum was held in Nairobi, followed by forums in Barcelona in 2004, Vancouver in 2006, Nanjing in 2008, Rio de Janeiro in 2010, Naples in 2012, Medellin in

2014, Quito in 2016, Kuala Lumpur in 2018, Abu Dhabi in 2020 and Katowice in 2022. The twelfth WUF will be held in Cairo in 2024. The Habitat III conference held in 2016 was at the same time the eighth WUF. Habitat conferences are held every twenty years since 1976. The first Habitat conference was held in Vancouver, the second in Istanbul and Habitat IV will be held in 2036 and it will correspond to the eighteenth WUF. Number of participants was increasing at WUF since the first one held in Nairobi with almost 1200 participants, reaching the peak in 2018 in Kuala Lumpur with 23 000 participants and slightly decreasing due to COVID 19 pandemics in Abu Dhabi and Katowice, reaching 17 000 participants at the WUF11.

New Urban Agenda adopted at the Habitat III conference in Quito recommends in its paragraphs 41 and 92 creation of national platforms and mechanisms for cooperation in urban development sphere such as national urban forum. National Urban Forum (NUF) was held in Belgrade on the 11th and 12th of April 2022 organized by the Ministry of Construction, Transport and Infrastructure of the Republic of Serbia, in cooperation with Standing Conference of Towns and Municipalities – Association of Towns and Municipalities of Serbia, Office of the United Nations Resident Coordinator in Serbia and United Nations Human Settlements Programme – UN Habitat. Organization of National Urban Forums is among the measures of the Sustainable Urban Development Strategy of the Republic of Serbia until 2030 (SUDSRS) adopted by the Government of Serbia in June 2019 and published in the Official Gazette of the Republic of Serbia 47/2019 and its Action Plan for years 2021 and 2022 adopted by the Government of Serbia in March 2021 and published in the Official Gazette of the Republic of Serbia 28/2021.

NATIONAL URBAN FORUM

The NUF in Belgrade had for its topic „Better future of urban settlements in the context of new public policies in the Republic of Serbia". The aim of the forum was to review key topics and activities in the field of urban development, as well as other policies within the ministry that have synergies with urban development policy: National Housing Strategy, Long-Term Strategy to Encourage Investment in Renovation of the National Building Fund (Energy Efficiency Strategy) and National Architectural Strategy. A special focus within the plenary session of the forum was on the directions for the revision of the Urban Development Strategy of the Republic of Serbia, while parallel sessions discussed special aspects of urban development through key topics supported by

the mentioned public policies: Green Agenda and Urban Development, Quality (of architecture) and built environment, and Sustainable Housing. Special attention was paid to the role of young people, women, and other vulnerable social groups in urban development, and also to the importance of exchanging experiences in the field of urban development at the macro-regional level, in Europe and globally.

The National Urban Forum, which, among other things, prepares national actors for participation in the World Urban Forum gathered many participants from the public and private sectors, academia, research institutions, civil society, economy, international institutions, and foreign participants. Conceived in this way, the National Urban Forum contributes to the establishment of a broader dialogue to better formulate and implement public policies in the field of urban development, housing, architecture, and energy efficiency, and for the forum participants to gain insight and opportunity to contribute to better formulation and implementation of urban policy. The National Urban Forum aims to contribute to urban settlements in Serbia being as sustainable, inclusive, resilient, and safe as possible, all with the aim of transforming our urban settlements for a better future, which was the theme of the Eleventh World Urban Forum.

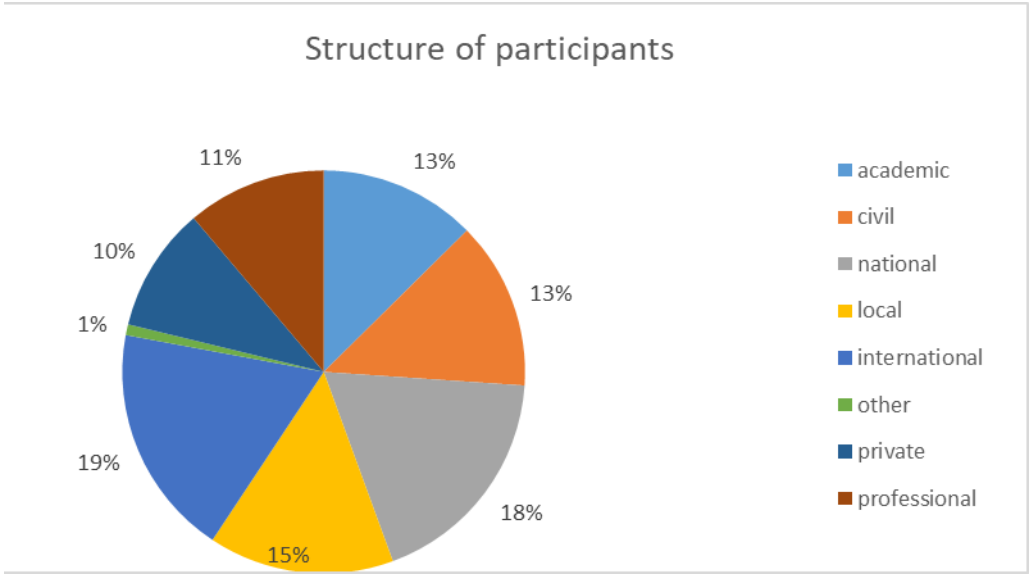

Figure 1 Structure of participants by sector at the National Urban Forum in Serbia in April 2022

Among the conclusions of the National Urban Forum in Belgrade in April 2022 the importance of dialogue, cooperation, sharing of good practices and financing of urban development from both local resources and through blending of different resources was pointed out. Common understanding of urban development topics is necessary, more involvement of academic community in the topics of urban development, challenges of urban sprawl, better quality of life and need to find the way for optimal participation of civic sector in urban development were among the conclusions of the forum. The participants of the National Urban Forum in Belgrade were invited to participate in World Urban Forum in Katowice in Poland in June 2022.

National Urban Forum in Serbia was one of thirteen national urban forums held prior to the WUF11 in Katowice based on the information available on the internet site of the WUF. National urban forums were held in Turkey, Malaysia, Israel, Spain, Cabo Verde, Guinea Bissau, Tunisia and Dominican Republic in 2021 and in Nepal, Lebanon, Serbia and Democratic Republic of Congo in 2022. The Pacific Urban Forum is a macro-regional urban forum which was held seven times before the virtual one in 2021 showing that the urban forum can be global, national but also macro-regional like for Asia-Pacific region, giving an example to South East Europe or Balkan countries which may have the Balkan Urban Forum in future. Special Session at the World Urban Forum was held on national urban forums in order to exchange and coordinate activities around national urban forums in the world.

Figure 2 Event on public spaces at National Urban Forum in Belgrade in April 2022

WORLD URBAN FORUM

The event Eleven Public Spaces in Serbia for World Urban Forum 11 and for Sustainable Development Goal 11 had six presentations:

- presentation Public Spaces for All– the first presentation gave an overview from global perspective of the topic of public spaces, pointing out main challenges such as social segregation and spatial inequality, poor planning, natural disasters and post-conflict situations, environmental health concerns, participation concerns. The shift should be made from the business as usual to sustainable urban development: compact cities instead of urban sprawl, integration instead of segregation, connectivity instead of congestion. Global Public Space Program which celebrated its 12th anniversary at WUF 11 places public spaces as key driver for change in order to have sustainable development through multi-scale approach, building partnerships and creating networks of diverse city stakeholders and disseminating knowledge and developing processes for variety of urban issues.

- presentation Public Spaces in National Urban Policy in Serbia – the second presentation gave an overview from national perspective, making link to global and European urban policies as well as to the national spatial development policy which is at the origin of the national urban development policy. Sustainable Urban Development Strategy adopted by the Government of Serbia in 2019 contains a measure on public spaces. This measure is elaborated by the activities in the Action Plan for the implementation of the Strategy in 2021 and 2022 and additional activities will be identified for the Action Plan for the implementation of the Strategy from 2023 to 2025.

- presentation Three Public Spaces in the City of Kruševac – the third presentation gave an overview of three public spaces which are in different phases of realization in the city of

Figure 3 Event on Public Spaces at World Urban Forum in Katowice in June 2022

Kruševac located in southern Serbia. The first public space is the main city square and the surrounding central urban zone of this medium sized city which is the champion of urban mobility in Serbia since it got the national prize for the year 2021 and the first Sustainable Urban Mobility Plan in Serbia was made for Kruševac in 2017. Major improvements in the urban mobility are the main characteristic of reconstruction of the central zone of the city of Kruševac. The second public space is an ongoing project for the neighborhood of Stari Aerodrom with sport facilities for the benefit of community and youth in particular. The third public space is the public park near the school center where some minor changes were made, but this space is suitable for future activities.

- presentation Public Spaces around Multi-family Building in the City of Niš – the fourth presentation gave an overview of four public spaces showing improvement of neglected green areas, exhibition of student works where the best solutions were awarded, a meeting organized with the managers of buildings where it was concluded that tenants agreed with the actions to be taken for improvement of public space, impact of informal groups of citizens and protests organized to protect public spaces, participatory improvements of urban plans which are reflected on quality of public spaces. For future we need better regulations, better procedures, better plans, better building rules and better implementation mechanisms.

- presentation Public Spaces in Belgrade - Linear Park and Park on Zemun Quay – the fifth presentation gave an overview of two public spaces in Belgrade showing the big brownfield railway site near the Danube river that is going to be transformed into the green public space based on the urban plan that was made in participatory way and the public space along the Zemun quay also near the Danube that will be realized using nature-based solutions.

- presentation on Urban Pockets in Belgrade – the sixth presentation gave an overview of two small public spaces in Belgrade with participatory approach pointing out urban identity and urban culture as well as urban gardening as tools, methods and approaches for transformation of neglected urban pockets in historic inner city neighborhoods of the capital city of Belgrade as initiatives led by civil society organizations in cooperation with local public authorities.

CONCLUSION

National urban forums are usually held prior to the World Urban Forum in order to motivate stakeholders from a country to participate to the global urban forum and to prepare the contribution of a country for the global urban forum. To support UN member countries in preparation of a national urban forum UN Habitat has prepared the guidelines explaining what is national urban forum, what are its objectives and how to set up a forum. By the guidelines it is recommended to have both Steering Committee and NUF Secretariat for the organization and monitoring of a national urban forum. The guidelines are available on-line and they can be a useful support to prepare a national urban forum. The fact that the WUF11 was the first global urban forum ever held in Eastern Europe where Serbia belongs as UN member state, it was an occasion to have better participation from Serbia at this event than usually and finally it was the case. Although official delegation was not formed for the WUF among 17 thousand participants around twenty were coming from Serbia. Representatives of all ex-Yugoslav countries were present at the WUF in Katowice. Three Caucuses on Eastern Europe were held during the WUF in Katowice, gathering stakeholders from East European countries which are not active enough in the activities of UN Habitat. The fruitful exchanges during those caucuses might give a result and rise activity of East European UN member states in UN Habitat. The event „Eleven Public Spaces in Serbia for the World Urban Forum 11 and for Sustainable Development Goal 11" was held both at the National Urban Forum and at the World Urban Forum as a link between those two vertical levels of governance, the global one and the national one. Examples of public spaces from cities of Belgrade, Niš

and Kruševac in Serbia were presented with good response of the audience at both forums.

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BASALT FIBRE-REINFORCED POLYMER BARS: ALTERNATIVE REINFORCING MATERIAL FOR SUSTAINABLE STRUCTURES

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Abstract

As the world faces the challenge of the global climate emergency, the construction industry must accelerate implementation of low-carbon technologies to meet net-zero targets. The most used construction material, concrete, is responsible for approximately 8% of global emissions. While more efficient use of materials and development of low-carbon mixes is one of the priorities, the durability of concrete structures and alternative reinforcing strategies must also be considered when designing for net-zero future.

One of the possible alternative reinforcing options are basalt fibre reinforced polymers (BFRP), a composite material with attractive mechanical properties and low embodied carbon. This paper presents the discussion of the sustainability of this material. Additionally, use case examples of alternative RC design utilising BFRP are presented. Some of the alternative designs were trialled at full-scale, as part of a collaborative research and development project led by Laing O'Rourke, an international engineering and construction company.

It was shown that BFRP bars have a potential for utilisation as a low-carbon alternative to steel. However, despite the low embodied carbon and other sustainability related benefits, the achievable reduction in carbon emissions can vary for different types of reinforced concrete elements.

Key words: Basalt fibre reinforced polymer, alternative reinforcement, sustainable structures

INTRODUCTION

Anthropogenic influence on climate change and biodiversity loss have been highlighted as some of the greatest challenges of modern age. Within this context, it is more important than ever that the construction industry, as one of the main contributors to the global emissions, re-examines the traditionally used materials, approaches, and technologies. Finding optimal engineering solutions for each application and focus on life cycle thinking is necessary to meet the net-zero carbon targets and prevent further damage to the environment.

Over the years, concrete has become the most used artificial material in the world, responsible for approximately 8% of the global emissions of CO_2 (Gibbons & Orr, 2020), largely due to cement manufacturing. Maintenance and repair works are often costly, disruptive to the local communities, and may involve the use of materials, equipment and processes damaging to the environment.

Increasing the life span and maintaining the integrity of the RC structures are some of the key challenges in the world of civil engineering, urgency of which is only further highlighted by the global climate emergency. High level of corrosion resistance is an extremely important factor in cases of chemical plants, structures in marine environment and especially for offshore structures. Even though it is possible to design reinforced concrete in such a way as to prevent the development of tension cracks, such large reinforcing percentage becomes uneconomical and unsustainable from the material usage and embodied emissions perspective, and hence not a viable solution. Other existing approaches (use of cathodic protection or stainless-steel reinforcement) are not sufficiently reliable and are often cost inhibitive.

With this in mind, one line of research is looking at the utilisation of basalt fibre-reinforced polymers (BFRP) for reinforcement of concrete structures. It is an economically competitive, low embodied carbon material, produced from a widely available volcanic rock (Inman, Thorhallsson, & and Azrague, 2017), with an excellent strength-to-weight-ratio and corrosion resistance. To prevent inefficient use of the material, which is caused by its low longitudinal elastic modulus, prestressing was proven to be an effective method, ensuring a significant increase of serviceability limit states governed capacity, even at prestress levels as low as 30% (Mirshekari, Donchev, Petkova, & Limbachiya, 2016; Pavlović, Donchev, Petkova, Limbachiya, & Almuhaisen, 2019). However, due to the novelty of material, there is much to be learned about its performance over time, even though some research into creep behaviour (Shi, Wang, Wu, & Zhu, 2015; Atutis, Valivonis, & Atutis, 2018) and prestress losses (Atutis & Kawashi-

ma, 2020; Pavlović A. , Donchev, Petkova, & Limbachiya, 2022a) has recently been conducted.

Currently, Eurocodes do not cover the use of FRPs as internal reinforcement. The second generation of Eurocodes is due to include an update to the Eurocode 2, which will for the first time include the use of FRPs as internal reinforcement. Completion of the work and publication of the second-generation documents is expected in 2022/23.

Sustainability of BFRP

Environmental Product Declarations (EPDs) of basalt FRP reinforcing available from two suppliers are listed in Table 1, declaring embodied carbon per kg of BFRP between 1.77 $kgCO_2e/kg$ to 3.14 $kgCO_2e/kg$ according to the latest update. The update to the EPD provided by Bastech reflects the change in supply chain; specifically changing the resin supplier.

Table 1 BFRP EPDs summary

Manufacturer	**Unit**	**LCA boundary**	**Result [kg CO_2e]**
Bastech (2021 - superseded)	1 kg BFRP (10mm bar)	Cradle-to-gate (Modules A1-A3)	2.56
Bastech (2022)	1 kg BFRP (10mm bar)	Cradle-to-gate (Modules A1-A3)	1.77
Orlitech/Orlimex (2021 – superseded*)	1 kg BFRP (6mm bar)	Cradle-to-gate (Modules A1-A3)	3.12
	1 kg BFRP (8mm bar)		3.08
	1 kg BFRP (10mm bar)		3.14

**due to different fibre supplier and manufacturing location; the new EPD is confidential*

Considering that the density of BFRP is nearly 4 times lower than that of steel, the comparison should not be done on mass unit basis. Independent LCA research study (Pavlović A. , Donchev, Petkova, & Staletović, 2022b), comparing volumetrically BFRP to steel (standard and 100% recycled) demonstrates that BFRP has lower embodied carbon (modules A1-A3). Specifically, Global Warming Potential (GWP) of BFRP was found to be 75% lower than standard steel and 22% lower than steel with 100% recycled content.

Volumetric comparison of BFRP by (Pavlović A. , Donchev, Petkova, & Staletović, 2022b) with corrosion resistant bars demonstrates that BFRP has lower embodies carbon than all other materials considered in the study. Specifically, the embodied CO_2e of BFRP (Modules A1-A3) is 88% lower than stainless

steel, 49% lower than galvanised steel, 44% lower than GFRP bars of the same dimensions (1m long 6mm diameter bar).

Comparison on volumetric unit basis is more useful, though not decisive, as the structural performance of BFRP reinforced versus steel reinforced units may not be equivalent. As a contribution to the field comprehensive, this paper presents potential savings which can be achieved by developing alternative design utilising BFRP for different precast concrete units.

METHODOLOGY

The information presented in this paper forms part of the Decarbonising Precast Concrete Manufacturing (DPCM), a part Innovate UK funded R&D project that aims to deliver a comprehensive feasibility study for implementing decarbonisation interventions at Laing O'Rourke's precast concrete manufacturing facility. The purpose of the project is to investigate available and emerging decarbonisation technologies, undertake feasibility assessments and develop deployment plans for those technologies.

Based on the initial assessment of alternative reinforcement options currently available, BFRP was selected for the trials, as the lowest embodies carbon option. A preliminary alternative design was developed for components of the Arup Vault Prototype and the Megaplank unit utilising BFRP. This was then used to compare the embodied carbon to the baseline design (with steel reinforcement). The calculations were conducted using EC2 aligned approach as per fib Technical Bulletin 40 for ultimate limit states (ULS), bending and shear resistance checks. Material properties used for BFRP design checks:

- Characteristic tensile capacity 1200 MPa,
- Longitudinal elastic modulus 50 GPa,
- Partial safety factor 1.40
- Density: 2.0 g/cm^3

Embodied carbon rates used in the comparative carbon assessment calculations are summarised in Table 2.

Table 2 Embodied carbon rates used in the preliminary assessment

Material	Embodied carbon rate	Source
Concrete	62 kgCO_2e/m^3	Provided by supplier (100% cement replacement)
BFRP	1776 kgCO_2e/t	EPD (UK manufacturer)
Steel	688 kgCO_2e/t	EPD (98% recycled content, UK manufacturer)

Megaplank precast concrete slab units (Figure 1) were designed based on a London-based office building project. The units are 9m long, 2.25 m wide, 175mm deep, supported on 4.5m c/c steelwork. Two versions of the Megaplank unit were considered:

- A typical unit reinforced with a single layer of bottom mesh.
- A unit with an additional 2m long hogging zone mesh.

For the trials, the headed bars were considered as steel bars in both the baseline and the alternative design, as headed basalt FRP bars weren't available on the market.

Figure 1 The Megaplank precast unit

The Arup Vault prototype (Figure 2) is an innovative, lightweight compression shell-based reinforced concrete floor system optimised for precast manufacturing. The design assumed ultra-low carbon concrete. It spans over a 9x9m grid, and it is comprised of:

- A compression shell consisting of 9 rectilinear panels. Each panel is 3x3m, 100mm deep.
- Perimeter tension ring consisting of 4 tie beams. The beams are 9m long, 200mm wide, variable height 300mm – 650mm.
- Columns with a square 485x485mm cross-section.

As the structural codes recommend that compressive load bearing capacity of FRP bars should be disregarded, an alternative design for the Arup Vault slab and beam units only was developed.

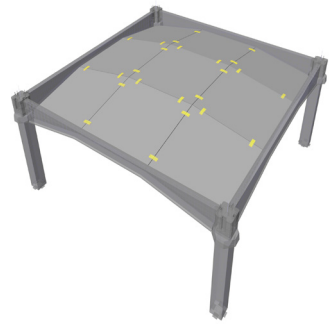

Figure 2 The Arup Vault Prototype 3D model

RESULTS AND DISCUSSION

Summary of the indicative preliminary alternative reinforcement and baseline reinforcement for each of the units considered is presented in Table 3.

Table 3 Summary of baseline and alternative indicative reinforcement of units

Element	**Baseline reinforcement (steel)**	**Alternative reinforcement (BFRP)**
ARUP slab	B8@200 mesh	6@125 mesh
ARUP beam	4B25 (main tensile) + B16 (cranked and L bars) 8@200 shear links	4Ø18 (main tensile) + Ø8 (cranked and L bars) 8@200 shear links
Megaplank (single layer bottom mesh)	12@150 + 8@200	8@100 + 8@300
Megaplank (with hogging zone mesh)	Bottom: B12/16@150 Top: B12/16@200	Bottom; 10/10@125/100 Top: 8/10@300

For the Arup Vault Prototype units, the preliminary carbon calculation comparing the alternative design to the baseline design with steel reinforcement indicated:

- For the slab units, 42% saving on the reinforcement embodied carbon, which translates to only 6% overall savings on the embodied carbon of the unit (including ultra-low carbon concrete)
- For the beam units, 72% saving on the reinforcement embodied carbon, which translates to 45% overall savings on the embodied carbon of the unit (including ultra-low carbon concrete)

For the Megaplank units, the preliminary carbon calculations comparing the alternative, BFRP reinforced option to the baseline steel reinforced option, indicated:

- For typical units with a single layer of mesh, approximately 56% carbon savings can be achieved on the reinforcement embodied carbon, which translates to approximately 11% overall savings (including ultra-low carbon concrete).
- For units with an additional top layer of mesh, approximately 67% carbon savings can be achieved on the reinforcement embodied carbon, which translates to approximately 22% overall savings (including ultra-low carbon concrete).

Based on the results of the carbon assessment, it was decided to go forward with manufacturing trials of basalt FRP reinforced version of the Arup Vault beams, and basalt FRP reinforced version of the Megaplank unit with additional hogging zone mesh. A structural testing programme incorporating all manufactured BFRP reinforced units is currently under development.

CONCLUSIONS

Basalt BFRP is a composite material with promising mechanical properties and decarbonisation potential. Although the environmental performance of BFRP bars, on a volumetric basis, is superior to other reinforcing bar options, the carbon savings achievable in a concrete unit may vary significantly depending on the type of elements. Specifically:

- Between 42% and 72% saving can potentially be achieved on the embodied carbon of the reinforcement.
- The carbon saving on the overall element (assuming ultra-low carbon concrete) was estimated to vary between just 6% and as much as 45%.
- The largest saving was indicated for a tie-beam unit, whereas the lowest saving was estimated for a compression slab unit.

The combined evidence gives further reassurance to the suitability of BFRP for developing sustainable and durable concrete elements when an appropriate use case is selected.

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AERIAL MOBILITY: FOR URGENT INNOVATION AND SUSTAINABLE APPROACH IN AIR TRANSPORTATION

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Key words: Aerial mobility, EVTOL, Sustainability, Air transportation, Sustainable Aviation, Innovation, aerial mobility, Intermodality, Radical, Shift, Point of view, Victor Papanek, Belgrade Airport, Solar Plant, Heating Plant, Waste plant, Self-sustaining infrastructure, Autonomy of energy.

INTRODUCTION

Since the dawn of commercial aviation in the 1920's the popularity of air travel has grown until an insatiable rate. With technology, design and enhanced fuel efficiency were allowing commercial aircraft to fly faster and cheaper than to any point in the world, curves of growth seemed unstoppable.

As a result, destinations around the world were under pressure to expand their existing facilities or to construct large new hubs. All this, and even though transport and construction are responsible for over 50% of greenhouse gas emissions each year. And these sectors are acutely exposed to the risks arising from climate change.

With state-of-the-art facilities, automated systems, artificial intelligence, vast construction project teams and design of many prestigious engineering and architectural offices, everything pointed to a new era in aerial mobility.

Until March 2020, where none of these assets was operational.

Pandemics showed that aerial mobility was not only providing growth to the economies but also a large part on environment damage (which, at the end, was the communication channel that facilitated the virus transmission to spread in the way it did). Pandemics showed that Air Mobility was so fragile and that needed to be reinvented into a more sustainable / resilient way of transportation.

The following paper will seek to discuss about innovation approaches in the world of aerial mobility to improve sustainability and reduce carbon emissions. Also, we will speak about other emergent types of aerial mobility such

as EVTOL (Electrical Vertical Take-off and Landing and their potential to re-configure our use of the land without heavy infrastructural interventions and examples like Belgrade Airport that have recently implemented self-generated energy productions.

Back to the ground, approaches like the implementation of Inter-modality, new policies, and new technologies to reduce carbon footprint, communication and sensibilization are also important items. During the lecture, we will explain how airport concepts were before covid 19-and failed- and the new ambitions which are leading airport industry to turn green (for example, designing terminals with no HVAC using bioclimatic approaches, terminals integrating more public areas with multipurpose functions, airports contributing to cogeneration of energies in the city, social interest of airports as communities' actors etc.).

Aerial Mobility – Check-in

Figure 1 David Plunkert "Thinking, fast and slow" The new York Times, November 25, 2011

Our office, 1PAX (which means One Passenger) designs projects that are related to demography and its movement. We must synthesize the demand for a program that seeks to "process" an unstoppably growing population. All that, happening within buildings - or infrastructures- that we shall consider as long-term time-spanning: This fact means that are not made for now, but for the needs of the future. We design Master Plans, airports and terminal buildings, train and metro stations, electric bus networks, and cyclable and pedestrian mobility facilities. More recently we have been asked to design experimental terminals for taxidrones, so called EVTOL (Electrical Take-Off and Landing): A type of aircraft- drone- capable to transport up to 4 persons using 100% electrical power.

Nowadays, we are designing the building prototype for the process sequence of arriving and departing passengers. In 2024, official date of the public launch of operations for the occasion of Paris Olympic Games, it will be possible to book a taxidrone flight from CDG airport to the heart of Paris in Gare du Nord.

We try to conceive all our projects as public spaces where the experience of the individual at the human scale is fundamental. On a wider extent, this approach tries to measure the ecological impact of these individual on the territory. Because yes, our main statement is that the human scale is the most sensitive to the living since it is the only one capable of perceiving it, and the only scale that gives the opportunity of a radical change of paradigm. Proof of this paradox, pandemics, were clearly a demonstration that the human scale affects directly and proportionally the transportation industry and all the others. Interlinked, not embodied one into the other, human flows act over the territory, in the words of Deleuze, like a "continuum" (*).

(*) Term borrowed from "The Fold" – Gilles Delleuze and Felix Guattari.

Figure 2 Conceptual Graph by 1PAX – inter-linked scales in a continuum.

So, there is no choice: Besides concrete actions and commmunity sensibilization (thinking "fast"), innovation, innovative thinking and innovative technology (thinking "slow") are the only responses we have for the moment to face the urgency of climate change. Our responses will therefore consist not into an

real reinvention but into a radical change of point of view of our way to inhabit the aerial territory.

*Figure 3 *Radical change of perspective / 1PAX Architects : Same object viewed from a different angle (DELLEUZE ,Cours Université Paris 8: Le point de vue, le pli, Leibniz et le baroque)*

The tools to predict people's movements were currently based on current statistics: **it is what people do now, not what they will do in the future**, what is shaping the "future" mobility. The technical word for this is "Forecast": We assume that 10 or even 30 years from now, people will continue to use transportation facilities the same way they do now. Furthermore, we stick to the fact that the human population will increase... and so will mobility: exponentially, irreversibly towards the highest level of connectivity possible, since that is the curve and trend of the homo sapiens. If one change overcomes (like the coronavirus Case 0 in Wuhan) the forecast failed: Now, we know that our tools are obsolete and always were.

X RAY IN AIR MOBILITY

For example, let's take air mobility with some numbers: The aviation industry carried a new record of 4.1 billion passengers on scheduled flights in 2017, according to provisional figures released by the International Civil Aviation Or-

ganization (ICAO). The world population in 2017 was estimated at 7.55 billion people. That means that in 2017, 53.4% percent of the world's population took a plane. Growth expectations in 2016 were up to 6% per year.

We are talking about billions of aircraft movements: 2017 was the first year that Cargo (Freight) flights surpassed passenger movements in the history of aviation, which leads us to link, more than ever, supply and travel. Without Freight and World Imports and Exports, our lives will not be the same!

And our numbers get better. 2018 far exceeded the results of 2017. Air traffic growth reached 7.5%. In total, the world's airports accommodated 8,277,676,508 passengers, 118,612,750 metric tons of cargo, and 95,772,011 aircraft movements (source: Airports Council International ACI 2018 edition of its Annual World Airport Traffic Report WATR Official Data).

To imagine that number of people, we can imagine 25 times the entire population of the United States of America taking a plane at least once in 2018.

Pre-Covid baseline forecast seemed unbreakable. And post-Covid and war in Ukraine events are not less astonishing. Air Mobility has become very difficult to predict.

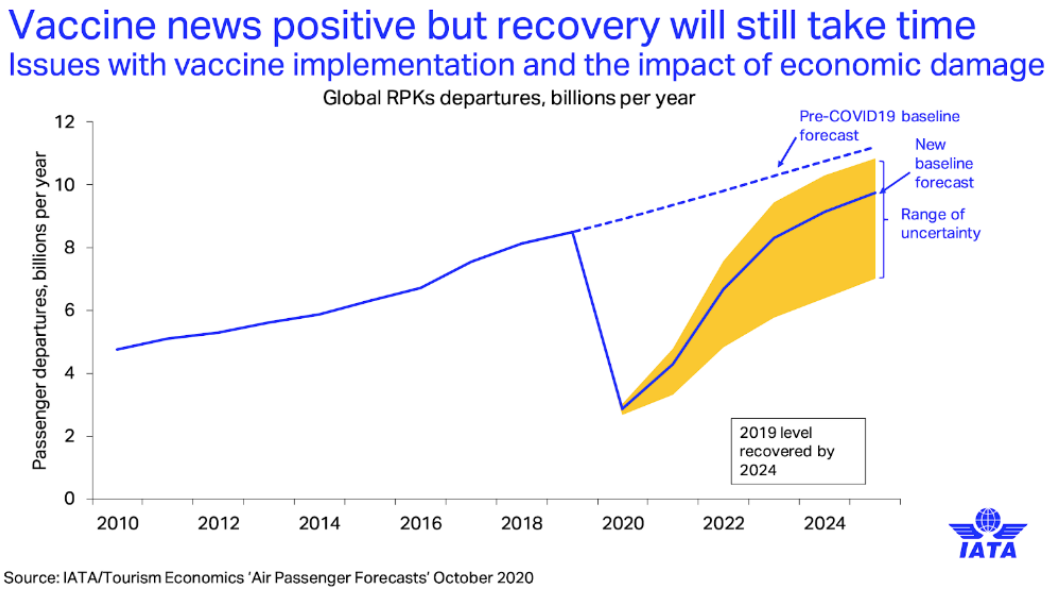

Figure 4 Comment: Economic damage is quoted but not the ecological damage. This topic is always absent on all IATA communications. "Recovery" refers to the recovery of the aeronautical industry, not the environmental one. (IATA : International Air Transport Association)

PASSPORTS CONTROL: IDENTITY CHECK

Technology and hyper-connectivity show with reliable data that the paradigm of the purpose of mobility infrastructures is changing to another level, much deeper. What used to be a matter of medium / vehicle / economic exchange, is becoming a sociological translation, accelerated by remote work. It would not be exaggerated to say that the "passengers" (the passengerness) and "drivers" (the drivingness) evoked by the researchers from the Knowledge Discovery and Data Mining Discovery (KDD Lab) would even lead to rethinking **the economic and social level of people**. Whether one is a "returner" (like a commuter) or an "explorer" (two categories of transport users) says a lot about human mobility patterns and provides us with unexplored clues thanks to the visualization and collection of digital data from individuals. This perspective, unsuspected and resolutely a product of capitalism, leads us to think of **nomadism** as another type of wealth.

It is because of this trend that the definition of "design of infrastructure" is not enough to change or save the world from the impact of an exponential human population on the move, especially an aerial one. Designs will survive the reality of construction materials, weather conditions (and the climate changes we have been observing), people's behavior regarding these multiple changes, and intensive use. Happily, the fact is that Design can only change its way of Designing (Papanek), is a great relief to tell the truth when we recapitulate all the facts that we have evoked. We may sound a bit cynical saying this – and It is not original as we are paraphrasing the famous architect and theorist Rem Koolhaas – but we don't want to be condescending. It would be condescending if we said that the destiny of Design can only shape the directions that all of society or power imposes on it, as well as its consumption or marketing rules. We need designers thinking out of the box.

Aerial mobility is conditioned by all these new behaviors that will shape its Design and its Design will reshape human behaviors again. We call this "inter-adequation".

As an example, Antoine Picon, (Author, Harvard Professor, renowned French researcher) wrote about ornamentation and how it had manifested to a monumental, even structural and societal scale, in the same way than this "passengerness" phenomena does. The perspective of considering infrastructures as ornaments at a territorial scale seemed pertinent and sadly true: the political impact of monumental adornment is not only a fact but appears as a mark of the political fact itself. In our professional career as an infrastructure designer, we

have seen many cases of ornamental planning, that is, without any technical support to corroborate its real need or development program, nor the environmental impact studies that should be almost mandatory for each project. In the words of the critic Deyan Sudjic , author of the book The Architecture of Power, "Understanding what motivates us to build, and also the elusive relationship between architecture and power, is basic to understanding our existence…(sic) it reflects our vanities and aspirations, our weaknesses and ambitions, as well as our complexes". We do not intend to illustrate this point by recalling the megalomaniacal projects of Hitler, Mussolini or Saddam Hussein, which are self-explanatory.

Identity is a real important factor to be taken into consideration when we speak about Air travel. Because the real exchange currency in airports to go from one location to the other is first, psychological, and only then, economical: Those locations are not only geographical but above all **ontological**. The airport territory(ie)s connects our body and brains to the stratosphere, inside aerial wall-less corridors drawn over Planet Earth. Stratosphere is carved by aircraft containing billions of passengers… transporting dreams, currencies, futures, pasts, healths, injuries, freight, homes, and many things more.

And the next wide question we asked to ourselves: Can we stop humans from being Passengers cumulating Tons of CO2?. We believe that the answer is No, it is too late. Air transportation has become a prosthetic for the life itself.

BOARDING—DAYDREAMING OF CLEAN PLANES, DRONES AND INHABITING THE EARTH WITHOUT DAMAGING IT

We have to embrace all the layers of this multiple personality disordered infrastructure: Airport-Machine, Airport-City, Airport-Pain, Airport-Shield, Airport-Toy, Airport-Dream, Airport-System, Airport-Business, Airport-Landscape. Unsurprisingly, we can assess the continuum we previously mentioned: airport users and aircraft industry have the same disorders.

While we wait for a solar, hydrogen or bio-fueled aviation, we are assisting to the arise of a new way of transport: the electrical air mobility, represented by Drones or better called "EVTOL" (electrical take-off and landing).

On that aspect, drones are perhaps an interesting option to innovate regarding Air Transport, so far thought as a collective way transport. Experts, gurus and start-ups CEOS say that it will become more than a transport: A device as common as a car or a mobile phone. A new kind prosthetic.

The Massachusetts Institute of Technology program "Beyond Smart Cities"; instructed us brilliantly about the potential of drone mobility, not only to improve the way of inhabiting the ground, but also a new way of development for countries that don't have existing infrastructures.

It is known that drones can be used for many things other than to deliver Amazon's orders: For example, Sir Norman Foster foundation called Droneport, seeks to promote the use of the electrical drone, which compared to other infrastructures, represents a more affordable solution. They can transport medicines, vaccines, blood, refugee first-aid kids, construction materials, educational or even agricultural material. Watering in the fields is currently being tested in Rwanda for example.

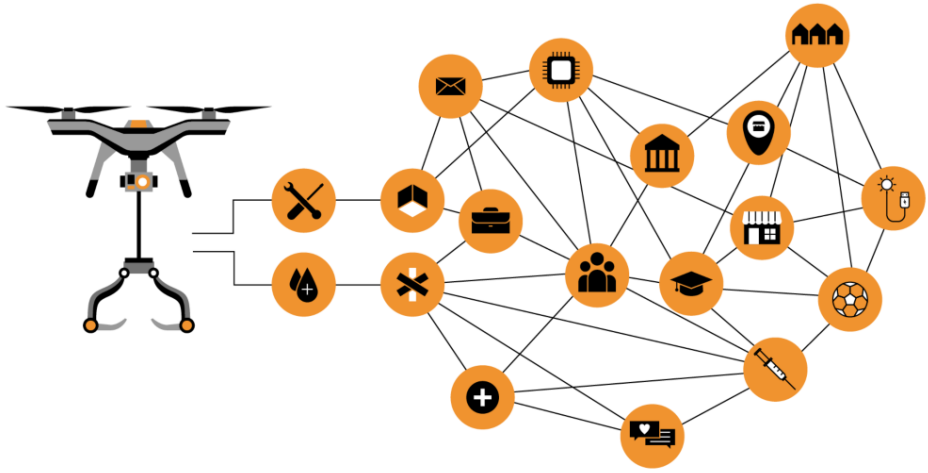

Figure 5 Norman Foster's uses of Droneport Program Uses

Regarding human transport, currently EVTOL aircrafts are being developed to the stage of functional prototypes. We found two types:

1) Personal EVTOL :

Figure 6 It is literally like a personnal flying car. Brands like Jetson from Sweden are currently commercializing aircrafts with prices that are less than a Mercedes Benz. Productions are sold out until 2024.

Home | Jetson - Personal Electric Aerial Vehicle (jetsonaero.com)

2) Collective EVTOL – air taxi

Figure 7 Volocity – by Volocopter. Volocopter and l'ONERA - The French Aerospace Lab, Paris Region, Ratp, Group ADP and Skyports are working to release and create new protocole accepted by Civil Aviation Authority allowing routes for Taxidrone.

UAM (Urban Aerial Mobility) is the latest trend regarding innovation and clean energy aviation. 1PAX has been selected by Skyports, start-up based in the UK, to design and deliver Europe's first full-scale testbed at the Cergy Pontoise Airfield, Paris, France. The site will be used by Skyports and leading vehicle manufacturers (Thales, Volocopter) for testing and demonstrating flight operations, ground infrastructure, technology integration, and the passenger experience (biometric and seamless readers provided by SITA).

Figure 8 Projected Vertiport – 1PAX

Figure 9 Vertiport under construction – 1PAX

Figure 10 Aerial View of Departing Aircraft Pod – 1PAX

TAKE-OFF: BELGRADE AIRPORT'S STEPS TOWARDS CONCRETE SUSTAINABILITY

1PAX designed the architectural proposal for the extension of Nikola Tesla Airport which from the very start, showed a strong will to be part of the sustainable transformation of air transportation. We provided the dimensioning, elaborate the airport planning report, and propose an architectural and urban response for the platform and its buildings. We contributed to the elaboration and design of the Concession Project. The following video (made by 1PAX) is the official communication of the airport regarding this project:

https://youtu.be/qjYdYoq2938

Belgrade Airport on this sense is a good example of what it is possible to do to reinvent an infrastructure with the "already-there" conditions and how to foster them with intelligence and a long-term vision:

- First, to reuse the existing facilities without demolishing and envigorate the existing environment (Museum of Aeronautics and Cycle lanes near the airport and Radiofar for example)
- To eliminate the impermeabilization of the ground as much as possible while increasing the existing one.
- Site buildings' construction shall be recyclable and easy to dismantle to liberate the ground once the works are finished.
- To use materials that are available and close to the site to reduce materials' eco-footprint.
- To foster electrical mobility (shuttles) and share of mean of transport.
- To produce its own energy: creation of a new Heating and Solar plants that will make the Airport autonomous in energy and self-sufficient.
- To clean the waste: Belgrade airport has also proposed the construction of a waste plant treatment on the ultimate phase.
- To reinvent the image of the Airport and its representation: Shall reflect Serbian identity and use its image to communicate environmental benefits (facades with CEFAR system, solar filter).
- Belgrade Airport put into operation a new solar plant (first in Serbia) that will produce approximately 1,130,000 kWh of green electricity annually, which is comparable to the annual consumption of about 430

households. In this manner, the airport's CO2 emissions will reduce direct and indirect emissions and will be decreased by 900 tons per year.

- Energy Plant: A new energy plant for production and distribution of the heating and electric energy has been put into operation. Using more environmentally efficient energy sources and switching from heavy fuels to natural gas, the new heating plant provides the benefit of reduction of environmental impact.

Figure 11 Heating Plant – Courtesy of Vinci Airports

Figure 12 Solar Plant – Courtesy of Vinci Airports

The new plant has 44MW of total heating capacity and is equipped with a state-of-art trigeneration system for production and distribution of the heating, cooling, and electric energy. The total heating capacity of the airport has been increased by 25%, thus covering all the needs for thermal energy not only of the current customers, but also of the future ones, as envisaged by the planned development of the airport, while the carbon footprint has been reduced by 25%, or equal to the reduction of green-house gasses by 3,000 tons of carbon-dioxide. The provided solutions and the choice of equipment helped achieving greater efficiency in the production and distribution of thermal energy. This system, together with the smart Building management system (BMS) will ensure an optimized energy consumption .

IN the words of Francois Berisot, Belgrade Airport CEO : "The new power plant for production and distribution of the heating and electric energy, in addition to decreased environmental impact on global warming and local air quality, provides great savings, both for the Airport and in terms of utilisation of available natural resources. Extensive works on airport modernisation and reconstruction include significant investment into environmentally sustainable business, realised to reach one step further in environmental impact reduction in terms of greenhouse gases, water and waste".

As a reminder, in December 2020, Belgrade Airport joined the Airport Carbon Accreditation Program (ACA) and Nikola Tesla Airport obtained a Level 1 certificate. This is only the beginning of implementation of the projects related to sustainable business operations at Belgrade airport as 1 MW solar power plant, two solid waste processing plants and a wastewater treatment plant are in its final phase.

Last but not least, the AIRPACT program: The Concessionary of Belgrade Airport and other 79 airports in the world, has created the AIRPACT program to limit the future consequences of climate change, by setting an ambitious target to cut its gross emissions.

Concessionary goals include 2 main targets for direct emissions:

FOR 2050**: NET ZERO GREENHOUSE GAS EMISSIONS.**

FOR 2030: 50% of reduction of greenhouse emissions (concession, compared to 2018)

And for indirect emissions, reduce of 20% the emissions produced in 2019

Regarding the construction of Belgrade Airport Expansion, it was performed: On the worksite facilities

- Perform energy efficiency assessments on and implement appropriate initiatives, such as thermal renovation, temperature control and eco-design
- ncrease the use of highly energy-efficient worksite facilities

Renewable energies

- Prioritize the use of renewable energy, especially by installing solar power systems to produce electricity for self-consumption. Power solar plant in the airport is the first one built in Serbia.
- Heating and Solar Plants creation, waste plant to be implemented at the end of the concession.

In terms of Indirect emissions:

Incentivize new customer solutions

- Applying environmental actions for customers to reduce their carbon footprint: sustainable emphasis in the construction solution, energy efficiency, sustainable mobility, waste and recycling sensibilization,
- Developing products, services and expertise in renewable energies to contribute fully to the energy transition and improve the energy mix of the future.
- Encouraging users to switch to low-carbon options for example, expanding electric vehicle charging capacity, carpooling facilities, multimodal hubs, express bus services and shared shuttles. Some airports adjusted the airport tax charges based on aircrafts' carbon emissions, contributing to developing sustainable biofuel and hydrogen systems.

Eco-design

- Developing tools to quantify carbon impacts of projects during the bidding phase in order to propose low-carbon alternatives.
- Implementing low-carbon strategies in architecture and engineering (Design approach).

- **Creation of the Airport Environment "Home" within the facilities to inform and sensibilize the community to global warming.**

CONCLUSIONS – HOW TO ACT

Building new airports shall be our latest way to resolve Growth. Reuse and reinvent existing airports, while increasing its performance and capacity is the major challenge for the airport of the future. This aim takes all our creativity and occupies all our effort and time.

And, at the same time, time is to innovate and to think out of the box. The passenger's must modify the narrative and his way to experiment air transportation. This is a key trend and a must for the years to come.

In the meantime, extend airports lifespan as much as possible by integrating smarter ways to use the facilities is a valuable strategy that will have meaningful results on the reduction of the airport's environmental footprint on the short, mid and long-term strategical planning. Preserve and create Identity, cultivate sustainability, boost economic growth to allow autonomy and not the opposite, ensure efficiency and operational excellence, raise the customer quality of service, design for expandability and flexibility while providing security and safety within the facility. The new airport terminal, as the old, will bring more development to the country, new jobs, but withmore dynamism in the economy and the impulse to the destination's sustainability and attractiveness.

But, this time, the airport of the future will share its potentials with the local activity and will boost ecology in the regions they serve. They shall not be (anymore) disconnected from the territory they occupy. They shall serve local economies. They shall help local business to progress. Besides their numerous and operational constraints, they shall be considered as part of a connected and alive landscape (human and natural) and shall contribute to the preservation of open and green areas. Implementing extensive green fields is the central core action on the reduction of global warming effects. The importance of these areas can be tangible from their contribution to the decrease of heat (radiation), glare, possible water collection, noise, and pollution reduction to zéro, maintaining biological mobility (plants and animals) and natural watercourses, …and even the increase of the customer well-being within the process. Green areas are more and more used as an alternative to public inner spaces within the terminal processes and even used as anti-pollution devices inside some European terminals.

All these aims combined, we believe that the identity of the airport shall be maintained and at the same time reinvented to communicate a more ecological statement jointly with a renewed and more efficient facility. Translated to an architectural envelope, the new airport facilities will reflect the use of sustainable solutions, not only environmental but also strategical.

Indeed, with all these actions combined we are not "fixing" 100% of any problem, but we are working to solve maybe the biggest one : the passivity. We shall turn to be part of the solution and not only the main problem.

The answer to the unsolvable problem of air transportation sustainability might rely in the human capacity to think fast (pragmatic) to implement actions from now, AND also thinking slow (imagination) : Fast, we can activate solutions with the present means. Slow, we must innovate, try, dream, change, design our future.

One without the other would not be truly humanistic. Our task shall move both fronts until reaching zero emissions. No less.

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URBAN TOOLBOX AND CITY ACTION LABS: APPLIED SPATIAL RESEARCH IN CONTESTED URBAN LABORATORIES

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PERIPHERY OR HOTSPOT: THE GEOPOLITICAL ORIGINS OF SARAJEVO'S LOCAL URBANISM

The reference in the title of this chapter to the "non-aligned city" is to the city's contested geopolitical landscape and the cyclical temporalities of conflict and prosperity that have become a permanent *modus operandi* of its local urbanism. Sarajevo's intense volatility, in terms of alternating periods of societal progress and intense destruction, has become an evident explanation of the discontinuous trajectory of its development. The variety of value systems, together with their visions, modes and concepts, has influenced the development of the city which has absorbed elements of each, synthesising them into a melting pot of both synergetic and contradictory architectural styles, programmes, building techniques and urbanistic paradigms.

Sarajevo can, therefore, serve as a litmus paper for understanding the local spatial implications of geopolitical shifts. This particular local spatial evidence, as a result of the described drivers, mechanisms, phenomena and forces, makes Sarajevo a laboratory from which it is possible to derive, extract and explain fundamental societal and, therefore, urban transformation processes.

The role of Sarajevo in 1914, as an "emitter" of geopolitical inflammation to the world, was concisely described by Susan Sontag: "the 20th century started in Sarajevo". The result, a "century of war", as put together by Eric Hobsbawm, accelerated the global epidemic of modernism, disproving Francis Fukuyama's prediction of the "end of history".

Sarajevo is still in a phase of post-war reconstruction and transitory economic liberalisation that has resulted in a semi-intentional case of resilience and

urban transformation under the forces of globalisation. The current post-socialist epoch has added a dimension of strong ideologies and weak institutions, paired with civic action in respect of an already historically complex cultural condition.

All of these factors have had an impact – and continue to do so – on the everyday lives of the people of Sarajevo who have mostly remained in their city regardless of which ruler arrived: Ottoman sultan; Austro-Hungarian Emperor; or Yugoslav king. The population of Sarajevo constructed ideas and produced knowledge within the context of their own political material, code and practice. The resilience and permanent reinvention of Sarajevo's urbanism is a result of a continuity of the transitions of its societal and urban model. It offers responses on how institutions and professionals should deal with the world that operates beyond the stable state when public institutions close, industrial production stops, commercial activities halt and the transportation system collapses. The "lesson from Sarajevo" is significant and needs to be told to a contemporary global society which is overwhelmed due to the interplay between political populism, economic crises, globalisation, climate change and social exclusion – especially today in the era of the "urban planet".

Just as Mexico City's cityscape serves as a real-life "Potemkin's village" stage, a film set simulating aesthetics and ambiance for more than 20 cities worldwide, Sarajevo's urbanistic bricolage and its radical transformations can be extrapolated to a series of urban conditions that are overseen within current global city networks based on uncritical information production and consumption.

Many cities today highlight the importance of local communities in the decision-making process. Sarajevo, with its structure of MZs that dates back to the time of socialism, is under pressure from various (geo)political and economic interests. The maintenance of public space, social cohesion and urban ecologies has been neglected on account of fostering a culture of consumption for tourists and high-income groups. This has not only contributed to individualism and the rise of a personal car culture (which is largely responsible for the infamous branding of Sarajevo as the most polluted city in Europe) but has created gentrification and spatial exclusion that led to the "Bosnian Spring" in 2014 as well as to similar protests in other European cities such as Barcelona, London and Berlin.

Figure 1: Reactivate Sarajevo Now Pavillon at La Biennale di Venezia in 2016,

METHODOLOGICAL BASIS AND CONCEPTUAL FRAMEWORK

The Urban Toolbox represents a repertoire of urban instruments and empowers to critically reflect on the urban environment with knowledge to navigate between theory and practice. The tools is used as a basis for reading cities and recognizing in them current operational modes, models and phenomena.

The Urban Toolbox promotes a critical and analytical, research-based approach on crosscutting scales and timelines by offering a methodology that respects the political, socio-economic and ecological components of urban design and planning. Through this lens, and with our Toolbox, we aim to tell the fundamental story of contemporary cities. The course provides information, analysis and knowledge to help especially students and young professionals to prepare for their own justifiable interventions in the future.

More specifically, in the process of developing the Tools and Toolbox, we look at how urban plans, instruments, visions, political decisions, economic reasonings, cultural inputs and social organization have influenced urban settlements in specific moments of change in cities that are exemplary in illustrating how these instruments have been implemented and how they have shaped urban environments. Moreover, the tools and cities be being compared and put into a system rather than a database showing unusual connections and fostering the transfer of knowledge among cities and Tools.

The City Action Lab is a format that seeks to produce Tools for the Urban Toolbox by analyzing and understand the various built and social layers that have manifested themselves in cities. The City Action Lab speaks to understanding the city, and making that information accessible to ensure that conflicting narratives catalyze conversation and not turmoil. The City Action Lab is hands on, and intends on encouraging and involving various stakeholders - the munic-

ipality, the planner, the architect, the citizen – in one conversation. From this mixing pot of various perspectives of experiencing and reading the city, everyone involved has the capacity and potential to act. The Action part is equipped with simple media that every participant can use. The strategies and ideas that emerge from these communicative collaborative relationships hold value and are ever-growing, in response to an ever changing and non-static context. Just like the Urban Toolbox, the City Action Lab results are online accessible and open to the public. It will encourage virtual interaction in order to aid spatial manifestation.

PROPOSITION: REACTIVATE SARAJEVO URBAN TRANSFORMATION NITIATIVE

To imagine the entire world reflected within one city is almost an impossible project. Many large metropolises try to position themselves as being open to all cultures and people. Sarajevo, by contrast, is a small city which has historically attempted to maintain a peaceful coexistence between cultures – one that has often been challenged in a destructive way. Today, Sarajevo is overwhelmed by a lack of coordination and by permanent discord between international spheres of influence and the needs of local stakeholders in striving to achieve solutions that reflect democratically defined interests and which share a common perspective on future development. Sarajevo's unique urban laboratory should move from its current status as a victim of geopolitical shifts but use its "non-alignment" to foster neutrality and non-partisan thinking for the benefit of its local communities in order to recover, amplify and reactivate its resources.

Realising these issues, I was searching for platforms on which the great problems of Sarajevo can be resolved – how architecture and urban design can become a tool for societal change. I was inspired by the philosophy of the ETH Zurich Chair of Architecture and Urban Design that seemed relevant for addressing post-conflict Sarajevo – becoming both a researcher and an activist-architect, aiming to define a brief for the future development of Sarajevo – a participative, alternative model that will implement the results of my doctoral research.

But how should that dissertation contribute to challenging the current urban model of Sarajevo?

All these challenges culminated in my decision to focus my approach, moving away from a mere theoretical position, and to shape my work in Sarajevo largely around the "Reactivate Sarajevo Urban Transformation Initiative", at the

intersection between academia and theory, activism and practice. This motivated me to work on an applied research model and engage in how to improve the precarious conditions of my city. Therefore, the Reactivate Sarajevo project I initiated in 2014 comprises a set of activities that form an alternative *modus operandi* – aiming to deploy urban intelligence in the real world.

This work-in-progress is oriented around three main areas of output:

- Digital Urban Planning Tool as a citizens-friendly interface aiming to enhance usability and establish an evidence-based decision-making platform. The Digital Tool would allow for a generation of scenarios with customised parameters regarding building regulations, future technologies and human behaviour. Moreover, it would calculate the impact of these scenarios on the existing built environment. Wider public participation would be possible through the creation and sharing of user-generated feedback.
- Integrated Urban Vision would be applied to create something new: a direct urban implementation policy that would integrate multi-disciplinary, inter-sectoral methods and methodologies grounded in both bottom-up and top-down approaches. Digital technologies would allow for a generation of scenarios and include evidence- based urbanism, visualising and evaluating spatial and societal after-effects. In this way, it would eliminate the main reason for the current conflict and hostilities marking Sarajevo's urban development – a lack of transparency, civic frustrations and unjustified decisions – making symbolic and comprehensible moves towards a knowledge-based society. This approach is an antidote to the current absence of coordinated planning policy that fails to guide the actions of multiple authorities and independent actors.
- City Action Lab Studio represents common ground between the actions of multiple authorities and independent actors which could be bridged with a permanent discussion, workshop and production area: the City Action Lab Studio. It leans on the "non-aligned" principles of solidarity (international, regional and local), collaboration and mutual partnership, as the initiative has continuously developed a framework to implement change. In doing so, it has prepared a sound environment that would facilitate an inclusive, integrated and multidisciplinary implementation in a newly-established and operational network of engaged real-world partners.

The activities of "Reactivate Sarajevo" include launching knowledge networks, establishing partnership alliances with real-world stakeholders, creating media impact with graphic and video materials, organising scientific events and exhibitions, conducting critical mapping and creating conceptual designs to test the "pulse" of public opinion. These acts serve as pieces in a mosaic that are necessary to engage in a contested city with a shortage of common formats of usual architectural research and practice: chambers, competitions and scientific foundations.

The chosen title of the experiment, "Reactivate Sarajevo", is based on the assertion that the re-urbanisation of Sarajevo is not yet finished. Instead of the (geo)political urbanism that imports generic architectures into the city, Sarajevo needs to recover and reactivate its existing non-alliance in terms of latent human, environmental and spatial potential.

My thesis is that, by reactivating the "non-aligned city", Sarajevo will be able to provide an alternative for the historic and contemporary mechanisms of its urban transformation: the perpetual cycles of urbanisation, destruction and reconstruction. By acknowledging and embracing geopolitical forces, Sarajevo should not become subordinate to them but use its historical role as both "emitter" and "recipient" of geopolitical forces to foster neutrality and non-partisan thinking for the common interests of its local communities. By combining top-down elements, such as institutional frameworks, with bottom-up activities, such as re-evaluating the participation and self-management potential of MZs, I am challenging its current fragmented and segregatory urban paradigm by creating a collective common ground for a new conversation on the future of the city.

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ENVIRONMENTALLY FRIENDLY COMPOSITE COATINGS ON TITANIUM AIMED FOR BIOMEDICAL ENGINEERING APPLICATIONS

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Abstract

The electrophoretic deposition (EPD) process was utilized to produce bioactive hydroxyapatite/chitosan/gentamicin (HAP/CS/Gent) coatings on titanium. Bioactivity of newly-synthesized composite coatings was investigated in the simulated body fluid (SBF) and examined by XRD, FTIR and FE-SEM. Obtained results revealed carbonate-substituted hydroxyapatite after immersion in SBF, emphasizing on the similarity of the biomimetically grown HAP with the naturally occurring apatite in the bone. Gentamicin release kinetics was investigated in deionized water at 37 °C by HPLC-MS. Release profiles revealed the beneficial "burst release effect" as a potentially promising solution against the biofilm formation in the initial period. When tested against human and mice fibroblast cells, both composite coatings declared a non-cytotoxic effect (viability >85 %), providing a promising basis for further medical application trials.

Keywords: coating, hydroxyapatite, gentamicin, electrophoretic deposition.

INTRODUCTION

Orthopedics nowadays is turning to tissue engineering and its tools to develop solutions for serious tissue damage and extensive trauma of the bone tissue. The main requirement in the bone implants field is to develop a functional, extended-life biomaterial that should possess excellent biocompatibility, good mechanical properties, corrosion resistance, antibacterial activity and bioactivity. Orthopedic implants are expected to induce bonding with surrounding bone tissue, without causing harmful effects to the host body. Having in mind me-

chanical and load-bearing requirements that orthopedic implants have to endure, metals and metal alloys are a primary choice due to the excellent combination of stiffness, toughness and strength. However, metallic implants are usually prone to corrosion, which in some cases can cause adverse effects on the host organism. Moreover, the lack of the osseointegration process when metallic implants are used limits their application. A promising approach for developing improved medical devices, orthopedic implants in particular, could be applying thin bioactive films on the metal surface [1]. The electrophoretic deposition process (EPD) is a convenient technique that allows obtaining of high purity composite coatings with controlled topography and morphology at room temperature [2]. The production of biocompatible materials that include drugs and/or biologically active molecules, maintaining the overall composite safe and non-toxic for medical use represents the main advantage of EPD technique. The capability of processing drugs and therapeutic agents at room temperature singled out EPD as a prospective technique for obtaining biomaterials, especially due to drug sensitivity to high temperatures [3,4].

The HAP/CS/Gent coating deposition was carried out in a single step, i.e. by co-electrodeposition from a three-component aqueous suspension [5]. This paper deals with the bioactivity and cytotoxicity of electrophoretically deposited HAP/CS/Gent composite coating on Ti substrate and gentamicin release profiles modeling [6].

MATERIALS AND METHODS

Materials

Hydroxyapatite (HAP) (nanopowder, < 200 nm particle size), chitosan (CS) powder (medium molecular weight (190−310) kDa, degree of deacetylation 75−85%), and gentamicin (Gent) sulfate solution (50 mg/mL in dH_2O) and titanium foil were purchased from Sigma-Aldrich, USA. As the substrate for the EPD process, titanium foil (0.25 mm thickness, 99.7%, Sigma) was employed. Before EPD, titanium plates were mechanically polished (grit emery paper and wet alumina) and ultrasonicated (15 min in acetone). All solvents used for drug release measurements were HPLC grade from J.T. Baker, USA or Sigma-Aldrich, USA. Deionized water was obtained by passing the distilled water through a GenPure ultrapure water system (TKA, Germany).

Electrophoretic deposition

Composite HAP/CS coating was deposited from an aqueous suspension of the following content: 1 wt % HAP powder and 0.05 wt % chitosan in 1 % acetic acid solution. HAP/CS/Gent was deposited from an aqueous suspension con-

taining 1 wt % HAP powder, 0.05 wt % chitosan and 0.1 wt % gentamicin sulfate. Measured pH values for both suspensions were 4.4. The suspensions were prepared according to the same protocol as reported in our previous research paper [5]. EPD was performed as a cataphoretic deposition process on Ti plate, serving as a working electrode (cathode) at previously determined conditions of deposition time of 12 min at a constant voltage of 5 V [5]. As counter electrodes (anodes), two platinum panels were employed. Uniform coating on both sides of Ti was achieved by placing the working electrode (Ti) between the Pt anodes at an equal distance of 1.5 cm. Deposited coatings were air dried at room temperature for 24 h.

Characterization

X-ray diffraction analysis (XRD) was performed by powder diffractometer Philips PW 1710 (Philips, Netherland) with Ni-filtered Cu Kα radiation (λ = 1.5418 Å). The intensity of diffraction was recorded at room temperature, between 4−70°, 0.05° step. PowderCell software was utilized for phase analysis. Fourier transform infrared spectroscopy (FT-IR) was performed by Nicolet IS-50 (Thermo Fisher Scientific, USA) in ATR mode (400−4000 cm^{-1} range). The achieved spectral resolution was 4 cm^{-1}. LEO SUPRA 55 equipped with In-Lens detector (Carl Zeiss AG, Germany) operating at 10 kV voltage acceleration was employed for field-emission scanning electron microscopy (FE-SEM). The concentration of released gentamicin was determined using a high-performance liquid chromatography (HPLC) (Thermo Fisher Scientific, USA) coupled with ion trap (LCQ Advantage, Thermo Fisher Scientific) as a mass spectrometer (MS).

RESULTS AND DISCUSSION

Bioactivity of HAP/CS/Gent coatings

Figure 1 shows the XRD diffraction patterns of HAP/CS/Gent coating after 7 day in SBF at 37 °C.

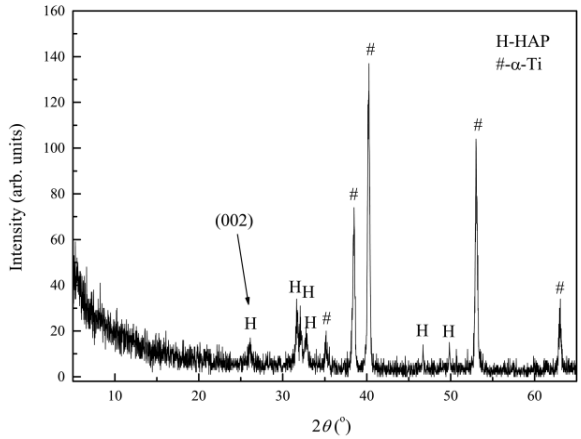

Figure 1. XRD diffraction patterns for HAP/CS/Gent coating after 7 day in SBF at 37 °C (Reprinted from [6] with permission from American Chemical Society, Copyright 2020).

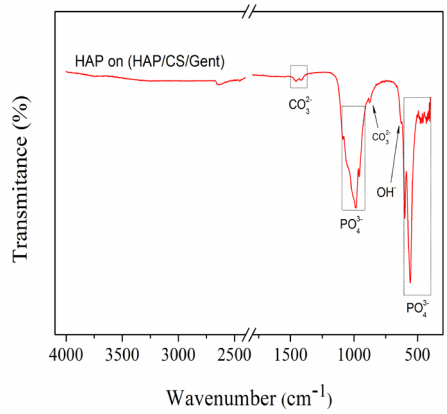

Figure 2. FT-IR spectra of HAP/CS/Gent coating after 7 day in SBF at 37 °C (Reprinted from [6] with permission from American Chemical Society, Copyright 2020).

Diffraction maxima of biomimetic coating, obtained on the top of HAP/CS/Gent coating after soaking in SBF, were assigned to HAP (JCPDS 09-0432) and the underlying titanium substrate (JCPDS 89-2762). Shifting of HAP peaks (002), (211) and (300) after immersion in SBF is typical for newly formed carbonated, bone-like HAP layer.

Figure 2 shows the FT-IR spectra for HAP/CS/Gent coating after 7 day in SBF at 37 °C.

After immersion in SBF, carbonate bands indicated the carbonated (AB-type) HAP which is similar to the structure of biological HAP. XRD results are in accordance with the FTIR analysis, confirming that biomimetic HAP corresponds to carbonate-substituted hydroxyapatite.

Figure 3 shows the FE-SEM microphotograph of HAP/CS/Gent coating after 7 day in SBF at 37 °C, where growth of a new apatite phase was observed.

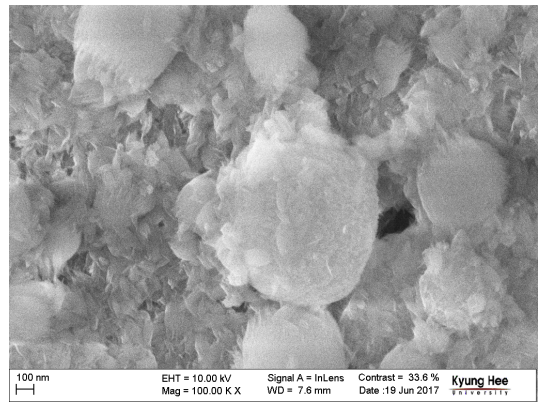

Figure 3. FE-SEM microphotograph of HAP/CS/Gent coating after 7 day in SBF at 37 °C (Reprinted from [6] with permission from American Chemical Society, Copyright 2020).

Having in mind that apatites with Ca/P ratio lower than 1.67 are usually considered as carbonate-substituted, EDS analysis additionally proved that biomimetic HAP grown on the top of HAP/CS/Gent coating is carbonate-substituted HAP, since the Ca/P ratio was calculated to be 1.46. The obtained results are encouraging since substituted HAP is known to improve the bioactivity and osteoconductivity and increase adhesion, growth and differentiation of osteoblast cells compared to the HAP that retains stoichiometric ratio.

Gentamicin release study

Gentamicin release profile for HAP/CS/Gent coating in deionized water at 37^{o}C (Figure 4) verified the initial burst release which could be very useful in preventing biofilm formation, followed by a slower release. Consequently, HAP/CS/Gent coating could have potential use as prolonged drug delivery systems for treating orthopedic infections.

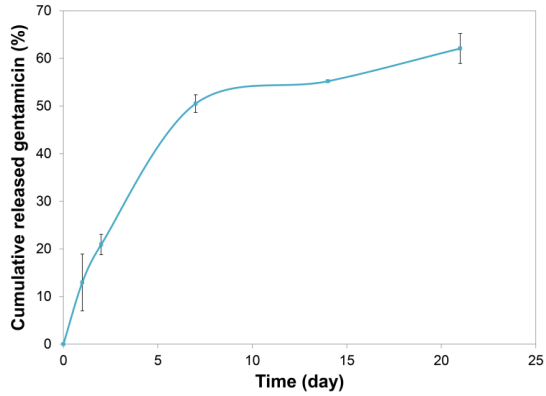

Figure 4. Cumulative gentamicin release from HAP/CS/Gent coating during 21 days in deionized water at 37 °C (Reprinted from [6] with permission from American Chemical Society, Copyright 2020).

Cytotoxicity testing

Trypan blue DET testing is a commonly used method for estimating the proportion of viable cells. The results of the DET test for MRC-5 (human fibroblasts) and L929 (mice fibroblasts) are given in Figure 5, proving strong evidence to support the non-cytotoxic effect for HAP/CS/Gent coatings.

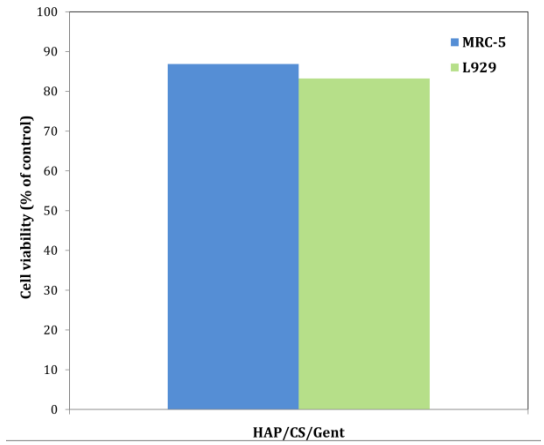

Figure 5. Cell viability of MRC-5 and L929 cell cultures in the presence of HAP/CS/Gent coating (Reprinted from [6] with permission from American Chemical Society, Copyright 2020).

CONCLUSION

Bioactive composite HAP/CS/Gent coatings aimed for orthopedic implant materials were produced using electrophoretic deposition on titanium. Osseo-promotive features were investigated in the SBF solution at 37 °C, using FE-SEM, XRD and FT-IR that confirmed AB-type carbonate-substituted HAP. Non-cytotoxicity effect of HAP/CS/Gent coating was proved towards MRC-5 and L929 cell lines. *In vitro* gentamicin release studies exhibited "burst" effect during initial period followed by a slower release in later times. It could be stated that bioactive HAP/CS/Gent composite coating electrophoretically deposited on titanium can be employed as a potential biomedical device with therapeutic impact, due to the ability to induce the growth of new hydroxyapatite.

ACKNOWLEDGMENTS

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A PLATFORM OF CRITERIA AND INDICATORS FOR SOCIALLY SUSTAINABLE RENOVATION DESIGN

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Abstract

Renovation is a good opportunity to modernize and improve various functions of a building in relation to the environmental dimension, as well as to solve existing problems related to the social dimension of sustainability, allowing buildings to better adapt to changing needs and desires of an increasingly heterogeneous tenant community. At the same time, the economic aspect of sustainability needs to be fulfilled. Hence, renovation of multi-family buildings demands careful planning and a high level of engagement between all stakeholders throughout the different phases of the renovation process in order to ensure that the project objectives are adequately satisfied and the project is financially, environmentally and socially successful. In this paper, an overview of the literature on various aspects, criteria and indicators of the social dimension of sustainability is given and a comprehensive platform is proposed that might facilitate the process of sustainable renovation of building and its evaluation in order to find the optimal solution (i.e. the optimal design variant). Guidelines for further research are also given.

Keywords: social sustainability criteria, sustainable renovation, multi-family buildings.

INTRODUCTION

The potential of the building sector for a positive change is considerable, which means that it can utilize resources more efficiently, become less invasive environmentally while socially more inclusive and ultimately become more

profitable. Holistic sustainable renovation is a highly complex and challenging task that requires careful planning and often a high level of engagement between all stakeholders in order to meet their conflicting interests and goals. It addresses cost optimization and energy efficiency, environment protection, utilization of sustainable materials, rational resources use, etc., as well as improvement of certain building functions that enhance tenants' health and well-being, which, at the same time, contributes to the sensitizing tenants to issues of sustainable development in general.

Moreover, sustainable building renovation should ensure social stabilization and wellbeing of tenants and reduce risk of an increased turnover, vacancy, tenant failure, vandalism and damage of the building. In order to provide long-term tenants' use of a building, renovation process requires consideration of different development scenarios that include deeper understanding of tenants' needs and desires, as well as tenants' conflicts related to their activities and attitudes. Accordingly, it implies a balanced structural, architectural and environmental modernization of building and its facilities taking into account limited financial resources. Due to the aforementioned complexity of the requirements and goals of the project, the design process is mostly iterative, which implies the design of a number of solution variants and the selection of the optimal one. Therefore, a relevant and comprehensive set of criteria that will enable the evaluation of variant solutions and serve as the guidelines during design is needed to facilitate the entire process and lead to the optimal solution.

LITERATURE PREVIEW

The environmental aspect, along with the economic aspect, has a greater focus in research compared to the social aspect (Gibson, 2006; (Park, Yoon, & Kim, 2017); (Raslanas, Stasiukynas, & Jurgelaitytė, 2013); (Sharifi & Murayama, 2013). In practice, interventions in the existing built environment that are aligned with the social aspect of sustainability continue to face many obstacles even though they are in high demand (Missimer at al., 2017; Pombo at al., 2016). There are still different perspectives on what the social aspect should include when renovating residential buildings, which reflects ambiguity and vagueness in defining goals, criteria and indicators. Consequently, guidelines for design and evaluation of building renovation solutions related to the dimension of social sustainability are not adequately addressed.

For instance, in "Sustainable Refurbishment", Research and Development Project supported by the Spanish Government, the three-principle category were

developed for evaluation of any existing residential buildings with respect to social sustainability aspect. They are the following: 1) User satisfaction, 2) Participation agreement and 3) Quality of life. The category "Quality of life" is defined by 53 sub-indicators, which are classified into the following three groups a) Health and comfort, b) Universal accessibility, and c) Design for all and common services (Izaskun at al., 2014).

In (Mjörnell at al., 2014), the authors have developed a set of social indicators based on the "Knowledge Matrix" tool - developed by public officials employed by the City of Gothenburg – considering the following six vital criteria categories of the social sustainability renovation: (1) Cohesive city (focusing on variation in the housing supply addressing the apartments of different sizes, rent levels, forms of ownership, accommodation suited to special needs (elderly, disabled, etc.); (2) Social interaction, teamwork and meetings (existence of physical environments such as indoor venues, collective farms, common spaces connected to entrances and stairways, laundry rooms, gardens, allotments, barbecue facilities, playgrounds, etc.; formal and informal groups, organized activities and events; participation in the retrofitting process, etc.); (3) A well-functioning everyday life; (4) Identity and experience (participation of stakeholders, quality indoor environment, quality of materials, workmanship, etc.); (5) Health and green urban environments including interplay between renovation project and "green", healthy environments and (6) Safety, security and openness (social protection and sense of safety of citizens).

Based on the most important theoretical methodologies for the renovation projects and methods widely used in practice such as BREEAM3 (UK), LEED4 (US), CASBEE5 (Japan), SBTool6 (Canada), etc.. authors in (Kamari, at al., 2017) have developed a decision-making support framework implementing three main aspects for sustainable renovation: "Functionality" (environment), "Feasibility" (economy) and "Accountability" (society). Social sustainability aspect, designated as "Accountability" was divided into the following six criteria: "Aesthetics", "Integrity", "Identity", "Security", "Sociality" and "Spatial". They were further decomposed into 44 indicators.

In Switzerland, for the purposes of the evaluation process of projects nominated for the "Sustainable Renovation Award" in 2012, organized by the City of Zurich, another important set of criteria was defined including all three aspects of sustainable renovation. Ten criteria were established in the category of social sustainability (Stadtentwicklung Zürich, 2012). They are the following: 1) Architectural and urban planning quality, 2) Process and planning, 3) Consideration and treatment of tenants, 4) Participation, possibility for involvement

in design process, 5) Social mixture, 6) Meeting places, 7) Offer of usages, 8) Disabled-free design, 9) Well-being and 10) Noise.

As can be noted from the cited literature there is a significant difference and diversity in defining categories (goals), criteria and corresponding indicators (sub-criteria) both qualitatively and quantitatively. They also vary from country to country. Consequently, a more comprehensive and authoritative evaluation of alternative renovation solutions requires a platform that will include all relevant criteria and indicators, which can help to perceive and evaluate all the essential features of social sustainability. Moreover, it could help architects in their design by pointing out the key elements that optimal design solution should contain.

PLATFORM OF RELEVANT CRITERIA AND INDICATORS

Based on the systematic review of the reference literature and research on the existing assessment methodologies (Stadtentwicklung Zürich (2012); Martinovits, A. (2015); Lütolf, T. (2018); Empfehlung SIA 112/1:2017 (2017); (SNBS) (2016)), a platform, which presents a set of criteria relevant for design of renovation variants that best satisfies social aspect of sustainability and thus, allows a more comprehensive and accurate assessment of renovation scenarios, is created and presented in Table 1.

Given the complexity of the renovation design process, the number of stakeholders involved and their conflicting interests, as well as for greater transparency, a hierarchical structure was chosen to represent the platform. At the highest level, there are seven categories, which are further divided into twenty-one criteria. The criteria categories (goals) summarized in Table 1 are as follows: 1) Enrichment of amenities and social infrastructure, 2) Respecting solidarity and fairness principles, 3) Fostering social and cultural life, 4) Facilitating usability and flexibility of the space, 5) Designing to promote community identity.

Table 1: Criteria categories, criteria functions and indicators of social sustainability relevant for the evaluation of multi-family building renovation

Criteria categories	Criteria functions	fi	Indicators
1. Enrichment of amenities and social infrastructure	1.1 Local social & cultural life, diversity of functions and offers, and embedding in the quarter	f_1	Enrichment of local life and increase of functions and offers diversity
			Embedding in the quarter and contribution to the role of the quarter
	1.2 Social function, flexibility and neutrality of the ground floors	f_2	Flexibility of the ground floor
			Adequate ceiling height of the ground floor
			Enrichment of functions and offers on the ground floor including social practices
2. Respecting solidarity and fairness principles	2.1 Accessibility of infrastructure and apartments	f_3	Barrier-free accessibility for children, parents with strollers, the elderly, people with disabilities
	2.2 Promotion of social, cultural and age-related mixing	f_4	Creation of different apartment sizes and apartment typologies (family apartments, lofts, etc.)
			Creation of different construction & materialization standards
			Rentable rooms and offices
			Multigenerational living
			Rental practice
	2.3 Reduction of space requirements: comfort, materialization, standards	f_5	Apartment area per person
	2.3 Support of disadvantaged persns	f_6	Apartment offers for disadvantaged people
	2.4 Consideration/ respect towards tenants	f_7	Renovation during habitation
			Offering temporary housing to tenants
			Return possibilities after renovation
			Arranging replacement apartments
			Duration of renovation
			Permanent castling within the settlement
	2.5 Ratio between rental costs after and before retrofitting	f_8	Appropriate ratio between rental costs after retrofitting and previous costs
	2.5 Rental costs per month	f_9	Affordable rental costs per month

3. Fostering social and cultural life	3.1 Design quality of informal meeting places in semi-public space	f_{10}	Inviting access zones (entrances, staircases, etc.)
			Communal spaces and infrastructure (common room, laundry, etc.)
			Outdoor common spaces for different user groups (children, youth, elderly, etc.)
			Spaces able to support and encourage social practices
	3.2 Design quality of spaces with retreat possibilities	f_{11}	Spaces with high privacy (rest, concentration and retreat)
	3.3 Differentiation of private, semi-public and public spaces	f_{12}	Good quality of the transitions and adequate connections between communal and individual areas
4. Facilitating usability and flexibility of the space	4.1 Barrier-free design	f_{13}	Improvement of access to the building and surrounding (e.g. elevator, staircases, ramps)
			Barrier-free design inside the building and apartments
	4.2 Usability and flexibility	f_{14}	Possibility of repurposing of specific areas
	4.3 Utilization diversity – improvement of utilization mixture	f_{15}	Connecting functions – incorporating various functions (residential, work areas, kindergartens. cafés, laundry facilities, grocery stores, etc.)
			Improving the offer of services (children's daycare, delivery of food biopackages, offers for the elderly, etc.)
			Sustainable management models (caretaker, tenant participation,etc.)
5. Designing to promote community identity and sense of belonging	5.1 Relation, dealing with the existing context	f_{16}	Adequacy of position, form, design of built structures
			Concept of colours, materials and constructions in relation to the local values
	5.2 Success of the project in relation to the orientation, wayfinding and clear lines of sight	f_{17}	Success of the project in relation to the orientation and wayfinding
			Success of the project in relation to the clear lines of sight
	5.3 Success of the space and design concept in relation to the emotional aspects	f_{18}	Success of the project in relation to the recognition, identification

6. Providing well-being and feeling of security	6.1 Success of the project in relation to the well-being and feeling of security and control	f_{19}	Visibility, good visual connections, social control
			Good lighting
			Relation to nature, recreation areas
7. Encouraging participation	7.1 Early involvement of tenants	f_{20}	Early notification to tenants about the retrofitting
			Regular informative and/or participation events
			Informing the inhabitants in the quarter and in the neighbourhood
	7.2 Providing personal design possibilities	f_{21}	Involving tenants and respecting their wishes and requirements in the furnishing of the apartments (e.g. kitchen, bathroom, etc.)

and sense of belonging, 6) Providing well-being and feeling of security, and 7) Encouraging participation. The individual indicators are set at the lowest level of the proposed hierarchical structure to determine more precisely the criteria and consequently facilitate design of renovation variants as well as their evaluation.

As expected, most criteria related to social sustainability are qualitative, i.e. 18 out of 21, Table 1, while only 3 criteria (i.e. 5th, 8th and 9th) are quantitative criteria. Therefore, this is another challenge of finding an adequate methodology for evaluating qualitative criteria characterized by subjectivity, vagueness, imprecision and ambiguity. Thus, it is going to be the subject of future research.

CONCLUSION

Enlisted criteria categories related to social sustainability include spatial (accessibility, neighborhood impacts), temporal (adaptability), material (life-cycle impacts) and social (services, health, comfort, safety) interrelations. The identified criteria and indicators presented in Table 1 could directly serve as a planning and design guidelines for design of renovation variants. Further research should include validation and prioritization of the identified criteria and indicators. The identification of suitable prioritization methods is another challenging task. The prioritization method required for the current study should be able to derive priority weight for each criterion, accommodate numerous criteria, take into account the uncertainty in stakeholder judgement, examine for inconsistency in judgement as well as to be suitable for group decision-making. Previous researchers have recognized Multi-Criteria Decision Making (MCDM) as the most appropriate method for prioritizing sustainability criteria (Lazar and

Chithra, 2020). Several authors have examined pairwise comparison methods like AHP - Analytic Hierarchy Process, ANP - Analytic Network Process, Relative Importance (RI) and ELECTRE. Another method adopted in literature for criteria weighing is Delphi technique, which involves direct rating of criteria prioritization. For selection of the optimal design variant, one of the Multi-Criteria Decision Making Methods (MCDM) such as VIKOR method, AHP, Weighted sum model (WSM), ELECTRE, Simple Additive Weighing (SAW), TOPSIS, etc., could be applied. Moreover, their fuzzy counterparts such as fuzzy VIKOR, fuzzy AHP, fuzzy TOPSIS, etc., could be also involved in the selection of the optimal design variant in order to account for the uncertainty in the stakeholders' judgment. However, a deeper exploration of their individual strengths and limitations is needed.

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SOCIALLY SUSTAINABLE RENOVATION OF RESIDENTIAL BUILDINGS - CHALLENGES AND POTENTIALS

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Abstract

Environmental and economic aspects continue to prevail over the social aspect of sustainable renovation of multifamily buildings both in theory and in practice. Recently, the cultural domain was added to these domains taking into account that the built environment is an important part of Europe's cultural heritage. In order to achieve sustainability objectives in building renovation process, all four domains of sustainability need to be explored simultaneously in a proper and balanced manner. With respect to the surrounding neighbourhood when sustainable renovation of the multi-family building is planned, a wider horizon of problem-solving is opened, which requires more complex analysis and deeper comprehension to ensure win-win situation both for the neighbourhood as a whole and its individuals. This paper considers some challenges and potentials related to renovation process, as well as certain principles and measures that need to be followed in order to ensure design solution that satisfies all sustainable domains in a balanced way. It also discusses some problems that need to be addressed in future research.

Keywords: social sustainability, social principles and measure, building renovation, holistic design.

INTRODUCTION

The Brundtland report (Brundtland, 1987) defines three different but interrelated domains in which sustainable principles need to be applied, i.e., economic, environmental and social domain. Their application should lead to livable,

equitable, viable situations and finally to sustainable development [Thuvander at al., 2012]. The cultural domain was added to these domains taking into account that the built environment is an important part of Europe's cultural heritage (COE, 2005). Namely, studies shows that about 37% of global tourism has a cultural motivation (Archimedes, 2007). Therefore, the cultural wealth should be protected and preserved, by applying adequate conservation measures and techniques in the process of sustainable renovation of buildings that will not damage their value.

Research demonstrates that 75% of total building mass are residential buildings, of which 36% are multi-family housing blocks and 57% of them were built in the period before 1970 (BPIE, 2011). New construction accounts for only 1%–1.5% annual addition to the total gross floor area (BPIE, 2011). Moreover, studies have shown that the actual life of buildings exceeds the estimated service life (Kohler and Yang, 2007; Van der Flier and Thomsen, 2006). Thus, the majority of the existing building mass will still be in operation in 2050. It gives a significant advantage for renovation over demolition strategy (Thomsen and van der Flier, 2009; Itard at al., 2006) regarding both resource use and environmental impact and including production as well as operation (Government, 2014).

In 2015, approximately 4 out of 10 people (42%) in the European Union lived in flats (EUROSTAT, 2015). Due to utilization of low-cost technologies, most of these multi-family housing blocks are characterized by poor energy performance (Di Giulio, 2012). Renovation is, on the one hand, an opportunity for both the environmental and social improvement of the construction fund by enabling the buildings to better adapt to the changing needs of the increasingly heterogeneous tenants community. On the other, renovation processes are complex and more uncertain concerning decision-making, planning, and execution than the process of new construction (Rosenfeld and Shohet, 1999: Femenías and Fudge, 2010; Revers, 2012]. Moreover, there is a possibility that architectural, cultural and social values may be overlooked in favor of energy and economic performance metrics (Blizzard and Klotz., 2012). In addition, the immaterial values of the built environment are often perceived as indistinct, unclear and therefore difficult to handle.

Holistic renovation which assumes all four domains of sustainability is a highly complex and challenging task. It needs to take into account often conflicting desires, needs, and values of the various stakeholders related to a number of important aspects such as energy, environmental, technical, and economic performance as well as various social, cultural, and architectural aspects (Jensen at al., 2017). This implies careful planning with the consideration of all relevant

factors, adequate decision-making and an appropriate level of engagement of various stakeholders through the different phases of project development. Consequently, this requires considerable effort, time, specific skills and knowledge of various stakeholders that are often lacking in such complex undertakings (Jensen at al., 2017).

SOCIAL SUSTAINABILITY – CHALLENGES AND POTENTIALS

The challenges we face today as a society are significant. These challenges include shortages of energy, natural resources, water and food; war and political instability; rising levels of poverty, homelessness and disease; decline in the quality of education and infrastructure, and exponential population growth. Addressing these challenges requires a paradigm shift in designing our world (Blizzard and Klotz, 2012). Systems on our planet are interconnected and, consequently, the problems we face today are intertwined. Thus, effective design solutions will have to account for this fact (Blizzard and Klotz, 2012). The reductionist approach can be ineffective or even have the opposite effect of its original intent.

Whole systems design is one approach to sustainable design offering great potential, however, the processes, principles, and methods guiding the whole systems approach are still not clearly defined or understood by practicing designers or design educators (Charnley et al, 2010, Golic at al., 2020). The Rocky Mountain Institute (RMI) describes the whole systems design as follows: "Whole systems design considers an entire system as a whole from multiple perspectives to understand how its parts can work together as a system to create synergies and solve multiple design problems simultaneously. It is an interdisciplinary, collaborative, and iterative process." (Blizzard and Klotz, 2012).

In general, social sustainability deals with how individuals, communities and societies live with each other and the ways to achieve the development goals by taking into account the physical boundaries of their places and planet earth as a whole (Colantonio and Dixon, 2009). In other terms, social sustainability merges "traditional areas and principles of social policy, such as equality and health, with new issues concerning participation, needs, social capital, economy, environment, and more recently with the concepts of happiness, well-being and quality of life" (Colantonio and Dixon, 2009). Thus, social sustainability could generate significant impacts at least in the following social sustainability dimensions and policy areas (Colantonio and Dixon, 2009): a) Demographic change (ageing, migration and mobility); b) Education and skills; Employment;

c) Health and safety; d) Housing and environmental health; e) Identity, sense of place and culture; f) Participation, empowerment and access; g) Social capital; h) Social mixing and cohesion; and i) Well being, happiness and quality of life. Evidently, these are essential areas for the local communities and neighborhoods and affects directly or indirectly all aspects of individual's life. Thus, integration of social aspect of sustainable renovation of residential buildings is very important issues, although a complex process requiring a comprehensive and multi-disciplinary approach enabling simultaneous consideration of all relevant (often conflicting) criteria, stakeholder preferences and the surrounding neighborhood.

In recent years, more stringent legislation has increased the requirements regarding energy efficiency, which can often only be achieved by extensive renovation of the building envelope, including measures such as improving the insulation, changing windows, increasing air-tightness, through installation of new heating and ventilation systems, which include renewable energy sources into consideration. Building managers and tenants are required to reduce the heating and operational costs of the buildings. On the other hand, the social aspect of building renovation is not in the same focus.

Authors in (Mayer and Haase, 2015) have proposed the following measure (rules) to be considered during renovation process of multi-family buildings in order to appropriately address social aspect: 1) Regulation/differentiation of privacy and community, focusing on categorization of public, semi-private and private areas, both indoors and outside; 2) Creation of "transition zones" between the apartments and common areas (e.g. through gardens, front gardens, vertical offset or appropriate facade design); 3) Integration of components, which allow control over participation of community (e.g., windows with curtains on the doors to staircases or sliding screens on private balconies, etc.); 4) Apartment zoning aimed at reducing the visibility of the more private areas; 5) improved acoustic insulation of interior; 6) Appropriate design of access and communication areas/storage spaces, etc.,; 7) Providing common storage areas next to the entrance (e.g., for bicycles and baby carriages, etc.); 8) Design of the private - outer space, which can be achieved through clear design of the transitions from special-use areas to common areas, and clear distinction between private outdoor spaces of neighbours (boundary can also be variable/adaptable); 9) Design of the common outside space, which can be achieved by using more robust, non-aging and low-maintenance materials/plantings, and offering common rooms for various groups of users (rest area, seating, children's play area in the sun/shade, or open/closed space play, etc.); 10) Promotion of living together by creating outdoor meeting places and/or common areas in which future residents will meet

each other. By promoting togetherness, common spaces play an important role in renovation process. When creating successful common spaces, the following three factors should be considered (Bohn, 2015): a) size, accessibility and animation, b) flexibility of use and c) catering for all generations.

Generally, social sustainability renovation should not only provide additional comfort, but it should also ensure that the quality of social infrastructure and local services is improved or at least maintained. It should also support community development, providing residents with opportunities to get involved in local decision-making, common activities through which they can meet other residents, build local networks and share social experiences. Therefore, it is very important to adequately apply social sustainability principles, measures and techniques when renovating buildings in order to ensure all potential beneficial effects on individuals and the community as a whole.

CONCLUSION

Social aspect of sustainability has not been sufficiently researched and the concept of social sustainability still remains vague (Sierra et al., 2018; Gomaa and Sakr, 2015; Liu et al., 2017, Golic et al., 2020). The tools, instruments and metrics to foster sustainable communities currently available are also biased toward environmental sustainability. A clear formulation of social sustainability goals often diverges in different directions causing difficulties in practical application (Sierra et al., 2018). For renovation projects to be sustainable (to encompass all four pillars of sustainability), it is important to focus on both the objective and subjective system of human values throughout the entire project life cycle (Kamari et al., 2017). In addition, it is necessary to take into account the building surroundings in order to exploit synergy effect between them. Although the perspective of problem-solving is broaden, the complexity of the building renovation project is increasing, which requires more elaborated analysis and deeper comprehension to ensure win-win situation both for the neighbourhood as a whole and its individuals. A clear and well-structured methodology, which can manage all processes and concerned stakeholders related to social sustainability renovation of buildings, is needed to enable the success of the project. Also, implementation of the social dimension in a sustainable renovation process requires a different set of skills and instruments, as well as effective participation and communication of building occupants and other stakeholders (Mjörnell et al,, 2015; Golic et al., 2020). Further, the social sustainability analysis needs to be integrated into the early phases of renovation planning in order to complement the environmental and economic analysis. Although the number of

studies has increased significantly in the last few years, there is still no general consensus on the main criteria and indicators, applicable methodologies, tools and renovation methods; therefore, further research is required in this area.

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ARCHITECTURAL FORM: APPLICATION OF VORONOI DIAGRAM IN ARCHITECTURE

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Abstract

Contemporary design methods increasingly rely on understanding natural changes and growth and the principles of self-organized biological structures that are represented using mathematical models. The overall objective of the presented research is the new approach to space planning described in the form of mathematical rules, which has always been the research focus of scientists and architects. The investigation is focused on Voronoi diagram algorithms that simulate natural shaping processes, which belongs to the higher logistical mathematical principle. This system involves the process of partitioning one plane into parts - Voronoi cells. Therefore, using a complex system of lines and Euclidean surfaces that are perfectly legibly arranged, architects and urban planners try do present the organizational and structural forms that could be found in nature. As an important source of inspiration, the method is used in the structural elements design and facade surface shapes, as well in various patterns in urban planning. Voronoi diagram, as an extremely abstract design act, enables architects a specific project and a variety of spatial design of the form, which is realized as a new, contemporary, attractive, and functional identity of the site.
Keywords: mathematical model, Voronoi diagram, nature, form, architecture.

INTRODUCTION

Modern design methods increasingly rely on the understanding of natural processes and principles of self-organized biological structures and their representation through mathematical models that are applied in various technologies. These methods, as a result, have an important role in shaping contemporary and ecological architecture, as well as urban planning. Further, development of digital technology has facilitated the creation of complex and intricate structures and surfaces, inspired by natural forms. As the improvement of research tools continues, so does the knowledge of the surface structure of living organisms,

which in turn is used as a source of inspiration in fields such as architecture (particularly in architectural structures), construction and materials science (Burry & Burry, 2010). One of the most interesting natural system discretization methods of architectural surfaces is the Voronoi Diagram, also referred to as the Dirichlet tessellation, which describes the division planes and space which is encountered in nature, such as the pattern of a tortoise's hell, dragonfly wing or the spots on the giraffe's skin.

The overall objective of the presented research is the new approach to space planning described in the form of mathematical rules, which has always been the research focus of scientists and architects. The investigation is focused on Voronoi diagram algorithms that simulate natural shaping processes, which belongs to the higher logistical mathematical principle. This system involves the process of partitioning one plane into parts - Voronoi cells. Currently, the Voronoi diagram is one of the rules in mathematics and geometry inspired by natural systems as an alternative to regular tessellation known and used in architecture (Gawell et al., 2014). Therefore, using a complex system of lines and Euclidean surfaces that are perfectly legibly arranged, architects and urban planners try do present the organizational and structural forms that could be found in nature. As an important source of inspiration, the method is used in the structural elements design and facade surface shapes, as well in various patterns in urban planning. Voronoi diagram, as an extremely abstract design act, enables architects a specific project and a variety of spatial design of the form, which is realized as a new, contemporary, attractive, and functional identity of the site.

MATERIAL AND METHODS

This paper discuss in detail use of this nature inspired system - Voronoi diagram in generating form, investigating the potential of non-regular grids on the global form response of the architectural structure. In particular, the study concentrates on the different Voronoi tessellation, describing the procedure for generating irregular patterns through parametric and non-parametric modeling and illustrates it through variaty applications from building envelope to urban planning, as well as interior elements.

Background of Voronoi Diagram

The Voronoi diagrams were named after Georgy Voronoy, and they are also called a Voronoi tessellation, a Voronoi decomposition, a Voronoi partition, as well as a Dirichlet tessellation (after Peter Gustav Lejeune Dirichlet). Voronoi diagrams have theoretical and practical applications in different fields, primarly in science and technology, but also in visual arts. Voronoi diagrams also occur

everywhere in nature emerging at different scales in nature's cell structures like leaves, honeycomb and animals fur and body patterns (giraffes, turtles, butterfly wings), as well as dried mud fields (Figure 1). This inspiration from nature in the design process is a very widely used method. Architects and designers take advantages of aesthetic features and structural systems of the objects found in the nature.

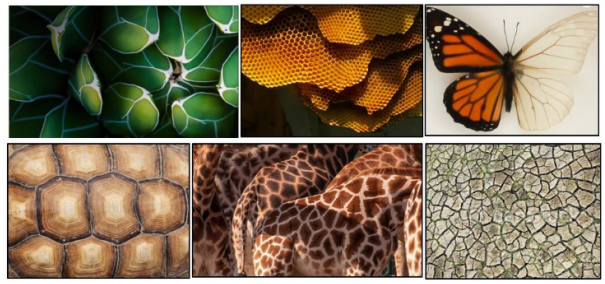

Figure 1 Different scales of Voronoi diagram in natures' cell structures

Informal use of Voronoi diagrams can be found as far back as Descartes in 1644. Dirichle used 2-dimensional and 3-dimensional Voronoi diagrams in his study of quadratic forms. British physicist John Snow used Voronoi diagrams in 1854 to illustrate how most of the people who died in the cholera epidemic in Soho in 1854 lived closer to the Broad Street water pump than to any other pump. Voronoi diagrams used in geophysics and meteorology to analyze spatially distributed data (such as precipitation measurements) are called Tiesen polygons after the American meteorologist Alfred Tiesen.

There have been many interpretation of the Voronoi diagrams across architecture, urban planning and design and landscape architecture. Their use in these fields has increased with the widespread use of parametric design in architecture. For example, to compare residential areas covered by hospitals, shops, cultural facilities, etc., with the help of diagrams, it is easy to determine where the nearest hospital, shop, etc. is, and thus determine where the same construction is needed.

In the context of innovative patterns for building forms, Voronoi diagram is certainly worthy of interest. It is an irregular biomimetic pattern based on the diagram, which derives from the direct observation of natural structures. Architects use this diagram to obtain a more organic looking structure and natural pattern in facade designs, dividing the space into sub-spaces, rather than imitate directly from nature.

In mathematics, a Voronoi diagram is a partition of a plane into regions close to each of a given set of objects. In the simplest case, these objects are just a random scattering of points across a plane (called seeds or generators). For each seed there is a corresponding region, called a Voronoi cell, consisting of all points of the plane closer to that seed than to any other. Given a set of points in a Voronoi diagram partitions the space such that the boundary lines are equidistant from neighboring points. Every boundary line passes through the center of two points, i.e. lines are drawn through midpoint of each line connecting adjacent points (generators), so that the place where they intersect is at the same distance from the generator. Then, they are connected to a network (Figure 2a). For these reasons, one possibility to construct Voronoi diagrams is by building each cell one by one in a way to extend the bisector of the segments linking every combination of points to obtain the outline of Voronoi cells (Figure 2b). Another way of constructing Voronoi diagrams, is by first building Delaunay triangulations and then extending the bisectors of the triangle edges which leads to the Voronoi diagram (Figure 2b).

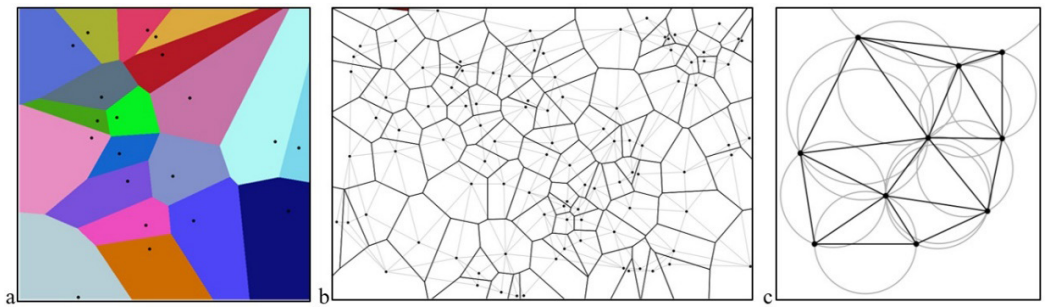

Figure 2 a. Example of Voronoi diagram; b. Voronoi diagram and Delaunay triangulation from 100 random points in a plane presented simultaneously c. No point falls inside the circle circumscribing each Delaunay triangle (fbellelli. com).

The Delaunay triangulation is just as amazing as the Voronoi diagram. In this way, a set of triangles is produced that connect our points, around which is possible to draw circles (Picture 2c). This implicate to one more different way to create a Voronoi diagram (Figure 3a-d) obtained from constant outward growth from dispered points.

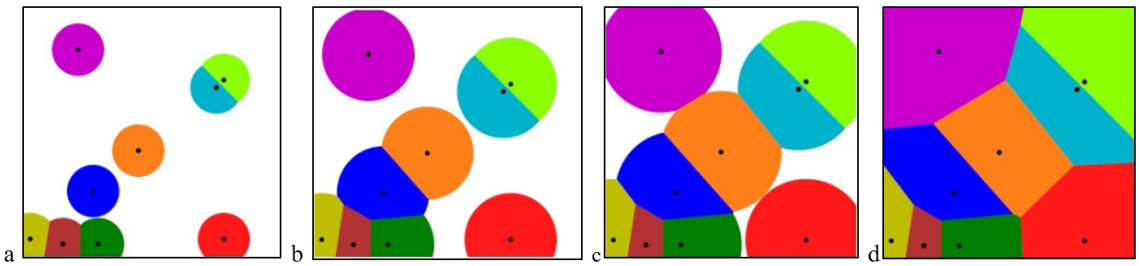

Figure 3a-d Voronoi diagram obtained from constant outward growth from dispered points (fbellelli.com).

Voronoi diagrams have simple components in different dimensions. Implementation of Voronoi diagram simulates the topological structure of space-filling, natural data exchange of particles in architecture and also divides the entire space into a set of sub-spaces according to data of objects (Pottman et al., 2007). According to authors (Pottman et al., 2007), simple Voronoi diagrams consists of Voronoi cell, Voronoi vertex, Voronoi foam and Voronoi space (Figure 4).

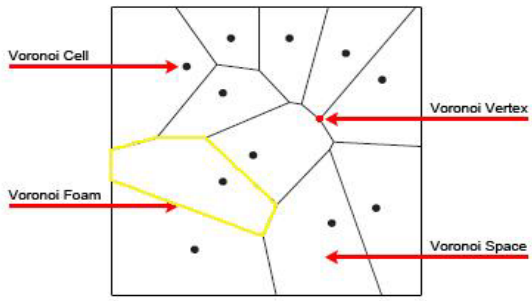

Figure 4 Voronoi diagram components (Pottman et al., 2007)

The relationship between the cell nucleus and the resulting geometry is complex in nature (Friedrich, 2008). For that reason, geometry and topology of each polygonal cells, such as size, proportion and number of edges is sensitive to the slightest change in position of each point anywhere in the neighborhood. Thereby is enabled that new different algorithms for computing Voronoi diagram and also technique that generate approximation of Voronoi diagrams are continuously being proposed to improve computation efficiency in different circumstances. That way more homogeneous Voronoi cells can be achieved.

Examples of architectural forms using the Voronoi diagram

After many interpretations across architecture and urban design, Voronoi diagram become one of the most important, leading trends in architectural design that seeks new forms of expression. In this chapter, practical applications of shaping architectural elements and forms using Voronoi diagram, have been presented and analyzed.

Voronoi Shelf, interior design installation

In this *Marc Newson's* installation, it can be seen a characteristic of organic application of Voronoi diagram represented through different sizes and shapes of cells, different wall thicknesses, and all in a pleasant state of harmony. The form, made from a single block of marble, gives the impression of a logical arrangement (Figure 5). The harmony of the relationship between the cells convinces that there is a reason why they are designed that way. This is not surprising given the natural structures to which these cells resemble. The visual form of the shelf reminds of creative process by imitating nature, but in fact each cell is arbitrary, i.e. designed by the author. There is no defined ratio of cell sizes, it is all the author's choice.

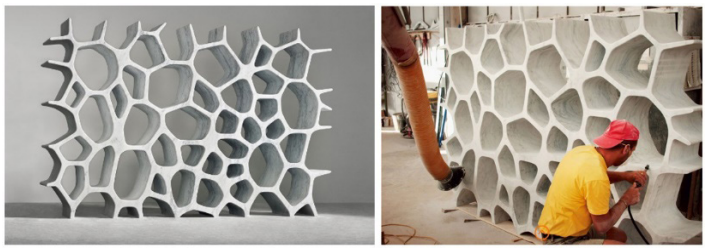

Figure 5 Voronoi Shelf and the process of its creation, artist Marc Newson (marc-newson.com).

Glorieta Juan Carlos I, Mula Spain

The scheme of Glorieta Juan Carlos I, a public square promenade, integrates the space into the surrounding urban fabric, breaking the rigidity of the previous configuration and establishes a direct connection between the square and city and community. The project, designed by architects from *ESC studio*, use of Voronoi diagram to create a pattern for pedestrian movement in an open square, while preserving the existing vegetation. The space planning of the square has been generated through a software that implements a Voronoi algorithm to divide the space into pedestrian paths and areas for various purposes (Figure 6).

The main circulation revealing a dynamic pattern that runs through the space among the programmed activity islands.

This interactive application also enabled citizens to participate in the new design process and propose their ideas and reflections on the perception of space and the way they approach the new design. Additionally, the scheme is designed as a self-sufficient, carbon neutral space with a series of climate control units scattered through the square, including PV cells, lighting and fog systems, that make a compromise with the environment, producing all the energy required for the functioning of the space.

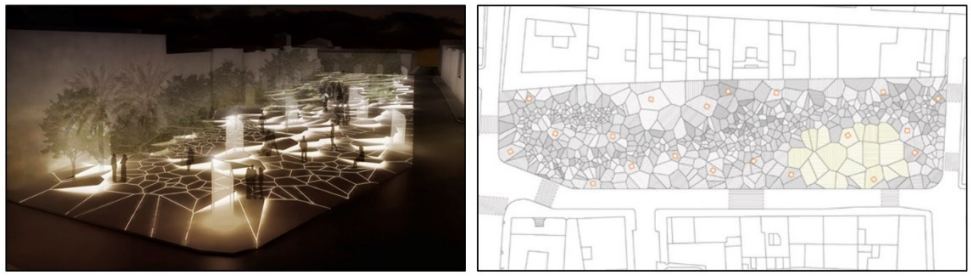

Figure 6 Use of Voronoi diagram to create a pattern for pedestrian movement in an open square, Glorieta Juan Carlos I, Mula Spain (archdaily.com).

Botanical garden pavilion, Gruningen Switzerland

The parametrically designed pavilion of Botanical garden in Gruningen, Switzerland by *Ida Buehrer Wuest Architekten* is similar to the principle of cell division. The design relates strongly to its context, inspired by the surrounding forest, not the built environment. Both the form and the structural concept derive from nature. The pavilion of 180 m^2 is conceived to harmonize with the forest and to expand it (Figure 7a,b). The form was developed using Voronoi diagram, known for natural neighbor interpolation, to represent the original layout of the trees in the forest (Picture 7d). Analogous to cell division in nature, the architects determined the general geometry of the roof in relation to the position of four scattered points, i.e. columns that illustrate the trunk of a tree, while the "branches" that connect them form different frames to support the ceiling glass (Picture 7c). The forest was augmented by this four steel trees that form the primary structural system of the pavilion. At about five meters, the trunks branch toward the tree top, which forms the natural roof. A secondary glass construction, suspended from the steel branches, encloses the inner space of the greenhouse.

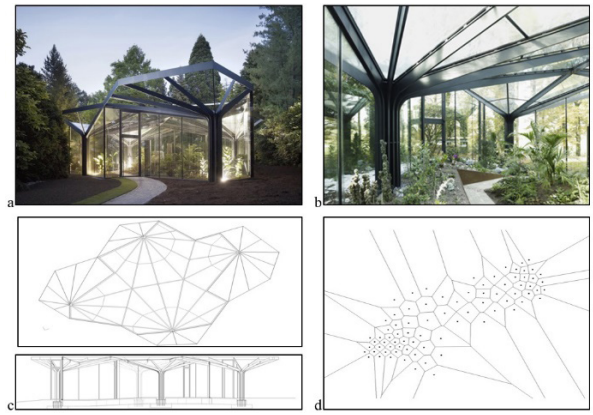

Figure 7 Structural system of pavilion made of four steel trees designed by Voronoi diagram, Botanical garden, Gruningen Switzerland (archdaily.com).

Alibaba Headquarters, Hangzhou China

The Alibaba Headquarters in Hangzhou, China is another example of the use of Voronoi diagrams. The architectural firm *Hassell* is designing a building of 150,000 m^2 of flexible office space. Architect slightly alliterated the pattern of Voronoi diagram on the building facade both for aesthetic reasons and to create stunning shadings for elevations, floors and courtyard in front of the building (Figure 8). The sustainable design of this facility has the function of bringing people closer to nature, contributing to their health, well-being and productivity.

Figure 8 Voronoi diagram in a form of double envelope and canopy for shadings of the glass facade
and the courtyard of Alibaba Headquarters building (archdaily.com).

DISCUSSION AND CONCLUSION

Voronoi diagram provided architects and urban planners a new parametric design tool for shaping space, which is used often in the recent years. It has been demonstrated that a diagram is a suitable strategy for architectural form with irregular grid, due to the pattern that is organic and occurs a great effect on a diagram. Besides, this diagram provides many advantages for architecture

because of its opportunities by coding points (seeds, generators) in the space and then doing space planning.

In the examples, the variety of application of this method were shown, which gives a specific aesthetic appearance. Using diagrams, we get a space that becomes more limited, and its forms provide a more natural environment for a person to live. For example, the result of this process in urban zoning creates a natural structure in urban space, i.e. good relationship between certain parts. On the buildings, created shapes are associate with biological ones, which not only have an aesthetic value, but also improve human awareness in the relationship and interaction with nature.

In addition, three-dimensional structures can be designed not only two-dimensional structure. In this context, it was proved with an Alibaba Headquarters project and Voronoi shelf that volumetric design can be shaped by using this diagram. Structural system, designed in Botanical garden pavillion allowed to imitate nature effectively with appropriate construction and lining material. All this indicates that Voronoi structures show also a positive efficiency in material consumption, suggesting to become a vital tool in shaping the system, which leads to more different solutions.

The reasons for use of Voronoi diagrams in generating architectural form can be listed as follows:

- Can be applied in both surface (2D) and spatial (3D) systems.
- Better structural properties.
- Variety of design options, and greater interactive and dynamic relationship between elements.
- Many natural forms can be interpreted in order to organize and structure space in new ways, based on proximity of a neighbor.
- Flexible and alternative opportunity for space arrangement, despite of occurring as randomly.

In conclusion, the paper confirms the potential applications of Voronoi diagram in shaping architectural forms, demonstrating that the innovative irregular patterns represent one more alternative to conventional forms. For this reason their application to design of architectural forms should be further investigated and encouraged.

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SUSTAINABLE INDUSTRIAL ARCHITECTURE: ECOLOGICAL DESIGN OF CONTEMPORARY WINERIES

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Abstract

Sustainable architecture has become an indispensable part of the planning and construction process. Given that industrial plants are determined as structures that pollute the environment while disrupting not only biodiversity but also the aesthetical image of the cities, eco-friendly and environmental design is increasingly recognized as a methodological approach in creating industrial architecture. Terrain topography, green roofs, passive design principles, and renewable energy sources contribute to the sustainability of industries but also change the conventional view of monotone big-box structures, pushing the boundaries in contemporary industrial architecture design. The paper examines the ecological sustainability of industrial architecture on the example of wineries. Given the technological requirements of the wine production process, the position of wineries in vineyards, and the fact that their architectural narrative seems to become a significant factor in creating a reputation for the sustainability of the wine industry in the market, the paper aims to recognize the most important ecological principles integrated with the design process of contemporary wineries. The paper is based on a case study of selected examples of wineries where architects were guided by bioclimatic design as a leading design tool and their comparative analysis.

Keywords: sustainability, industrial architecture, ecological design, contemporary wineries

INTRODUCTION

Sustainability as a concept of making future improvements focuses on goals that cover multiple dimensions of mankind. Agenda 2030 (UN, 2015) put into action 17 Sustainable Development Goals (SDGs), including Increase Industry, Innovation, and Infrastructure (SDG 9), Mobilize Sustainable Cities and Com-

munities (SDG 11), Influence Responsible Consumption and Production (SDG 12), that are directly reflecting the fields of industry and production. Industrial architecture should provide the necessary conditions - space and infrastructure to make production sustainable. Therefore, industrial buildings should be considered with great concern regarding sustainability. Although sustainability in the field of architecture may be misled by the greenwashing (Donovan, 2015) and other light-minded ideas without substantial influence on sustainability, industrial architecture, rooted in the rational, logical, and cost-effective building construction idea, has always been close to the essential sustainability concept.

In contemporary terms of given SDGs, sustainability of industrial architecture should be regarded as: building industrial facilities based on intelligent urban planning that creates safe, affordable, and resilient cities, to seek innovative design solutions and technologies in the construction process (from architectural concept to the building execution), and to incorporate the ideas of recycling and waste reduction in construction and occupational phase (UN, 2015). Industrial architecture aims to include these assignments in the conceptual design phase, making the architecture responsible for the sustainability. That has led to the design solutions that push the boundaries of the typical and typological industrial architecture, that combines the new and lasting assignments of sustainability with contemporary building aesthetics.

The ecological dimension of sustainability in industrial architecture is particularly recognizable in the contemporary wineries' design process, given the specifics of the technological wine production, in the context of the microclimatic conditions that need to be ensured, waste production, transport solution, but also the fact that wineries represent not only production facilities but also facilities of public importance. Construction in harmony with nature, which aims to increase the energy efficiency of the building and minimize energy consumption, has been especially evident since the beginning of the XXI century with the expansion of the wine industry on the world market and the development of wine tourism (Anderson and Pinilla, 2018). In the EU, wine production affects a large amount of energy consumption, as indicated by the fact that wineries annually consume around 1,750 million kWh, where the primary energy source is electricity with 92%, followed by fossil fuels - gas and diesel with 9% (Vela et al., 2017). Certain studies show that wineries with wine production of over 50,000 hl/year consume electricity of 4kWh/hl, while smaller wineries with 25,000 hl/year or lower consume electricity of 16kWh/hl (Malvoni et al., 2017). Further, the transformation of once isolated industrial facilities into a hub for introducing

visitors also reflected the increased need to provide appropriate environmental comfort for the new users.

The need for ecological sustainability in designing wineries has encouraged many architects to translate the eco-design into unique architectural forms, which today makes wineries one of the most recognizable construction works in the world. The paper analyzes the ecological principles applied in designing contemporary wineries. The research is based on a case study of selected examples of constructed buildings, whose concept was entirely derived from the aspiration towards eco-design, and their comparative analysis. The main research goal is to identify the ecological principles most often applied in wineries.

MATERIALS AND METHODS

Ecological principles for designing contemporary wineries

Ecological principles for designing architectural buildings are the subject of many authors. Shu-Jang et al. (2004) discussed seven main principles of the eco-design concept: meet the inherent needs of humans (reduce resource consumption), move toward resource sustainability (efficient use of energy and materials), maintain ecological integrity (understanding of local climate, topography, soil, and water), emulate natural ecosystems (integration of economy and ecology), eliminate natural debt, protect natural habits (avoid ecological damage) and increase environmental literacy (environmental protection as social responsibility). A few years later, Gultekin and Alparslan (2011) categorized ecological principles for building design as indicators for energy conservation (use of renewable energy sources-RES, energy-efficient envelope, and form design), water conservation (reduce and reuse of water), material conservation (material selection and reuse) and livable design (urban design, design for human comfort). The eco-design of buildings should reflect the ecological dimension of sustainable development. Akadiri et al. (2012) state that in designing, architects should try to conserve energy, water, material, and land and protect human health, enabling appropriate thermal and acoustic comfort, natural ventilation, aesthetics, and functionality. Given that industrial facilities are large consumers of energy, one part of the author's research dealt with the ecological and energy-efficient design of modern production facilities (Wang et al., 2019).

The ecological sustainability of wineries is primarily related to the technological process of wine production. To reduce the energy used in the production process, designers often use the natural fall of the terrain and constant soil temperature for wine maturing by burying the facilities in the ground (Stanojević

et al., 2018). Sustainability is also achieved through the application of passive cooling principles, the use of water and greenery, the appropriate position of roof and wall openings to ensure natural ventilation, and using shading systems (Drazdil et al., 2015). All the mentioned tools influence the efficiency of production process, but often creates an authentic architectural expression. In some cases, architects opt for natural, recycled materials, while special attention is paid to waste recycling (Maicas and Mateo, 2019). Numerous buildings show the increasingly frequent use of RES systems, using wind generators, solar panels, geothermal pumps, and rainwater collection tanks.

Applied research methodology

The research includes a case study of four contemporary wineries characterized by ecological design and sustainability in the context of the global challenges of climate change. Wineries were selected based on the following criteria:

1. They were built in the last five years in rural areas of southern Europe.
2. The primary motive of the architects in conceptualization was eco-friendly and bioclimatic design, which resulted in the specificity of the urban planning, form, the selection of materials, and the application of renewable energy sources (RES).
3. They are certificated as ecologicaly sustainable buildings.

The comparison of the analyzed buildings is based on a presentation of applied ecological design indicators, previously theoretically defined.

RESULTS AND DISCUSSION

The case study of selected wineries

Bodegas Beronia, Ollauri, La Rioja, Spain

The Beronia winery was built in 2020 and is the first industrial facility for wine production in Europe that has a sustainable Leader of Energy-Efficiency and Sustainable Design (LEED) gold certificate (Archello, 2020). It is integrated with the environment, burying the volume in the ground. That results in the possibility of using the gravitational fall and the natural temperature of the soil for wine aging. The production area is underground, while the visitor zone is glazed with a view of the surrounding vineyard. IDOM architects were guided by the idea of creating a building with a unique expression that has minimal impact on the environment. Ecological sustainability is reflected in the selection of materials, and technical systems, so the building is characterized by good thermal insulation, use of natural lighting, application of photoelectric sensors, systems for

passive solar protection, rainwater collection, application of biomass and special roof membrane RubberGard EPDM with the low carbon footprint.

New Peralada Winery*, Catalonia, Spain*

The winery is situated in North Catalonia in Spain. The building was designed according to the standards for winning the LEED gold certificate for sustainability in construction. RCR Architects designed a facility that is almost completely buried, guided by natural gravity and soil temperature use, minimizing the impact on the environment. The gently curved volume rests on the historic part of the property, which dates back to the beginning of the 20th century and currently functions as a visitor center (ERF, 2021). The winery includes two levels, with the upper part of the roof covered with greenery. The building relies on geothermal energy, which reduces energy consumption for heating and cooling water by 37%. The primary idea is to create a new wine landscape, integrating the building.

Carillon D'Angelus, Saint-Magne-de-Castillon, Libourne, France

The facility was opened for visitors in November 2021 in Libourne, France. DPLG architects designed a winery that represents a balance between heritage and innovation due to the need to expand the production capacity of old Chateau Angelus. The building has a High Environmental Value (HEV) and Building Research Establishment Environmental Assessment Method (BREEAM) certificate. The wine cellar uses 100% natural gravity to transport materials (Drago, 2022). Technological innovations are set in vineyard processing and wine production using modern equipment and techniques. The RES application is represented by photovoltaic solar panels on the roof, which provides the production process electricity.

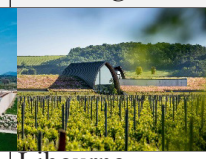
La Cantina Pizzolato, Treviso, Italy

The winery is located in Treviso, Italy. Made Associati architects designed a winery with a rustic look that matches the authentic historical setting, using beechwood material with the Program for Endorsement of Forest Certification (PEFC) (Official site, 2017). The winery is not integrated with the environment and is on relatively flat terrain. A part of the cellar for wine aging is buried. Other stages of the production process (reception of grapes, processing, fermentation) are located on the ground floor, while on the first floor, there is a tasting room. From the perspective of ecology the architecture stands out with the installation of a double wooden facade that acts as a sunscreen and an integrated waste processing system. The facility is self-sustaining in terms of electricity, with photovoltaic solar panels on the roofs.

The comparative analysis

Table 1 gives an overview of ecological design parameters for each of the analyzed wineries through four aspects: ecological, urban design (I), ecological form and materials (II), passive cooling systems (III), and application of the RES and recycling systems (IV). The results show that most buildings tend to integrate the winery volume with the environment. Buildings are buried in a part of the production zone regardless of the terrain configuration, creating the possibility of using the gravity drop and neutral soil temperature for wine maturation. In terms of passive cooling, green roof and shading system are increasingly being used. From the aspect of the RES system and recycling, all buildings envisage an integrated waste processing system, and the majority opt for the application of geothermal energy and solar rooftop photovoltaic panels, with the application of water and rainwater recycling.

Table 1. *Comparison analysis of selected eco-designed wineries*

Winery name	*Beronia*	*Peralada*	*D'Angelus*	*Pizzolato*
Sources of figures are given uder the table				
Location	La Rioja, Spain	Catalonia, Spain	Libourne, France	Treviso, Italy
Year	2018-2020.	2017-2021.	2019-2021.	2017.
Area / Floors	10.303m²/2floors	18.200m²/2floors	4.400m²/2floors	2600m²/3floors
I Ecological urban design				
orientation	to northeast	to west	to south	north-south
terrain in slop	to southeast	slightly to south	slightly to south	no
terrain integration	completely	partially	partially	no
II Ecological form and materials				
one-volume form	+ / curved form	+/ curved form	- / few volumes	- / few volumes
buried form	+ / buried	+ / buried	+ / semi-buried	+ / semi-buried
inovative materials	+ /roof membrane	-	+ /roof membrane	-
natural materials	+/ roof vegetation	+/ roof vegetation	+/ roof vegetation	+ /benchwood
double glazing	+ / glass facade	+ / glass facade	+ / glass facade	+ / openings
thermal mass wall	good insulation	good insulation	good insulation	double facade
III Use of passive cooling systems				
cross ventilation	-	-	+ / higher parts	+ / higher parts

solar shading	+ / console slab	+ / native plant	-	+ / wood panels
ventilated roof	+ / standard	+ / standard	+ / standard	+ / standard
green roof	+ / vegetation	+ / vegetation	+ / vegetation	-
soil temperature	+ / production	+ / production	+ / production	+ / production
IV Use of RES and recycling systems				
solar panels	+ / on the roof	-	+ / on the roof	+ / 570 roof pan.
biomass use	+ / boiler	-	-	-
geothermal pump	+/11wells/ tubes	+ / 538 wells	-	-
waste tretman	+ / integrated	+ / integrated	+ / integrated	+ / integrated
rain collector	+ / used in vines	+ / rain reservoir	-	-
water purifier	-	-	+ / filtred water	+ / filtred water

Note. The Figures in Table are taken from: Archello, 2020; ERF, 2021; Drago, 2022; Official site, 2017.

CONCLUSION

The paper analyzes the ecological parameters for the design of contemporary wineries. The results obtained from a comparative analysis of wineries built in the southern part of Europe in the last five years, characterized by a strong ecological narrative, show that the most common parameters that architects opt for when designing are: the use of optimal orientation with the integration of structures into the environment, buried or semi-buried forms covered by a green roof, solar shading systems, solar roof panels, and geothermal pumps, as well as waste processing and water recycling systems. Pictures illustrate that by applying ecological principles, the architectural form of buildings can become more attractive and authentic. The conducted research points to the contribution of architectural practice in achieving the sustainability of the wine industry and draws attention to the importance of sustainable concepts in industrial architecture.

ACKNOWLEDGMENTS

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BEHAVIORAL ANALYSIS OF POLYISOCYANURATE FOAM SANDWICH PANELS UNDER TENSION LOAD

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Abstract

The paper describes the experimental and numerical investigation of the behavior of polyisocyanurate (PIR) sandwich panels subjected to a tension load. In order to obtain optimal results, laboratory and numerical analyses of the specimens were compared. The loads that are considered in this paper are tension loads. Laboratory tests were performed on small dimension sandwich wall panels (width 100 mm). In addition to the laboratory tests, a numerical analysis was carried out on the models. Numerical analysis was carried out in ANSYS software code. The numerical model accurately predicts the results of laboratory tests in the mechanical testing of sandwich panels.

Keywords: wall sandwich panels; PIR core; tension; finite element modeling

INTRODUCTION

Sandwich panels as facade elements are preferred elements in the building industry. The structure of sandwich panels are two facings which are relatively thin and of high strength, and a core of high thickness and low density. The facings can be made of steel, aluminum, wood, fiber-reinforced plastic or even concrete. The core can be made of cork, balsa wood, rubber, solid plastic material (polyethylene), rigid foam material (polyurethane, polystyrene, phenolic foam), mineral wool slabs or from honeycombs of metal or even paper (Davis, 2001, p. 2). Nowadays, the structure of wall sandwich panels are two metal facings which enclose a rigid core (polyisocyanurate foam or mineral wool). The metal facings are very thin. Steel sheets have a minimum thickness of about 0.5

mm and aluminum of about 0.7 mm. The metal surface can be lightly profiled, also known as "micro-profiled", or deep-profiled. Therefore, the flat faces carry bending moments as tensile and compressive stresses, and the core carries shear force. If the faces are deep-profiled, they convey additional bending moment and shear force related to their bending and shear stiffness (Studzinski et al., 2014). The core is usually made of rigid plastic foam material and mineral wool. Characteristic properties of rigid foam (PIR), specially fire resistance, were discussed in papers (Mofrad et al., 2019). The behavior of mineral wool sandwich panels under bending load at room and elevated temperatures was studied by Ashjan Shoushtarian Mofrad et al. (Mofrad et al., 2020). The core material must have enough strength and stiffness to contribute the composite action and to enable the structural sandwich to carry the design loads (European Recommendations for Sandwich panels, 2000). The adhesive bond between the facing and the core must carry a shear stress equal to the shear in the core. Prevention of the relative slipping of facings requires a core with a sufficiently high shear modulus as well as adequate shear strength (Budescu, M. et al., 2004). In this study, the initial objective is to verify the numerical results with experimental results of the maximum tension sandwich panel with thin steel faces and PIR foam core. The Finite Element Method represents an efficient and reliable method for the structural analysis of complex structures.

TEST ARRANGMENT

Kingspan wall horizontal sandwich panels KS1000 NF/TF with PIR core, and of 100 mm thicknesses were chosen for testing. Each specimen has a cross section like the one pictured in Figure 1.

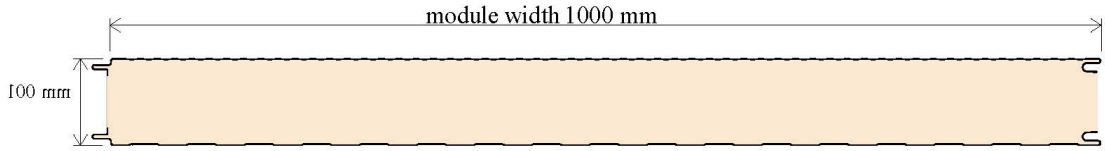

Figure 1. Cross section of panel PIR core 100 mm

Specimens dimensions are 100x100 mm^2, connected by glue SikaDur 52, for the sheet whose thickness is: d = 5 mm. In order to accurately obtain the maximum load capacity of the panel, the specimens had to be tied with a screw and a tension test was performed over the screw (Figure 2). The instrument that we used to measure the maximum load capacity of the panel is "Dynatest". The maximum force that can be transmitted by the instrument is up to 100 kN. In

addition, also measured was the displacement due to the action of the tearing force, and the designated instrument was "Compac". The test setup is shown in Figure 3.

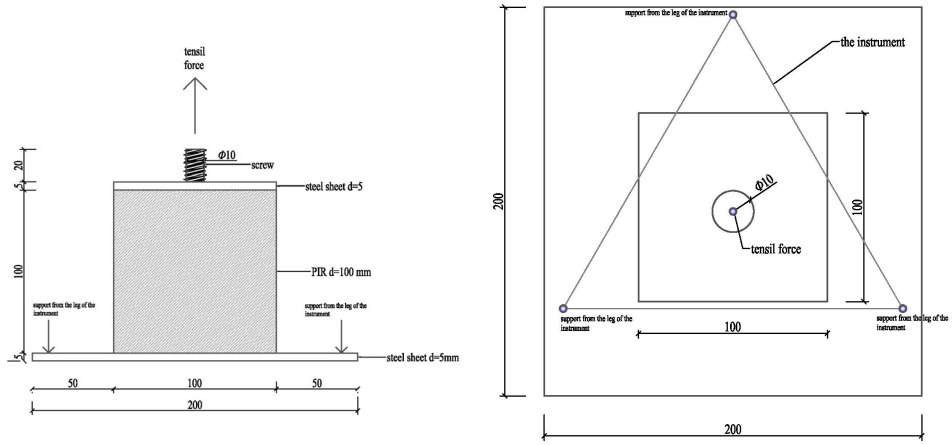

Figure 2. Tensile test; cross section and background of the specimen

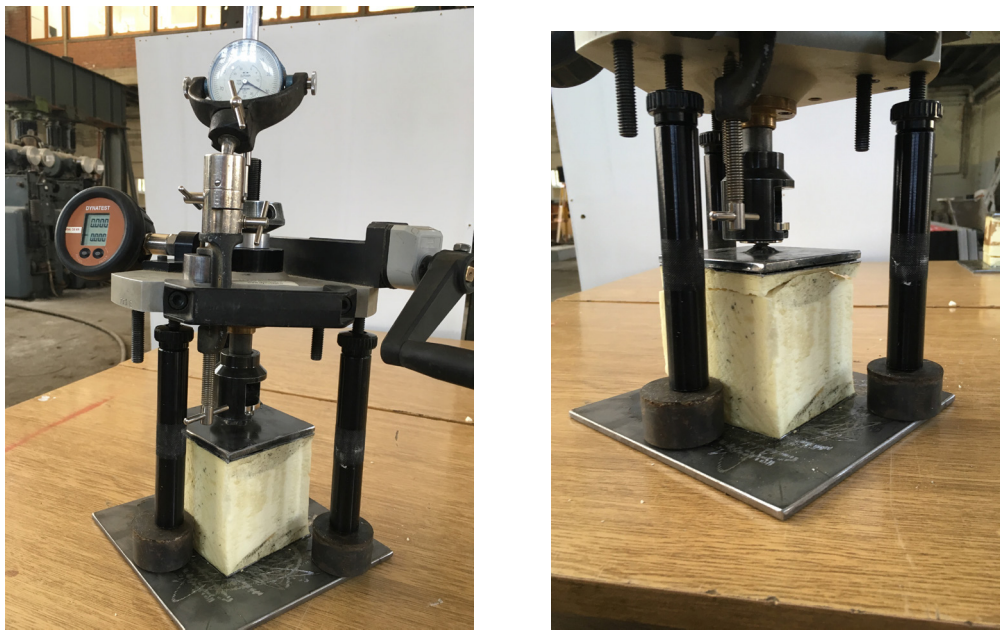

Figure 3. Specimen, left: before the test, right: after test (failure of panel core)

NUMERICAL MODELING

This section presents the results of the numerical simulation of the test specimen shown in Fig. 2. The structural analysis was done using the finite element method. ANSYS software code was used for this purpose. Figure 4 shows the finite element model of specimen.

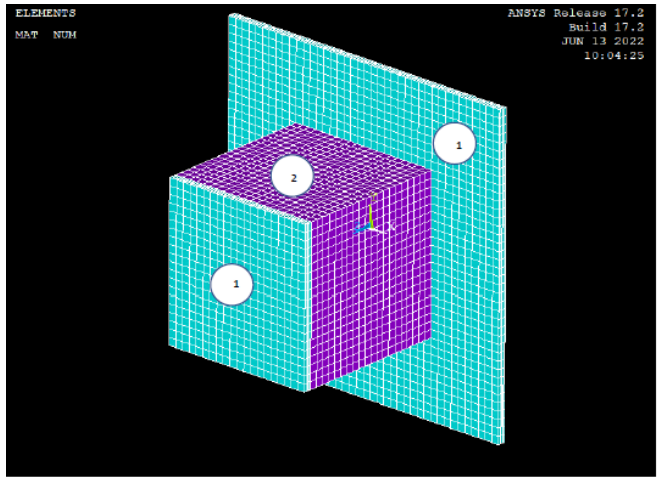

Figure 4. Finite element model of specimen: (1) steel sheets, (2) polyisocyanurate foam

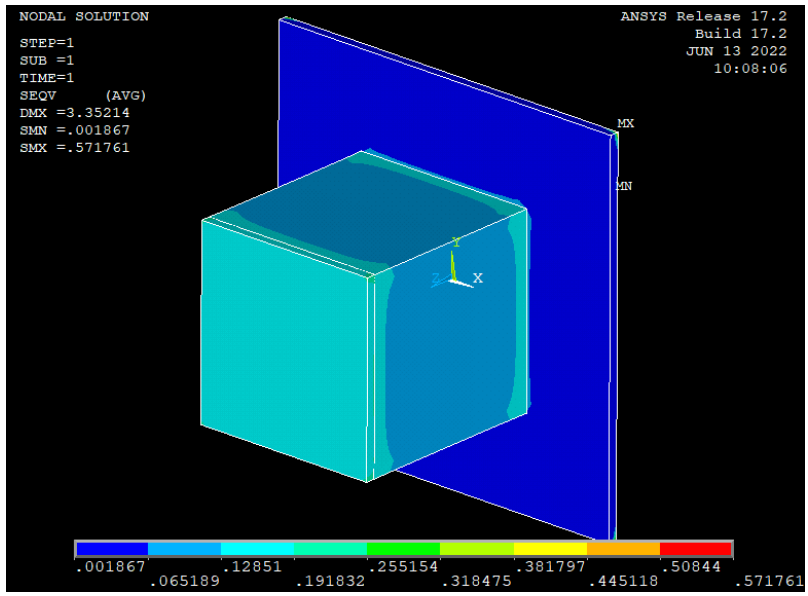

Figure 5. Von Mises stresses in nodes, S_{max}=571kN/mm² subject to force F=1.279kN

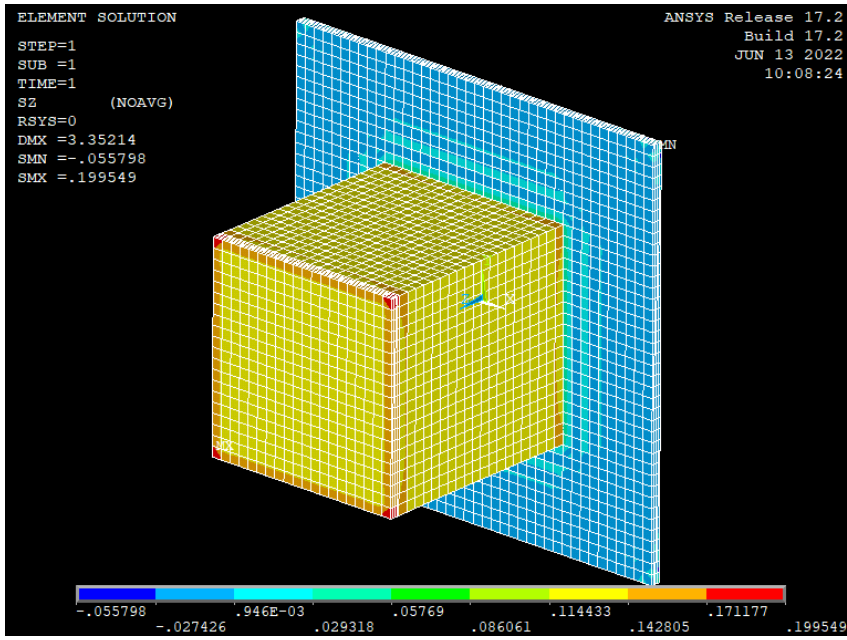

Figure 6. Stresses in the axial direction in the finite elements S_{max}=199kN/mm² subject to force F=1.279kN

Figures 5 and 6 show the corresponding stresses states in the test specimen itself for the corresponding force, F, with which the test specimen is loaded as shown in Figure 2.

CONCLUSION

The attention in the paper is focused on the analysis of the behavior of sandwich panels under tearing load. At this load, as a rule, the filling or the glued joint itself are critical. The paper presents the results of experimental research on the one hand and the results of computations on the other. For numerical analysis, the finite element method was used using the ANSYS software package. Using FEM for structural analysis as well as experimental analysis, the strength analysis of complex sandwich structures can be successfully realized. The Finite Element Method represents an effective and reliable method for the structural analysis of complex structures as well as for the structural analysis of sandwich structures such as those considered in this work.

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EVALUATE THE SMARTNESS OF PUBLIC BUILDINGS USING PYTHAGOREAN FUZZY AHP INTEGRATED MODEL

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Abstract

Implementing "smart" design solutions and technological processes makes buildings comfortable and safe for users, maximizing energy efficiency and enabling rational use of resources with minimized maintenance and construction costs. "Smart" buildings are defined by systems for managing energy, materials, water, and land, using wireless technologies and sensors that improve thermal, visual, and acoustic comfort. Since different public facilities do not have the same "smart" systems functions, there is a need to develop an integrated model for determining the degree of smartness. In this paper, different indicators related to the development of "smart" buildings are divided into six groups - green buildings construction, energy management system, safety, and security management systems, occupancy comfort and health, building automation and control management system, communication and data sharing. The paper aims to develop a scoring system for the smartness of public buildings. The decision-making process in developing a scoring system requires an appropriate optimal solution selection. The research focuses on the Pythagorean Fuzzy Analytic Hierarchy Process (PFAHP) as one of the methods of multi-criteria decision making (MCDM) and its implementation.

Keywords: Smart Buildings, Smartness, Public Buildings, Pythagorean Fuzzy AHP, Multi-Criteria Decision-Making

INTRODUCTION

Contemporary urban development strategies are focused on achieving different aspects of sustainable cities. According to previous studies, by 2050. 70% of the global population will occupy urban areas (Lopes and Oliveira, 2017). Many researchers discussed the issue of the development of future cities, and they all emphasized the correlation between sustainability and the need for urban areas to be liveable, resilient to global challenges, and responsive to their citizens (Desouza and Flanery, 2013). Future cities should be designed with high ecological comfort and energy efficiency, and minimized negative environmental impact.

As a sustainable response to the set requirements, the Smart City concept originated in the last two decades as a result of the fourth industrial revolution and is developing from the idea of using innovative IC technologies to improve people's quality of life and transform the existing environment in ecologically, economically, culturally and sociologically more self-sustainable and resilient (Li et al., 2019). The Smart City paradigm has spread to many different segments of urban areas: government, economy, mobility, environment, people, and liveability (Milošević et al., 2019). From modern and advanced urban infrastructure applying data sensors, use of public e-government and e-commerce platforms, through non-stop traffic development, to heritage digitalization and virtual tours, innovative technologies based on big data, Internet of Things platforms, and remote sensing images have become part of people's nowadays.

The application of IC technologies has influenced the improvement of the construction industry, which has an impact on the development of the Smart Buildings concept. The roots of smart buildings lie in the mechanical engineering development of self-regulating environmental systems in the 18th and 19th centuries. Nevertheless, only at the end of the 20th century use digital computers and inventions, the Smart Buildings concept spread by integrating technologies in different systems in buildings (for example, elevators and air conditioning). Nowadays, smart buildings represent facilities with high-tech Heating, Ventilation, and Air-conditioning (HVAC) systems, improved materials, and significant energy savings. According to European Commision (2018), facilities in the EU were responsible for 40% of energy consumption, so the Smart Buildings concept is strongly focused on energy minimization with the improvement of users' comfort.

There is no standard definition of a Smart Building. So far, many researchers and experts have presented different scientific and practical findings which help

to understand the transformation of conventional facilities into more efficient and adaptive ones. Buckman, Mayfield, and Beck (2015) defined a Smart Building as "a building which integrates and accounts for intelligence, enterprise, control, and materials as well as construction as an entire building system". These facilities have centralized automation and management systems for monitoring and control. Different microclimate conditions, sound, and light data can be collected using sensors and tracks to minimize energy use (Arditi et al., 2015). The Smart Buildings concept was presented by the European Performance of Buildings Directive (EPBD), while in 2018, its revision introduced Smart Readiness indicators enabling rating of the smartness of the buildings (European Commision, 2018). Further, the Global e-Sustainability Initiative SMARTer2030 report gives a technological vision of Smart Buildings in 2030, emphasizing the impact of IC technologies in achieving higher levels of energy efficiency (SMARTer2030, 2015).

The evaluation of the smartness of architectural buildings is a multidimensional issue. It is related to the type of implemented innovative technologies but also depends on how the technologies are integrated and the system type that they improve. This paper examines the issue of rating the smartness of public buildings using multi-criteria decision-making. The proposed research is based on ranking the criteria set for a Smart Building development using the Pythagorean Fuzzy Analytic Hierarchy Process (PFAHP) to find the optimal indicators for the conventional public buildings' transformation into smart ones.

MATERIALS AND METHODS

Due to the complexity of the set research goal, and the many different criteria which influence the development of Smart Buildings, the research framework consists of the following steps:

1) Defining and adopting the indicators related to the development of smart public buildings;
2) Defining and implementing the Pythagorean Fuzzy Analytic Hierarchy Process (PFAHP);
3) Developing a scoring system for the smartness of public buildings.

Assessing the smartness of buildings: defining indicators

According to previous research on the smartness of the buildings (Gunatilaka et al., 2021; Dakheel et al., 2020), indicators are divided into six main groups (Table 1):

- Green buildings construction (G) - Indicators are related to green and ecologically-friendly processes in different construction phases, from urban planning to materials usage.
- Energy management system (E) - Indicators are related to systems for increasing energy-efficiency and minimize energy use, enabling building to adapt to weather conditions.
- Occupancy comfort and health (O) - Indicators are related to different aspects of user's comfort (thermal, visual, acoustic…), which influences their wellbeing and health.
- Safety and security management system (S) - Indicators are related to safety of people lives with disaster security support and privacy policy.
- Communication and data sharing (C) - Indicators are related to use of different innovative smart technologies which enables communication between other systems in buildings.
- Building automation and control system (B) - Indicators are related to automation systems for monitoring, track and control of data and changeable conditions.

Table 1. Overview of criteria to evaluate smart buildings

G	Green buildings construction	E	Energy Management System
G_1	Land management	E_1	Energy-efficient procedures usage
G_2	Bioclimate design	E_2	Smart metering
G_3	Use of ecological materials	E_3	Energy-efficient electrical appliance usage
G_4	Use of RES systems	E_4	Use of advanced HVAC control systems
G_5	Use of greenery	E_5	Energy storage systems and backup energy
G_6	Waste management	E_6	Use of dynamic building envelope systems
O	Occupancy comfort & health	S	Safety & Security Management System
O_1	Functionality	S_1	Control of access and movement detection
O_2	Thermal comfort	S_2	Securing lives and assets
O_3	Indoor air quality	S_3	Fire prevention, detection, and protection

O_4	Visual comfort	S_4	Weather prediction and disaster response
O_5	Acoustic comfort	S_5	Cyber security
O_6	Personalized control of appliances	S_6	Publish safety and privacy policy
C	Communication & data sharing	B	Building automation & control system
C_1	Cloud base data storage	B_1	Data gathering devices with sensors
C_2	Internet of Things	B_2	Remote implementation monitors building
C_3	Data protection	B_3	Real-time monitoring system
C_4	Wireless communication	B_4	Software implementation
C_5	Cyber system	B_5	Asset tracking

Implementing the Pythagorean Fuzzy Analytic Hierarchy Process

Pythagorean numbers

Let X be a non-empty universe of discourse. A Pythagorean fuzzy set $\widetilde{A}_P$ in X is defined as:

$$\widetilde{A}_P = \left\{x, \langle \mu_{\widetilde{A}_p}(x), v_{\widetilde{A}_p}(x)\rangle, x \in X\right\}. \quad (1)$$

The degree of indeterminacy is expressed, where $\mu_{\widetilde{A}_p}(x): X \to [0,1]$ denotes the degree of membership and $v_{\widetilde{A}_p}(x): X \to [0,1]$ denotes the degree of non-membership of the element $x \in X$ to the set $\widetilde{A}_P$ and satisfy condition $0 \leq \mu^2_{\widetilde{A}_p} + v^2_{\widetilde{A}_p} \leq 1$ (Peng and Yang, 2015; Kahraman et al., 2017) Therefore, the degree of indeterminacy is given by $\pi_{\widetilde{A}_p} = \sqrt{1 - (\mu^2_{\widetilde{A}_p} + v^2_{\widetilde{A}_p})}$.

Let $\widetilde{A}_P = (\mu_{\widetilde{A}_p}, v_{\widetilde{A}_p})$ and $\widetilde{B}_P = (\mu_{\widetilde{B}_p}, v_{\widetilde{B}_p})$ be two Pythagorean fuzzy sets. Then, the basic operations are defined as follows

- $\widetilde{A}_P \oplus \widetilde{B}_P = \left\langle \mu_{\widetilde{A}_p}, v_{\widetilde{A}_p} \right\rangle \oplus \left\langle \mu_{\widetilde{B}_p}, v_{\widetilde{B}_p} \right\rangle = \langle (\mu^2_{\widetilde{A}_p} + \mu^2_{\widetilde{B}_p} - \mu^2_{\widetilde{A}_p}\mu^2_{\widetilde{B}_p})^{\frac{1}{2}}, v_{\widetilde{A}_p} v_{\widetilde{B}_p} \rangle$
- $\widetilde{A}_P \odot \widetilde{B}_P = \left\langle \mu_{\widetilde{A}_p}, v_{\widetilde{A}_p} \right\rangle \odot \left\langle \mu_{\widetilde{B}_p}, v_{\widetilde{B}_p} \right\rangle = \langle \mu_{\widetilde{A}_p}\mu_{\widetilde{B}_p}, \left(v^2_{\widetilde{A}_p} + v^2_{\widetilde{B}_p} - v^2_{\widetilde{A}_p} v^2_{\widetilde{B}_p} \right)^{\frac{1}{2}} \rangle,$
- $c \times \tilde{A}_P = c \times \left\langle \mu_{\tilde{A}_p}, v_{\tilde{A}_p} \right\rangle = \langle (1 - \left(1 - \mu^2_{\tilde{A}_P}\right)^c)^{1/2}, v^c_{\tilde{A}_P} \rangle, \ , c > 0$
- $\widetilde{A}^{\lambda}_P = \langle v^c_{\widetilde{A}_P}, (1 - \left(1 - \mu^2_{\widetilde{A}_P}\right)^c)^{1/2} \rangle, c > 0.$

Pythagorean fuzzy analytic hierarchy process (PFAHP)

The Pythagorean fuzzy set (PFS) is proposed by Yager (2013), generalizing fuzzy sets by considering membership and non-membership. The proposed Pythagorean fuzzy analytic hierarchy method is presented through the phases: linguistic evaluation and weights in fuzzy numbers. First, the experts must rate their opinion on the dimensions against the identified indicators according to the problem. Experts provide ratings based on a five-point pairwise comparison scale of the fuzzy AHP. Then, experts are asked to rate using Pythagorean fuzzy number (PFN) linguistic scales defined by the two parameters. The linguistic variables are shown for Pythagorean fuzzy sets in Table 2.

Table 2. The linguistic variables for PFAHP

Absolutely weak dominance (AW)	⟨0.1, 0.9⟩	Fairly strong dominance (FS)	⟨0.6, 0.4⟩
Extremely weak dominance (EW)	⟨0.2, 0.8⟩	Very strong dominance (VS)	⟨0.7, 0.3⟩
Very weak dominance (VW)	⟨0.3, 0.7⟩	Extremely strong dominance (ES)	⟨0.8, 0.2⟩
Fairly weak dominance (FW)	⟨0.4, 0.6⟩	Absolutely strong dominance (AS)	⟨0.9, 0.1⟩
Equal importance (E)	⟨0.5, 0.4⟩		

PFAHP consists of the following steps:

- Creating a hierarchical structure for setting goals.
- Construct a pairwise comparison between criteria in dimensions based on a hierarchical system about preferences such as matrix $A = \left(a_{ij}\right)_{n\times \mathrm{n}}$, with pairwise comparisons are constructed for all considered preference criteria, where a_{ij} , $i, j = 1, 2, \ldots, n$, is equal based on the linguistic scale $\widetilde{A}_P = (\mu_{\widetilde{A}_p}, v_{\widetilde{A}_p})$
- Aggregation the preferences of experts. Check the consistency of the comparison matrix using Saaty's classical consistency analysis.
- Calculation of fuzzy weights and global fuzzy weights of criteria.
- The defuzzification process is conducted.

RESULTS AND DISCUSSION

Based on the experts opinions, the hierarchical structure was created, and matrices were compared, such as the matrix of the main criteria given in Table 3.

For the applied PFAHP method, the experts have provided comparison matrices for all six sub-criteria groups. Consistency conditions were met for all comparison matrices ($CR < 0.1$).

Table 3. Comparison matrix of main criteria for PFAHP (CI=0.01967; CR= 0.01586<0.1)

⟨0.5, 0.5⟩	⟨0.5, 0.4⟩	⟨0.7, 0.3⟩	⟨0.7, 0.3⟩	⟨0.7, 0.3⟩	⟨0.8, 0.2⟩
⟨0.5, 0.6⟩	⟨0.5, 0.5⟩	⟨0.7, 0.3⟩	⟨0.7, 0.3⟩	⟨0.7, 0.3⟩	⟨0.8, 0.2⟩
⟨0.3, 0.7⟩	⟨0.3, 0.7⟩	⟨0.5, 0.5⟩	⟨0.5, 0.4⟩	⟨0.5, 0.4⟩	⟨0.6, 0.4⟩
⟨0.3, 0.7⟩	⟨0.3, 0.7⟩	⟨0.5, 0.5⟩	⟨0.5, 0.5⟩	⟨0.5, 0.4⟩	⟨0.6, 0.4⟩
⟨0.3, 0.7⟩	⟨0.3, 0.7⟩	⟨0.5, 0.6⟩	⟨0.5, 0.6⟩	⟨0.5, 0.5⟩	⟨0.6, 0.4⟩
⟨0.2, 0.8⟩	⟨0.2, 0.8⟩	⟨0.4, 0.6⟩	⟨0.4, 0.6⟩	⟨0.4, 0.6⟩	⟨0.5, 0.5⟩

The results of ranking the indicators relevant to Smart Building development are presented in Figure 1. Indicators within groups G (green building construction) and E (energy management system) are at the main criteria level recognized by experts as a prerequisite for the Smart Building construction for public purposes. On the left picture, the weights of the main criteria and sub-criteria for indicators groups G and E are given, while on the right, are the final weights of all subcriteria. The obtained results show that bioclimate design of the building (G_2), smart metering (E_2), use of ecological materials (G_3), data gathering devices with sensors (B_1), use of renewable energy sources (G_4), energy-efficient procedures usage (E_1), use of advanced HVAC control systems (E_4) and securing lives and assets (S_2) have a dominant role in the development of Smart Buildings for public purpose.

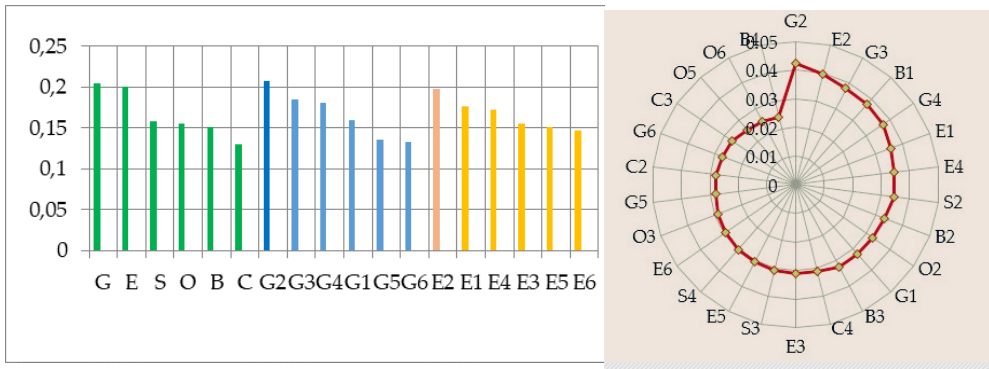

Figure 1. The weights of criteria and sub-criteria G and E (left); final ranking of sub-criteria (right)

CONCLUSION

In this paper, by applying the PFAHP method, the ranking of indicators relevant for the development of Smart Buildings in the context of the broader Smart City concept is carried out. The obtained results indicate that in the initial stages of the technological transformation of the construction industry, it is necessary to fulfill the requirements related to the ecological sustainability of buildings using natural materials, RES systems, bioclimatic design, and appropriate measures to improve energy performance, before the introduction of technologies and the creation of control and automation systems. The research takes public-purpose buildings as a case study, opening the possibility for future research to focus on residential facilities, applying other fuzzy multi-criteria analysis methods. Finally, the research emphasizes the importance of creating a scoring system for assessing the degree of smartness of architectural buildings. The applied methodology can be used practically in decision-making processes in the urban sector and local self-governments of cities.

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MONITORING OF PROTECTED AQUATIC SYSTEMS IN SERBIA AND CROATIA – A PROJECT PORTRAIT

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Abstract

The need to exert additional effort in the process of protecting wetlands and the habitats they represent led to the creation of the SeNs WETLANDS initiative. Wetlands are areas with a rich biodiversity that are increasingly sensitive to modernization and exploitation. The SeNs WETLANDS Project's fundamental pillar is transnational and interregional collaboration with inter- and trans-disciplinary approach to environmental conservation, with a particular emphasis on protected and vulnerable wetlands. The SeNs Wetlands Project's primary objectives include enforcing integrated cross-border analytical monitoring of critical physicochemical parameters and existing threats, as well as biodiversity and the protection of the aquatic and terrestrial environments. Agricultural runoff and sewage drained from neighbouring communities have a significant negative effect on the water quality of Tompojevaki ritovi and Lake Zobnatica in Serbia and Croatia, respectively. Absence of wastewater treatment systems, as well as green buffer zones between agricultural land and lakes, has been proven to have a major negative effect on the water's quality. The results show that water in Zobnatica Lake can be classified as class III at best, as mild-eutrophic state, moderate eco-status, and for Tompojevački ritovi quality water belongs to the class IV/V, with high trophic state.

Key words: surface water, protected areas, physicochemical parameters

INTRODUCTION

Implementing integrated cross-border monitoring for the physicochemical parameters and current hazards, as well as the protection of protected aquatic areas and biodiversity, are the main goals and objectives of the SeNs Wetlands Project (Internal report and material of the Project, Obrovski, 2022, 121, Sremački, 2020, 187, Vojinović Miloradov, 2020, 89). The sensory monitor network designed to increase environmental protection and smart use of wetland and other waters (SeNs Wetlands) Project partners are: The lead partner, Faculty of Technical Sciences (SER), Faculty of Electrical Engineering, Computer Science and Information Technology in Osijek (CRO) Institute for Nature Conservation of Vojvodina Province (SER) and Public Institution for Management of Protected Natural Values of Vukovar-Srijem County (CRO).

The Project was carried out by integrated continuous monitoring system for the aim of gathering and analysing cross-border data. The data for physicochemical parameters for every location can be seen and followed on the website of the Project in real time (http://senswetlands.ferit.hr/sens). Physicochemical parameters include several groups of basic parameters, nutrients, salinity, cations of metals and organic substances - pH, air and water temperature, dissolved oxygen, chemical oxygen demand (COD), biological oxygen demand (BOD_5), total organic carbon (TOC) (physicochemical parameters); anions - nitrites ($NO^-_{2\,(aq)}$), nitrates ($NO^-_{3\,(aq)}$) and orthophosphates ($PO^{3-}_{4\,(aq)}$), and ammonium nitrogen cation (NH^+_4-$N_{(aq)}$), total nitrogen and phosphorus (nutrients); sulfates ($SO^{2-}_{4\,(aq)}$), chlorides ($Cl^-_{(aq)}$), fluorides ($F^-_{(aq)}$), conductivity, total chlorine (salinity) and cations nickel ($Ni^{2+}_{(aq)}$), iron ($Fe^{2/3+}_{(aq)}$), zinc ($Zn^{2+}_{(aq)}$), chromium ($Cr^{6+}_{(aq)}$), copper ($Cu^{2+}_{(aq)}$)(metal cations) and organic aromatic compound phenol (C_6H_5OH). All the physicochemical parameters were analyzed in the Accredited Laboratory for monitoring of landfills, wastewater and air, Department of Environmental Engineering and Occupational Safety, Faculty of technical sciences, University of Novi Sad. The standard EPA and HACH methods were used for all Laboratory measurements - EPA 170.1, EPA 150.1, EPA 120.1, EPA 360.1, EPA 365.3, HACH 8507, HACH 8192, HACH 8155, HACH 8021, HACH 8113, HACH 8023, HACH 8167, HACH 8023, EN ISO 11905-1, Method 8047, Method 8150, Method 8146, Method 8009, Method 8143 and ISO 15705. The sampling procedure was conducted according the Manual for sampling no. Q3.LA.06. and Standard SRPS EN ISO 5667-1:2008 (Guidelines for development of sampling programs). SRPS EN ISO 5667-3:2007 (Guidelines for protection and handling of the sample). SRPS EN ISO 5667-6:1997 (Guidelines for abstraction of samples

from rivers and streams) (Internal report and material of the Project, Obrovski, 2022, 121, Sremački, 2020, 187, Vojinović Miloradov, 2020, 89).
This type of research was for the first time conducted in the scope of SeNS Wetlands Project no. 135, within the IPA INTEREG CROATIA-SERBIA Program. The main motivational challenge and driving force of the Project is the recognition of the significance of INTERREG cooperation and collaboration within the framework of the environment protection of sensitive aquatic and protected areas via application of analytical methods and new remote sensing and electro methods.

THE AREA AND SCOPE OF THE PROJECT

Ecosystems that have been impaired or degraded have a lower tolerance and adaptability to changes in environmental conditions and climate change. The optimal revitalization of ecosystems necessitates a high level of inter- and trans-disciplinary, cross-border activity. The Project addressed one of the Pannonia Region's and bordering agricultural landscapes' major cross-border challenges, which are characterized by a high percentage of arable land and increased pressures on natural systems. Water pollution from agricultural sources is a common cross-border problem, caused by cultivation reaching the water line. Despite the fact that natural habitats are highly fragmented, the region contains a significant number of Natura 2000 sites, both existing and planned. The Project sites are located within hydrological systems of watercourses (Bosut in Croatia and Krivaja in Serbia) that have been designated as ecological corridors. The wetland in Croatia has a direct effect on the water quality of the Natura 2000 site located downstream, and the Project site in Serbia has been proposed for Nature Park protection.

Surface water of the Lake Zobnatica is the type of freshwater. Zobnatica Lake was formed in 1976 in the valley of a small river, Krivaja, with an area of 226 ha (Figure 1). The primary purpose of the lake is the irrigation of agricultural areas and leisure activities in Bačka Topola municipality. Tompojevački ritovi are a sensitive water body of wetland type, covering the area of 684 ha in the Vukovar-Srijem County (Figure 1).

Figure 1 Lake Zobnatica and Tompojevački ritovi

All of the activities surrounding Lake Zobnatica and Tompojevaki ritovi, as well as the fact that both observed Lake and Wetland are semi-closed water bodies, make it extremely vulnerable to environmental disbalance. Agriculture and waste water drained from surrounding rural and urban settlements are the most significant anthropogenic activities affecting the quality of the Lake's surface water.

The measuring locations are inside hydrological watercourse systems that are known ecological corridors. The water quality of water bodies that fall under the purview of the geo-network Natura 2000 site is directly influenced by the Wetland of Tompojevci in Croatia and the Lake Zobnatica in Serbia. Water pollution from agricultural sources is a common problem of both Serbia and Croatia. The water quality is one of the drivers of biodiversity depletion in wetlands. Buffer/filter function of the bankside vegetation have not been recognized widely, field data from the Pannonia region are scarce and mostly gained by indirect methods. The most significant pollutants that cause eutrophication were quanti-

fied and their seasonal dynamics was tracked continuously by sensors placed in measurement wells.

PROJECT RESULTS

In the Tables 1 and 2, the guidelines for selected parameters and values for classification of water quality from By-law on maximum allowable values of pollutants in surface and ground water and sediment and timeframe for their achievement and the maximum allowable values (MAV) of physicochemical parameters for class I and II quality of water for lakes below 200 m of sea level are shown.

The results were further evaluated and compared to guidelines shown in by-laws of Serbia and Croatia and compared to German standards of evaluation and assessment (By-law on alterations and amendments for water quality guidelines, By-law on maximum allowable values of pollutants in surface and ground water and sediment and timeframe for their achievement, Cron, 2018, 75).

Table 1 The excerpt of parameters and values for classification of water quality (By-law on maximum allowable values of pollutants in surface and ground water and sediment and timeframe for their achievement (Official Gazette no. 50/2012))

Parameter	**Unit**	**Class I**	**Class II**	**Class III**	**Class IV**	**Class V**
pH	-	6.5-8.5	6.5-8.5	6.5-8.5	6.5-8.5	<6.5 or >8.5
Conductivity	µS/cm	<1000 / BLQ	1000	1500	3000	>3000
Dissolved oxygen	mgO_2/L	- / BLQ	- / BLQ	5	4	<4
PO_4^{3-}	mg/L	- / BLQ	-	0.2	0.5	>0.5
NO_2^-	mg/L	0.01 / BLQ	0.03	0.12	0.3	0.3
NO_3^-	mg/L	- / BLQ	-	6	15	>15
NH_4^+-N	mg/L	- / BLQ	-	0.6	1.5	>1.5
$SO_{4\ (aq)}^{2-}$	mg/L	50 / BLQ	100	200	300	>300
$Cl^-_{(aq)}$	mg/L	50 / BLQ	-	150	250	>250
Total chlorine	mg/L	0.005	0.005	-	-	-
TOC	mg/L	- / BLQ	-	15	50	>50

HPK	mgO_2/L	10 / BLQ	15	30	125	>125
BPK_5	mgO_2/L	- / BLQ	-	7	25	>25
Chromium [1] (total)	µg/L	25 / BLQ	50	100	250	>250
$Cu^{2+}_{(aq)}$	µg/L	5/22/40/112*		500	1000	>1000
$Zn^{2+}_{(aq)}$	µg/L	30/200/ 300/500*	300/700/ 1000/2000*	2000	5000	>5000
$Fe^{2/3+}_{(aq)}$	µg/L	200	500	1000	2000	>2000
Phenols	µg/L	<1	1	20	50	>50

*BLQ – base-line quality; * - depending on the water hardness 10, 50, 100 and 500 $mgCaCO_3/L$*

Table 2 The maximum allowable values of physicochemical parameters for class I and II quality of water for lakes below 200 m of sea level

Parameter	Unit	Class I	Class II
pH	-	6.5-8.5	6.5-8.5
Dissolved oxygen	mg/L	8.52	7
TOC		2	6
BPK_5		2	5
NH_4^+-N		0.1	0.3
NO_3^-		1	3
PO_4^{3-}		0.02	0.1
Total phosphorus		0.05	0.2
Cl^-		50	100

The semi-closed reservoir Lake Zobnatica and the wetland Tompojevaki ritovi are highly sensitive and fragile eco-systems that require much higher and strict maximum allowable values of monitored water quality parameters than rivers. According to the results and MAVs Zobnatica Lake can be classified as class III at best, as mild-eutrophic state, moderate eco-status which allows bathing and recreation activities. The results of analytical measurements compared to MAVs, particularly the two physicochemical parameters, conductivity and dissolved oxygen, examined surface water of Tompojevački ritovi belongs to the class IV/V quality water, with high trophic state (By-law on alterations and amendments for water quality guidelines, By-law on maximum allowable values

of pollutants in surface and ground water and sediment and timeframe for their achievement, Cron, 2018, 75).

DISSIMINATION OF THE PROJECT

The data and work from Project SeNS Wetlands enabled the production of about 12 conference papers and 4 original journal papers:

1. Sremački, M., Obrovski, Petrović, M., Mihajlović, I., Dragičević, P., Radić, J. and Vojinović Miloradov, M. (2020) Comprehensive environmental monitoring and assessment of protected wetland and lake water quality in Croatia and Serbia

2. Vojinović Miloradov, M., Mihajlović, I., Sremački, M., Petrović, M., Obrovski, B., Sabadoš, K., Kicošev, V., Dragičević, P. and Radić, J. (2020) Portrait of the INTERREG IPA Project between Croatia and Serbia, SeNs WETLANDS

3. Obrovski, B., Mihajlović, I., Vojinović Miloradov, M., Sremački, M., Španik, I. and Petrović, M. (2022) Groundwater quality assessment of protected aquatic eco-systems in cross-border areas of Serbia and Croatia

4. Sremački, M., Obrovski, B., Mihajlović, I., Petrović, M., Vojinović Miloradov, M., Kisošev, V., Dragičević, P. and Radić, J. (2018) Surface water quality of protected aquatic systems in Serbia and Croatia

INSTEAD OF CONCLUSIONS

The results of performed analyses and measurements during shows that eco-status of Lake Zobnatica and wetland Tompojevački ritovi varies from moderate to bad, making it exceptionally important to emphasize the need for the protection and preservation of these sensitive water systems. Uncontrolled discharges from settlements, agricultural areas, and activities pose a significant threat to the water and environment. There are many good practice examples in countries such as Serbia and Croatia, as well as Europe that demonstrate that protecting the most sensitive waterways and semi-closed aquatic systems can only be accomplished through a process of awareness and implementation of the most viable solution.

ACKNOWLEDGEMENT

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E-WASTE APPLICATION IN NANOTECHNOLOGIES: PROMISING SUBJECT FOR RAISING AWARENESS ON RECYCLING IN HIGH SCHOOLS STUDENTS POPULATION

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Abstract

The sustainability of the raw material chain is extremely important topic since the classical mining is increasingly being replaced by raising the efficiency of the recycling system for already used materials that have expired in some way. With the rapid development of electronic products, huge amounts of waste electrical and electronic equipment (WEEE) have been generated with printed circuit boards (PCBs) as one of the most frequently found one. However, they are also a promising secondary resource due to the presence of useful metals in high concentrations such as Cu, Zn, Sn, Fe, Ni and Al. Present study shows how the recycling of copper from WEEE can be demonstrated to the high school students as an educational tool, and how copper recovered in such manner can be also used directly as the colloid suspension for direct synthesis of the nanomaterials (Torreggiani et al., 2020, 2021).

Educating young generations on the importance of all sorts of recycling is undisputable, and the WEEE recycle is the area where future still must bring new knowledge. Results presented here show that new innovative results obtained

in the nanotechnological application of colloid metal solutions recovered from WEEE can raise awareness of the high school students on the importance of raw material sustainability. At the same time, two effects are obtained, the education in environmental protection and also the increase in students' interest in STEM subjects, most particularly chemistry and chemical technology.

Key words: e-waste, nanotechnology, recycle, secondary education

INTRODUCTION

An indispensable part of civilizational development is the development of the industry related to electronic devices. Using them makes everyday life easier and more practical. The modernization of technology and the production of electronic and electrical devices are among the fastest growing industries in the world. Rapid advances in technology, urbanization, and the shortening of the lifespan of electronic equipment have significantly accelerated the generation of electronic waste. Electronic waste or e-waste is a term that refers to waste generated from all electronic and electrical devices and their parts without the intention of reuse. E-waste is also called WEEE - waste of electrical and electronic equipment (Abdelbasir et al., 2018).

WEEE covers a wide range of products - almost any household or business item with circuits or electrical components powered by a power supply or battery. Electronic waste is considered a serious social problem and a threat to the environment. Some suggested categories that are considered WEEE could be: temperature exchange equipment (cooling and freezing equipment such as refrigerators, freezers, air conditioners and heat pumps), screens and monitors (televisions, laptops, notebook computers and tablets), lamps (fluorescent bulbs, tungsten bulbs, compact fluorescent bulbs, high intensity bulbs and LED bulbs), large equipment (washing machines, tumble dryers, dishwashers, electric ovens, large printing machines, copying equipment and photovoltaic panels), small equipment (vacuum cleaners, microwave ovens, ventilation equipment, toasters, electric kettles, electric shavers, scales, calculators, radios, video cameras, electric and electronic toys, small electric and electronic tools, small medical devices and small instruments for monitoring and control) and small IT and telecommunications equipment (mobile phones, GPS, pocket calculators, routers, personal computers, printers, telephones and e-book readers) (Perkins et al., 2014).

CURRENT STATE OF THE E-WASTE ACCUMULATION ND RECYCLE

In 2019, 53.6 million tons of e-waste were produced worldwide, which is 21% more than in 2014. If this trend continues, that number could, according to the estimates, reach 74.7 million tons by 2030, which means that the amount of e-waste is growing by about 3 to 4 percent every year. That's nearly double the 2014 figure, all fuelled by higher electrical and electronic consumption, shorter device life cycles, and limited repair options. In addition, the United Nations Environment Program (UNEP) has estimated that around 45 million tons of e-waste are generated worldwide each year. The increasing amount of this waste has forced governments to impose restrictive regulations on e-waste disposal (International Telecommunication Union, 2021; Rosane, 2021).

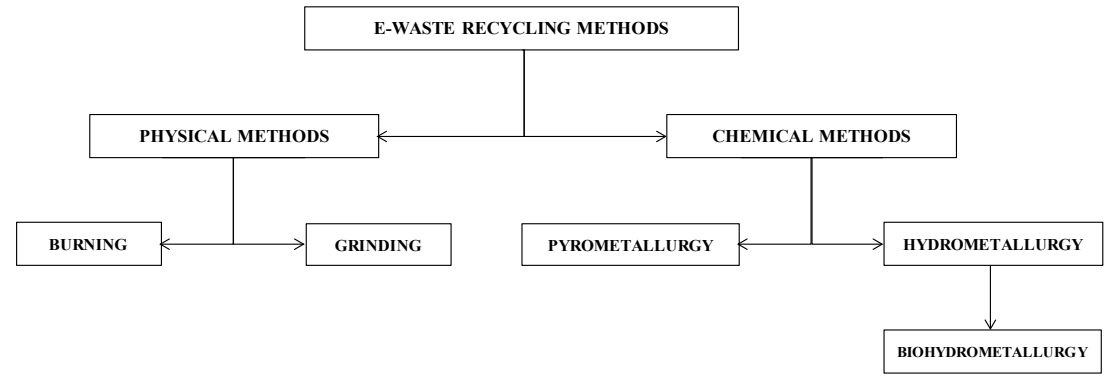

Figure 1. *Scheme showing current tendencies in e-waste recycle*
Figure 2.

Universal method for recycle of the WEEE does not exists, however, the directions of the recycling research is becoming relatively clear as can be seen from the Picture 1. Most often, the recycle starts with the disassembling into smaller parts, than even the shredding of the parts, and finally, either pyrolytic or chemical ways of extracting the valuable components is applied. The choice of the method depends on the available resources and equipment at the collecting or recycling centre. Many parts of the electronic waste are simply the large metallic parts from iron or aluminium alloys which can be easily separated and further processed as the typical metallurgical recycle, as well as the polymer parts which could also go directly into appropriate recycling lines (such as polyethylene, polypropylene, melamine resins etc). However, one sort of the electronic waste is drawing wide attention of the international scientific community and that is the printed circuit boards (PCB). PCBs are the usual part of the computer and

other electronic devices memory-holding devices, and they contain primarily copper, tin, as well as gold, silver, platinum and other valuable metals. In the past these components were recycled by different chemical leaching methods which often included aggressive acids. Recently, less aggressive, and even completely environmentally acceptable solvents are used for this purpose and hopefully will dominate in the future. After chemical leaching, copper or other components become available in the form of colloidal solutions, for which, typical metallurgical applications are not economically meaningful. On the other hand, such solution can be used as the raw materials resource for nanotechnologies which is an emerging subject. Present paper will suggest how this type of experiment is easily reproducible in the laboratories even in the high schools.

Demonstration of the metal leaching from the PCBs, can thus become a tool for colourful and easy-to-remember green chemistry lecture within the chemistry curriculums, while at the same time teaching young generations on the importance of this type of recycling. Moreover, it should be emphasized that this class of materials is interesting to the pupils since it is something close to their hearts. In particular, many recent studies are showing alarmingly increased daily screen time in this age group rising to several hours a day depending on different sources (Lissak, 2018; Nagata et al., 2020; Wang et al., 2018). Therefore, performing experiments with used electronic devices could increase pupils' interest in these subjects but can also lead to the more responsible handling of these devices and consequently the decrease in e-waste reduction, which can be an attractive separate study. Below is the short introduction in recent developments in application of e-waste in nanotechnologies.

E-WASTE AND NANOTECHNOLOGIES

Nanotechnology has become an increasingly prevalent route to the chemical innovations in the fields such as medicine, water treatment and energy storage for improving technologies related to human health, communications, and transportation. The process of utilizing wasted PCBs as raw material to produce metal nanoparticles has also recently become a new research direction. Extracting nanomaterials from e-waste could bring a double contribution, both in terms of economic and ecological aspect (reduction of accumulation of potentially toxic waste). Most particularly, copper from e-waste is an attractive and widely studied subject. Cu-based nanoparticles (Cu-NP) can be used in technologies where high thermal conductivity or high-strength alloys are necessary, as well as for the production of various antibacterial and antiviral materials. They are also used in photochemical catalysis, electronics, optics, biosensors, gas sensors,

electrochemical sensors and solar (photovoltaic) energy conversion. There were many obstacles in e-waste-based copper recycle such as energy efficiency, economical aspect, environmental acceptability, and others. Recently, there are two main directions: mechanochemistry (cryomilling) and chemical leaching with non-harmful solvents. The mechanochemical methods include continuous milling with ball mills under very low temperature such as -119 °C. Low temperature assure less vaporized toxic substances and gasses, while obtained materials are usually very small particles of polymers and metal oxides which later can be separated with less harmful methods.

Chemical separation and extraction of metal ions from the milled e-waste is possible using an aqua regia or other strong acids and their mixtures (Nithya et al., 2021). This practice is still found in some of the developing countries, but it should be avoided and strongly prohibited. New results suggest that chemical extraction can be very efficient with very mild reagents. One of the most successful examples in the literature is the extraction using ammonium carbonate, ammonium chloride and ammonium citrate, which react with the copper specifically and separate it from other metals in the crashed e-waste. After obtaining the copper solution, nanoparticles can be synthetized using L-ascorbic acid and the CTAB surfactant. This exact method was reproduced with the focus on the best results from the cited study and is the core of the suggestion for introducing e-waste-based nanotechnologies in the high school curriculums (Abdelbasir et al., 2018; Seif El-Nasr et al., 2020).

NANOTECHNOLOGIES IN HIGH SCHOOL CURRICULUMS

In recent years, studies are showing that due to importance of nanosciences, such subjects should be added to the biology, physics, and chemistry curricula in secondary schools. Schools should initiate and support implementation of the curriculum reforms which provide virtual and simulated laboratories, laboratory equipment, teaching materials, blended learning environments and opportunities for professional development of teachers so that they can transfer the knowledge (Ipek et al., 2020). Nanotechnology can be integrated in different disciplines and creative activities within the schools. Some studies aimed to develop a STEAM activity on nanotechnology for students in high school level and showed that the proposed nanotechnology STEAM activity encouraged the students, especially those whose basic science process skills were in the moderate level. Therefore overall recommendations in the international literature without doubt show that guidance for the teachers to further promote the skills and understanding of the

nanotechnologies for students are becoming common (Khamhaengpol et al., 2021; Yu & Jen, 2020).

CASE STUDY: RECENT RESULTS

Recent project results and thesis developed through the EU-funded project "RM@Schools", have dealt exactly with the subject suggested in present paper. Namely, scientists in Italy and Bosnia and Herzegovina have approached the high schools and helped in training both the teachers and the pupils in extracting the copper ions from the e-waste as well as challenging the synthesis of nanomaterials in school labs. Project is even working on developing a specific toolkit for teachers with appropriate learning materials, standardly written curriculum and with the appropriate funding for the basic equipment for such a challenge.

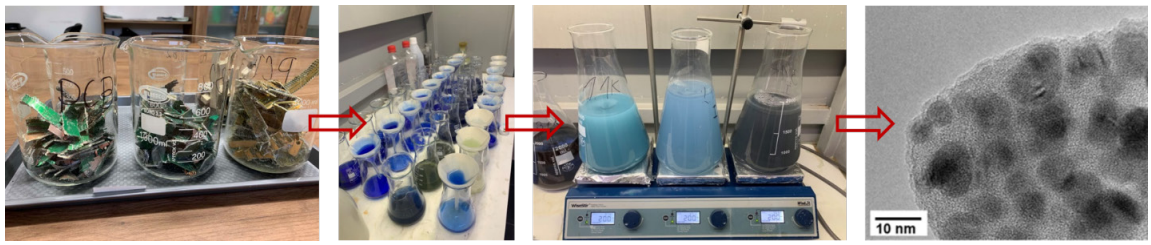

Figure 3. *Results obtained in recent study through the "RM@Schools" project (not previously published)*

The idea is to develop relatively safe experiment which can be done even with the modest laboratory tools and which can as such familiarize pupils with the subject of nanotechnology, but even more importantly with the environmental problematic of the electronic waste management necessity. As the Picture 2 shows, by mechanically shredding the peace of the old computer PCBs, a small peace can be obtained which fit into the classical laboratory beaker. After this procedure, the reagents for extraction are added and with few hours' times a concentrated solution of the copper ions is obtained. Later, after simple separation of the physical parts of the remains of PCB, the clear solution remains, to which the surfactant can be added. This image shows reaction with the CTAB which was a p.a. grade surfactant. In the last phase the experiment, the magnetic stirring was performed with gradual addition of the sodium hydroxide solution during which the nanoparticles are formed. In the ideal conditions, these obtained precipitated nanoparticles are subjected to the heat treatment and later analysed by TEM microscopy and XRD as is shown. These, previously unpublished data are showing clear formation of the CuO particles of 3-15 nm in diameter range.

PROPOSITION OF SETUP FOR THE HIGH SCHOOL LAB EXPERIMENTS

Picture 3 shows a simplified schematic representation of the processing of E-waste, in order to introduce high school students in an empirical and experimental way to the processing of electronic waste, which can be a raw material for new products, in particular the copper oxide nanomaterials.

The first stage is the collection of E-waste, followed by crushing using different types of pliers and other mechanical tools to separate the visible plastic parts from the PCB that would interfere with the flow of analysis and obtaining copper nanoparticles. After the selection and mechanical preparation of samples, the second stage is the process of extracting copper from PCB boards using a solution of the following ammonium chloride salts, NH_4Cl, ammonium citrate, $(NH_4)_2C_6H_6O_{7,}$ and ammonium carbonate, $(NH_4)_2CO_3$. The solid/liquid ratio is 1:30, that is, add 150 mL of ammonia salt solution to 5 g of the sample. This procedure can be followed by mixing which can be improvised with glass sticks in the school laboratory.

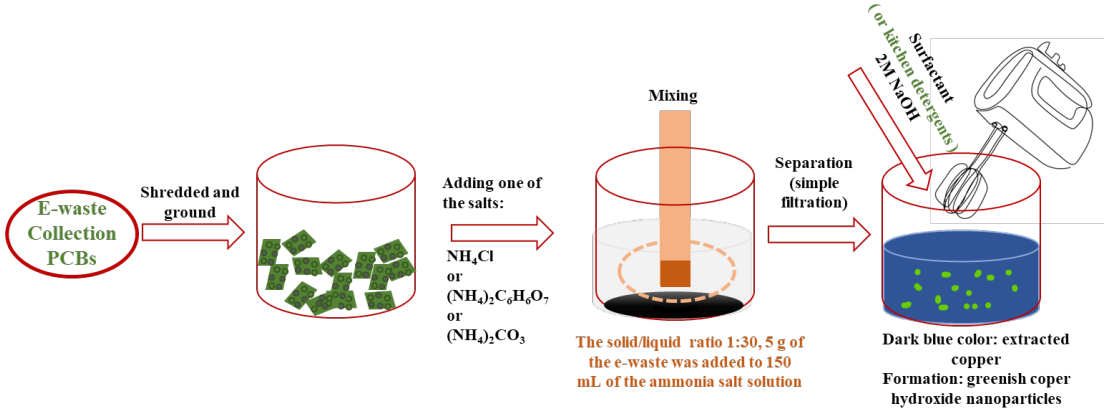

Figure 4. *The schematic representation of the processing of electronic waste into nanoparticles, feasible in the average school laboratory*

During the mixing change in the color of the solution will be from colorless to a blue color, which indicates that the copper has bound into a complex with ammonia $[Cu(NH_3)_4]^{2+}$. The resulting filtrate is further used for the synthesis of copper nanoparticles using the microemulsion method with the addition of surfactants. If the schools has limited budget and is not able to afford CTAB or other p.a. grade surfactants, a classical, kitchen detergents for handwashing the dishes

can also be used in ratio 1 soup spun per liter, and also these concentrations can be varied. The filtrate than should be slightly heated to a temperature of about 35-37 °C with some hot water bath or similar. Using the glass or semiautomatic pipette, the 2M NaOH solutions is further added with stirring to achieve the optimal pH for the formation of copper hydroxide nanoparticles within the micelles. If the schools do not possess the magnetic stirrer, process of the mixing can be performed improvising with the kitchen-type mixer. This process is gradual and visually very attractive. The experiment continues until the pH of 13. In ideal conditions, the obtained precipitate would be heat treated at 800 °C and characterized by the transmission microscopy, however, even with this level of the demonstration, the experiment is sending a powerful message and visualizing the process of recycle for nanotechnology. As the theoretical preparation for the experiment, high school students can be educated about the importance, roles, and possibilities of the circular economy, as well as the challenges that arise, where the importance of secondary raw materials is shown through a safe and simple experimental work.

CONCLUSION

Present paper is an attempt to raise awareness of the importance of collaboration between academic community and high school communities in promotion of both natural science, chemistry, the nanochemistry area, and the circular economy as well as the ecology and recycling as the subjects. Information was gathered through the international collaboration in long-lasting project emphasizing and promoting European raw materials chain sustainability and education of the young generations-future experts in this area. Decrease in number of students of natural and technical sciences is a lasting problem in recent years all around Europe. Experimental approach and enrichment of the high school curricula with the subjects like the one suggested here e-waste recycle in nanotechnologies, could motivate and recruit students to choose these professions and to strengthen European experts' workforce in the area of material exploitation and processing.

ACKNOWLEDGMENTS

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A NEW MODELING METHOD FOR DETERMINING PLASMA PARAMETERS IN THE LOW IONOSPHERE UNDER X-RAY RADIATION

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Abstract

Intense radiation can generate additional ionization in the Earth's atmosphere and change its structure. This extreme solar radiation and activity create sudden ionospheric disturbances and consequently affect electronic equipment on the ground and signals from space, potentially induce various natural disasters and influence on sustainable development. The aim of this work is to present our study, on few examples, of sudden ionospheric disturbances induced by the large solar flares. All data are recorded by VLF Belgrade station systems and the model computation is used to obtain the daytime atmosphere parameters induced by this extreme solar radiation. We analyzed in details physics of the D-region during consecutive huge solar flares which continuously perturbed this layer. We give perturbed ionospheric D-region simple approximative formula for electron density.

Keywords: observations; solar radiation; Sun activity; atmosphere; disturbances; dataset; modeling, sustainable development

INTRODUCTION

In today's science, special attention is paid to the extreme weather events, climate change, preservation and protection, because they have been identified as important for sustainable development in our century. Consequently, a very important question nowadays in modern society is - can we predict the magnitude of impact of explosive solar events (such as solar flares) on Earth, humans, electronic equipment and on nature generally. This question is difficult and complex, and the answer is not so simple. By analysis we cannot with certainty pre-

dict the event itself but we can statistically estimate the consequences of these explosive events on ionospheric parameters, perhaps predict dam-age to electronic equipment, predict disruption of GPS, etc.

Ionosphere as a huge segment of atmosphere has a tendency to be constantly separated in different regions D, E, and F, with different physical characteristics and chemistry (Brasseur & Solomon, 2005; Mitra, 1974; Nicolet & Aikin, 1960) which depend on incident radiation. At the time of solar flares and consequently during sudden ionospheric disturbances (SID) events the increase of the ionospheric electron concentration at all altitudes is noticeable. As a result of radiation effects, the solar-induced SID and plasma irregularities causes perturbations in the received amplitude and phase of Very Low Frequency (VLF in narrow band 3 -30 kHz) radio signals - in narrow band 3 -30 kHz- mainly in the D region which is located between the Earth's lower atmosphere with dense air and its strongly conducting ionosphere. Nowadays, special attention is paid to the extreme weather events, climate change, preservation and protection, because they have been identified as important for sustainable development in our century. Consequently, a very important question in modern society is can we predict the magnitude of impact of explosive solar events such as solar flares on the Earth, humans, electronic equipment and on nature generally and can we estimate the consequence of these catastrophic events?

In this contribution we focus on amplitude and phase data of worldwide transmitters of radio signals recorded by Belgrade VLF stations (Scherrer et al., 2008; Šulić & Srećković, 2014).VLF signals from the emitters located all over the world are constantly recoded by this equipment. Events of X-ray solar flares monitored by GOES satellites are further identified using radio stations system of receivers. For these events, VLF wave enhancements are measured and analyzed for the daytime atmosphere. Our research aims to improve the knowledge on the importance of extreme events and space weather for the overall sustainable development.

RESULTS

In this research we have studied the amplitude (A) and phase (P) data, obtained by monitoring VLF radio signals emitted by worldwide transmitters during solar-induced SIDs. All the data were registered by receiver systems at a Belgrade site. The receivers can simultaneously record several signals emitted by different emitters (located at different countries and territories) at the fixed frequencies. The time resolution of the recorded data can be in range from 0.001

to 1 s, which is applicable for detection of various SIDs from very short-term disturbances lasting several ms to very long perturbation. The technicalities and description of the Belgrade site are presented in (Šulić & Srećković, 2014).

Here we present the study of sudden ionospheric disturbances induced by the large flares. The monitoring and investigation of VLF data has been carried out simultaneously with the examination of the correlative incoming solar X-ray fluxes collected from Geostationary Operational Environmental Satellite (GOES) (Garcia, 1994). For our study the most important are registered data of incoming solar radiation X-ray flux in the XRS band of 0.1-0.8 nm.

In the presence of SIDs, a standard numerical procedure for the estimation of plasma parameters is based on comparison of the recorded changes of amplitude and phase with the matching values acquired in simulations by the Long-Wave Propagation Capability (LWPC) numerical software package (Ferguson, 1998) as explained in (Nina, Čadež, Srećković, & Šulić, 2012; Nina, Čadež, Šulić, Srećković, & Žigman, 2012; Šulić, Srećković, & Mihajlov, 2016).

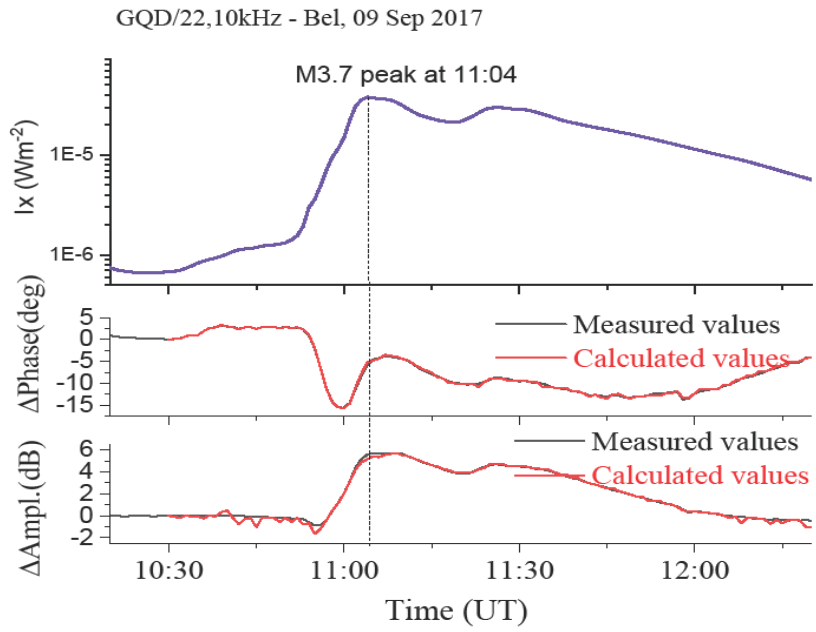

Figure 1. Observed amplitude perturbations on GQD, radio signals measured at Belgrade and calculated one. (middle panel) Observed and calculated phase perturbations. (lower panel) Time variation of X-ray irradiance measured by GOES-15 satellite on 09 Sep 2017. Simultaneous variations of X-ray flux, delta amplitude and phase of GQD/22.10 signal against universal time during occurrence of M3.7 class solar flare on 09 Sep 2017 (upper panel)

M3.7 class SF occurred on 09 Sep 2017 is an illustrative example of long lasting intense solar radiation (~ 60 min) which induced SID and caused variation in VLF signal. Also, this example is good for showing the methodology of our analysis. In Figure 1 is presented simultaneous variations of X-ray flux, amplitude and phase of GQD/22.10 kHz signals against universal time during occurrence of M3.7 class SF on 09 Sep 2017. Lower panel shows observed amplitude perturbations on GQD, radio signals measured at Belgrade station with calculated values (red line), and in the middle panel there are presented observed and calculated phase perturbations (red line). Time variation of X-ray flux measured by GOES-15 satellite on 09 Sep 2017 is on the upper panel. One can see that shapes VLF signal parameters are stretched and similar to the shape of the X-ray flux.

The daytime exponential profile of electron density in general use for VLF modeling (Wait and Spies, 1964) is given by:

$$N_e(h,H',\beta) = 1.43\cdot 10^{13}\exp(-0.15\cdot H')\exp[(\beta-0.15)\cdot(h-H')] \quad \mathrm{m}^{-3} \quad (1)$$

where β in km^{-1} is time-dependent parameters of sharpness and *H'* a reference height in km. Here *Ne (h,H',β)* and *h* are given in m^{-3} and km, respectively. Electron densities can be obtained from the observed amplitude and phase perturbations by a trial-and-error method where the density profile is adjusted until the simulated amplitude and phase (using LWPC code) match with observed data. In this way, the obtained Wait's parameters β and *H'* can be used in Equation (1) for further simulations.

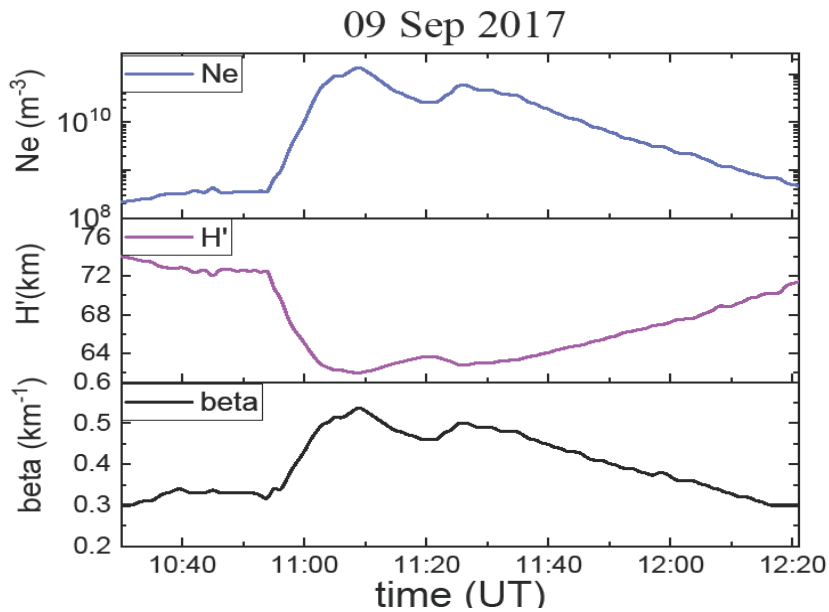

Figure 2. Effective reflection height H', the sharpness β and electron density at reference height h=74 km during occurrences of M3.7 class solar flare on 09 Sep 2017 from lower to upper panel, respectively.

In Figure 2 calculated parameters are shown: time dependent effective reflection height H', sharpness β and electron density at reference height during occurrences of M3.7 class solar flare on 09 Sep 2017 from lower to upper panel, respectively.

Approximative expressions:

To enable the better and more adequate use of data, we give electron density results obtained using simple and accurate fitting formula based on a least-squares method, which is logarithmic and represented by a second-degree polynomial with height dependent coefficients a1(h), a2(h), a3(h):

$$\log Ne(h, Ix) = a_1(h) + a_2(h) \cdot \log Ix + a_3(h) \cdot (\log Ix)^2 \qquad (2)$$

Here Ix is solar X-ray flux (Wm^{-2}), and h is height (km).

Figure 3 shows variation of X-ray flux, as measured by GOES-15 satellite, and the corresponding electron density evaluated at reference height 74 km versus universal time UT during five successive flares on 10 Jun 2014. The red

line presents results obtained using simple and accurate fitting formula (2). With circles are presented Ne obtained by the mentioned above method Eq. (1). For this explosive X class solar flares electron density grows for almost two orders of magnitude.

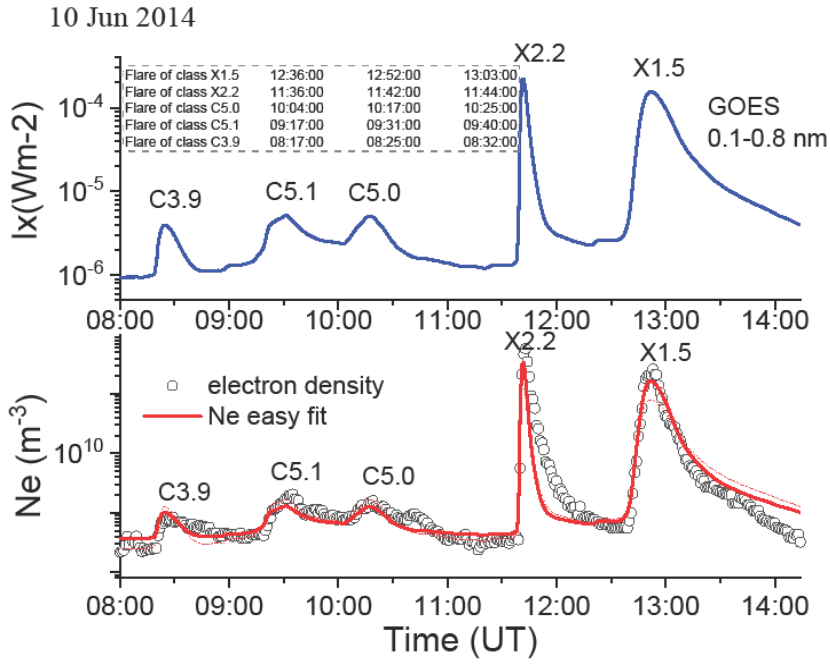

Figure 3. Variation of X-ray flux, as measured by GOES-15 satellite, and the corresponding electron density evaluated at reference height 74 km versus universal time UT during five successive flares on 10 Jun 2014. The red line presents results obtained using simple and accurate formula (2) based on a least-squares method. With circles are presented Ne obtained by the mentioned above method.

CONCLUSION

The magnitude of impact of solar flares on Earth and consequences of these explosive events is analyzed. The VLF radio data and important ionosphere parameters, during the enhancements of X-ray flux due to the flare, are presented and obtained in our study. The computation is applied to the altitude profile of electron density of the perturbed D region, during occurrences of solar flares. It can be noticed that the intense solar radiation, namely solar extreme events lead to an increased electron production rate and can increase electron density up to

few orders of magnitude depending on flare intensity with distortion of the amplitude and phase VLF signal. Also, we give a simple approximative and accurate formula for altitude electron density profile which is valid for non-perturbed and also for perturbed D-region.

The results confirmed the advantageous usage of the presented method for investigation solar-terrestrial coupling processes and detecting and analyzing space weather phenomena such as solar explosive events. This study advances knowledge about the extreme radiation, as an undoubted requirement for understanding space weather and sustainable development.

Notably, the data and its complexity in analysis and research of D region and space weather highlight the interdisciplinary nature of study.

ACKNOWLEDGEMENTS

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IRON OXIDE NANOPARTICLES: SYNTHESIS, CHARACTERIZATION AND APPLICATION

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Abstract

In this work, we present a brief review of the simple synthesis of iron(III)-oxide nanoparticles (Fe_2O_3 NPs), their characterization and potential application as nanosorbents and voltammetric sensors. Fe_2O_3 NPs were obtained from Fe^{2+} and Fe^{3+} salts by the solid-state method and characterized by transmission electron microscopy (TEM), energy dispersive spectroscopy (EDS), Ultraviolet-visible spectroscopy (UV-Vis) and Fourier-transform infrared spectroscopy (FTIR). The morphology and average size of Fe_2O_3 NPs estimated by TEM show that Fe_2O_3 NPs are spherical in shape with an average diameter of 3 nm. EDS qualitative analysis confirms the presence of Fe and O in NPs chemical composition. The potential application of Fe_2O_3 NPs was proposed as nanosorbents of heavy metal ions Pb^{2+} and Cd^{2+}. Further, Fe_2O_3 NPs can be applied as voltammetric sensors due to significant selective electroanalytical signal amplification in determining Pb^{2+} and Cd^{2+} ions.

Keywords: Iron-oxide nanoparticles, nanosorbents, voltammetric sensor.

INTRODUCTION

Nanotechnology is a field that has attracted the attention of many researchers in the last few decades due to numerous possibilities of nanometer sized particles (1 – 100 nm). Nanoparticles (NPs), inorganic and organic, find application in different areas, such as catalysis, medicine, optics, electronics, sensors, wastewater treatment, *etc*. Much attention is focused on inorganic metal and metal-oxide NPs and various methods for their synthesis and application (Jokić, et al. 2019; Veljović, et al. 2020). Interest in metal and metal-oxide NPs is be-

cause they have a large surface area-to-volume ratio that enhances their surface chemistry. In addition, metal NPs has unique optical and spectroscopic properties arising from the collective oscillation of electron with incident electromagnetic waves of visible light, called localized surface plasmon resonance (SPR) (Henglein, 1993). In absorption spectra, the SPR band is more pronounced for noble metals than metal-oxide NPs.

Recently, numerous studies reported nanosorbent materials with a high affinity to absorb or adsorb organic or inorganic molecules. Nanosorbent can be materials such as carbon tubes, polymeric, zeolites, metal and metal oxides nanoparticles, with a quite promising effect on water and wastewater treatment (El-sayed, 2020; Singh, et al. 2019). Heavy metal ions in environments are a serious problem for living organisms and public health because they are non-biodegradable and tend to bioaccumulate (Goodyear, et al. 1999). That is why their quantification and removal are very important.

Besides studying various nanomaterials as sorbents of heavy metal ions, the same materials were studied for electrode modification. For example, recently, electrochemical characterization and application of gold NPs were reported (Sierra-Rosales, et al. 2018). Modifying electrodes with nanomaterials increases their surface area and has a variety of potential applications.

In this work, we present the synthesis of Fe_2O_3 NPs by a simple solid-state method (Jokić, et al. 2019) and their characterization by TEM microscopy and EDS analysis, and UV-Vis and FTIR spectroscopy. Fe_2O_3 NPs were studied as sorbents of Pb^{2+} and Cd^{2+} ions and as promising voltammetric sensors.

MATERIAL AND METHODS

Materials

The following materials were employed in the study reported here: Iron(II)-sulfate heptahydrate ($FeSO_4 \cdot 7H_2O$), Iron(III)-chloride hexahydrate ($FeCl_3 \cdot 6H_2O$), potassium chloride (KCl), potassium hydroxide (KOH), lead(II)-nitrate ($Pb(NO_3)_2$) and cadmium(II)-nitrate ($Cd(NO_3)_2$), all from Sigma Aldrich, were used as received. All used chemicals were of analytical grade. Water purified with Millipore Mili-Q with a resistivity of 18 MΩ was used for solution preparation and washing of the reaction mixture.

Synthesis of iron-oxide nanoparticles

Our previous work described that iron-oxide NPs could be synthesized using a simple solid-state method (Jokić, et al. 2019). Knowing that Fe^{2+} and Fe^{3+}

salt were used for NPs synthesis, the chemical reaction goes on by the following equation (Jokić, et al. 2019):

$$FeSO_4 \cdot 7H_2O + 2FeCl_3 \cdot 6H_2O + 8KOH \rightarrow Fe_3O_4 + 6KCl + K_2SO_4 + 17H_2O \quad (1)$$

$$4Fe_3O_4 + O_2 \rightarrow 6Fe_2O_3 \quad (2)$$

According to the chemical reaction, iron-oxide NPs are iron(III)-oxide (Fe_2O_3) NPs.

TEM measurements

The morphology and the average size of obtained Fe_2O_3 NPs were estimated by transmission electron microscopy (TEM). TEM measurements were carried out using FEI Talos F200X at an operating voltage of 200 kV. Energy dispersive x-ray spectroscopy (EDS) from TEM was employed to check the composition of the elements in NPs. The average particle size was determined by the image analysis using the software ImageJ.

UV-Vis and FTIR spectroscopy

Absorption spectra of iron oxide colloidal dispersion were measured by Perkin Elmer Lambda 35 UV – Vis spectrophotometer using the quartz cuvette with a 1cm path length. FTIR spectra were measured by NICOLET I5 ATR spectrometer.

Electrochemical measurements

Electrochemical measurements were performed at PalmSens 3 potentiostat/galvanostat/impedance analyzer with PSTrace software (PalmSens BV, Netherlands). The electrochemical cell consisted of Ag/AgCl (1M KCl) reference electrode, platinum wire counter electrode (CH Instruments, USA) and working GCE (CH Instruments, USA). Optimal working parameters in the analysis of Pb^{2+} and Cd^{2+} for DPASV were: deposition potential of -1.4 V, deposition time of 30 s; in stripping step: pulse amplitude of 50 mV and pulse time of 10 ms (Sukeri, et al. 2011).

RESULTS AND DISCUSSION

Surface morphology characterization

TEM measurements determined the morphology and average particle size of synthesized NPs. The TEM micrograph of Fe_2O_3 NPs with particle size distribution (PSD) is presented in Figure 1 a). Obtained Fe_2O_3 NPs are spherical with an average diameter of 3 nm. Along with TEM measurements, EDS mapping and spectra were done to confirm the chemical composition of NPs, respec-

tively. EDS spectra of NPs are presented in Figure 1 b), and EDS mapping in Figure 1 c).

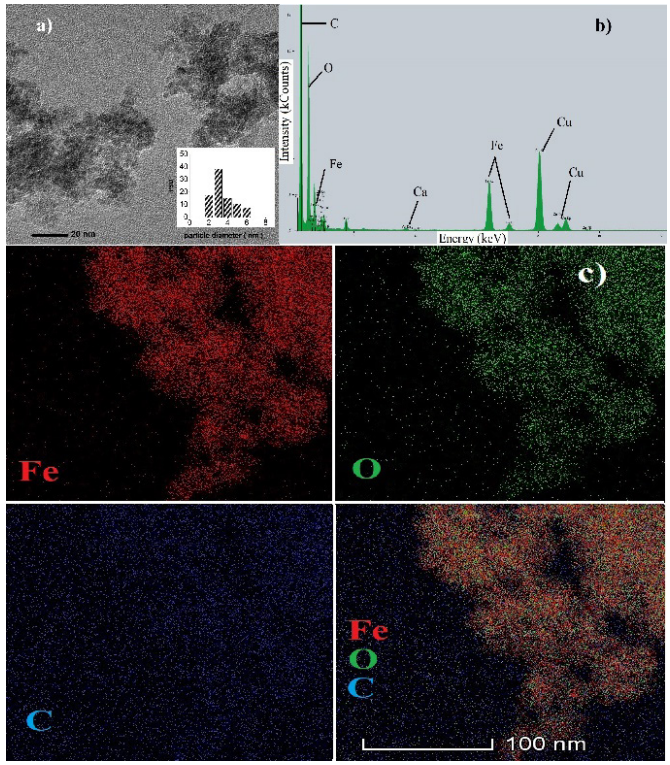

Figure 1. (a) TEM micrograph of Fe_2O_3 NPs, inset PSD; (b) EDS spectra of Fe_2O_3 NPs, (c) EDS mapping for Fe_2O_3 NPs.

Samples were prepared at room atmosphere in cooper grid, so C and Cu are expected in EDS spectra and mapping. The energy dispersive spectra and mapping of the samples obtained from the TEM-EDS analysis (Figure 1 b) and c)) clearly show that the sample prepared by the above route has pure Fe-O phases. However, EDS spectra show the presence of a small amount of Ca. The presence of Ca can be explained in a manner of NPs synthesis which is done in a ceramic mortar.

UV-Vis and FTIR spectroscopy

Synthesized Fe_2O_3 NPs are soluble in water and can be used as nano-powder or colloidal dispersion in an aqueous solution. In further work, colloidal dispersion of Fe_2O_3 NPs is characterized by UV-Vis spectroscopy and Fe_2O_3 NPs powder by FTIR spectroscopy (Figure 2).

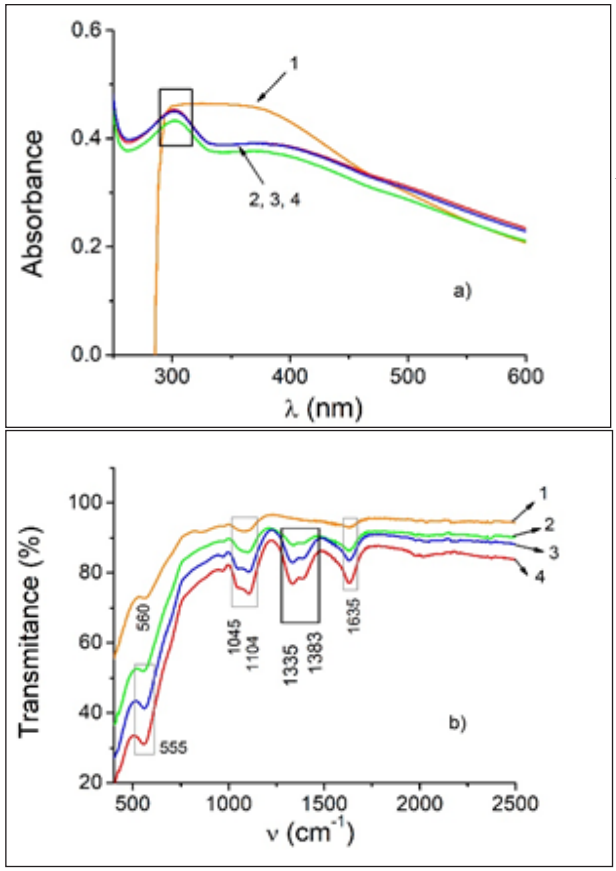

Figure 2. a) Absorption spectra of colloidal dispersion Fe_2O_3 NPs – line 1 (orange), Fe_2O_3 NPs in presence of Pb^{2+} ions – line 2 (red), in presence of Cd^{2+} ions – line 3 (green), in presence of Pb^{2+} and Cd^{2+} ions – line 4 (blue);

b) FTIR spectra of Fe_2O_3 NPs – line 1 (orange), Fe_2O_3 NPs in presence of Pb^{2+} ions – line 2 (red), in presence of Cd^{2+} ions – line 3 (green), in presence of Pb^{2+} and Cd^{2+} ions – line 4 (blue).

Absorption spectra of colloidal dispersion possess a board SPR band from 300 – 400 nm. Sorption of Pb^{2+}, Cd^{2+}, and a mixture of Pb^{2+} and Cd^{2+} ions together was followed by UV-Vis and FTIR spectroscopy. In absorption spectra of colloidal dispersion Fe_2O_3 in the presence of metal ions, a new absorption band at 301 nm appears. Chemical modification of NPs leads to a change in electronic properties, which is related to a change in optical properties (Henglein, 1993). The absorption band at 301 nm indicates the surface modification of Fe_2O_3 NPs due to the sorption of Pb^{2+} and Cd^{2+} ions. In the FTIR spectrum of Fe_2O_3 NPs band at 560 cm^{-1} is assigned to Fe–O stretching vibrations, while the band at 1635 is from bending vibrations of adsorbed –OH from water molecule on the surface of NPs (Jokić, et al. 2019). The presence of Pb^{2+} and Cd^{2+} ions band at 560 cm^{-1} slightly shift to 555 cm^{-1}, indicating in sorption of metal ions (Rajput, et al. 2016). Bands at 1335 and 1383 cm^{-1} appear in samples after the sorption of metal ions on the surface of NPs. However, these bands near 1400 cm^{-1} correspond to CO_2 stretching vibrations. Knowing that NPs are good absorbents of CO_2 from the environment, new bands at the FTIR spectrum are due to the absorption of CO_2.

Electroanalytical application

Fe_2O_3 NPs are effectively used to treat water and wastewater polluted with organic chlorine compounds and heavy metals (Ali, et al. 2016), and due to their excellent characteristics and magnetic properties, nanoparticles have recently found application in environmental analytics in the detection of heavy metals and other compounds. In our study, we found that synthesized Fe_2O_3 NPs, added to analyzing solution, was shown to have a selective amplifying effect on determining of Cd^{2+} and Pb^{2+} by highly sensitive differential pulse anodic stripping voltammetry (DPASV), as it can be seen at Figure 3. Iron oxide nanoparticles are interference in determining of Pb^{2+} ions at all concentrations. Contrary, these nanoparticles are an excellent choice for the determination of Cd^{2+} at low concentrations because they enhance its voltammetric signal, at the same time lowering the detection limit.

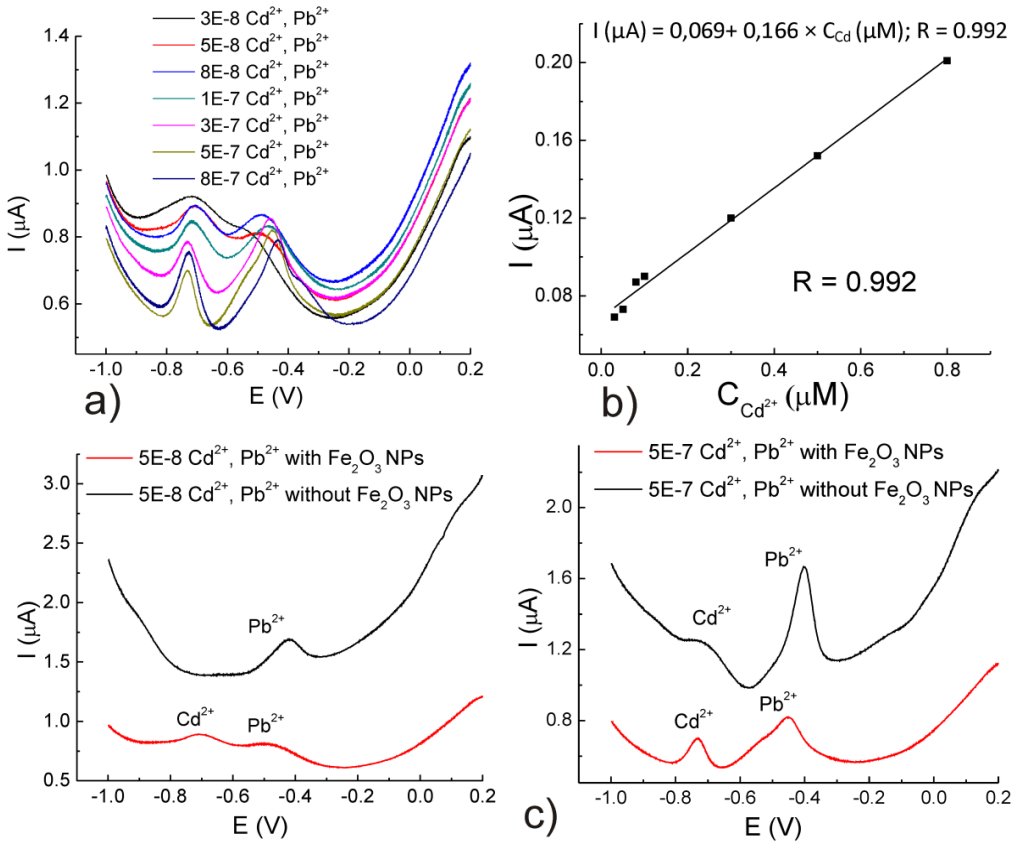

Figure 3. a) DPASV profiles of small concentrations of Cd^{2+} and Pb^{2+} ions in acetate buffer pH 4.5 with adding of Fe_2O_3 NPs; b) corresponding calibration graph and regression equation for determining of Cd^{2+} ions; c) a comparative study of the selective amplifying effect of Fe_2O_3 NPs on studied metal ions.

CONCLUSION

This work provides a brief overview of the Fe_2O_3 NPs synthesis, characterization and application. The simple solid-state method shows that spherical Fe_2O_3 NPs can be obtained. The average diameter of NPs of 3 nm was estimated by TEM measurements, while EDS spectra confirm the chemical composition of NPs. By UV-Vis and FTIR spectroscopy and electrochemical study, sorption of Fe_2O_3 NPs Cd^{2+} and Pb^{2+} ions on the surface of NPs was confirmed. An electrochemical study shows the amplifying effect of Fe_2O_3 NPs on studied metal ions. Future research aims to clarify the nature of such interactions and possible synergistic effects of some metals and enable even better application of Fe_2O_3 NPs for electrochemical purposes.

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PHYSICAL-CHEMICAL CHARACTERIZATION OF PHOSPHATETUNGSTEN BRONZE DOPED WITH IRON FROM HETEROPOLY SALTS AS PRECURSORS

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Abstract

Heteropolyacids, with a general formula of$H_{3+x}AM_{12}O_{40}\cdot nH_2O$ (x=0-1; A=P, Si, B, As, Ge;M=Mo, W; n=30-6) are of special interest as newmaterials because of their high conductivities. Among them special attention deserves the 12-tungstophosphoric (29- WPA) acid. Heteropolies of acids and salts heteropolises of acids can also be used as starting materials for the production of tungsten bronzes. These bronzes have a specific structure that results from the collapse of the Kegin anion at a temperatures up to 602 ^{0}C. This structure is layered and consists of interconnected PO_4tetrahedra and WO_6octahedra. In such a structure, pentagonal and hexagonal openings (cavities, channels) are formed in which there is a complete or partial exchange of H^+ ions in WPA. In this paper, 12-tungstenphosphoric acid was synthesized, ion exchange gave 12-tungstenphosphoric acid of the transition metal ($FePW_{12}O_{40}\cdot nH_2O$). Thermal analysis determined the temperature of the phase transition (the temperature at which the structure of the Kegin anion is disturbed) at a temperature (about 600 ^{0}C) to obtain phosphate tungsten bronzes doped with iron. Physico-chemical methods IR, XRPD and SEM were used to characterize the material. Due to their ionic and electronic conductivity and other useful properties, heteropoly compounds have wide application: as new materials, superionic conductors, in biology, pharmacy and medicine. This paper presents a new contribution to the elucidation of problems related to structure, identification of conductive species and examination of WPA phase transformations to bronze formation by different methods and design of obtained structures, and our further research will be directed in these directions.

Keywords: heteropoly acids, phase transformations, phosphortungsten bronzes

INTRODUCTION

Polyoxometalates (POMs) are a class of molecular anionic metal-oxide clusters, although they have more than a hundred years of history, they continue to attract the attention of researchers as catalysts, solid superionic proton conductors at room temperature, applicable in various electrochemical devices, and also as photochromic, biochemical and biomedical active materials (Mioč U, 1994). Polyoxometalates can be divided into two main categories, isopolyacids (IPAs) and heteropolyacids (HPAs). IPAs contain only transition metal ions and oxide ions, while HPAs contain one or more heteroatoms such as P^{5+} , Si^{4+} and As^{5+} . HPA systems are very attractive due to the diversity and selectivity of their properties and structures. One of the most important properties of HPA is strong acidity. The best-known group of polyoxometalates (POM) are heteropoly compounds (HPC) with the Kegin anion structure. 12-tungstenphosphoric acid (WPA), 12-molybdophosphoric acid (MoPA) and 12-tungstensilicic acid (WSiA) are the three best-known acids with Kegin structures (Mioč U, 1994). Due to their properties, heteropoly acids and related compounds represent a very important group of compounds, whose application is based on their redox properties and high ionic charge. Heteropoly acids with incorporated heteropoly anions, of the metal-oxygen type, which represent the basic structural unit of the Keggin anion. The octahedra are connected to each other through oxygen atoms and form a very stable and compact heteropolyanion skeleton. Cations can be: hydrogen, alkali metals and other metal ions. More than twenty types of structures, including four to forty metal atoms and from one to nine heteroatoms, such as molybdenum, tungsten, and vanadium heteropolyanions are known (Dimitrijević R, 1995). Phosphate-tungsten bronzes are obtained by thermal treatment of 12-tungstenphosphoric acid and their salts. Tungsten bronzes, which contain metals of groups I, II and III, have electrical properties ranging from semiconductor to conductor, depending on the concentration of metal atoms in the given bronze, while in some cases the bronzes go into a superconducting state (Bierstedt P, 1966) . Tungsten bronzes are used in batteries and fuel cells, and are also good catalysts for the electro-reduction of oxygen in acidic electrolytes. Heteropoly acids and their salts are precursors for obtaining bronzes . Heteropoly acids belong to a large class of compounds whose structure includes two or more types of highly oxidized inorganic acid residues . The theoretical explanation of the properties and the first three-dimensional structural formula of a heteropoly acid with well-defined atom positions and their coordination was given by Pauling (L, 1929) Using X-ray diffraction, Keggin was the first to determine the crystallographic structure of 12-tungstenphosphoric acid (J, 1934), so it is

assumed that its basic structural unit is the Keggin anion. The Keggin anion has a coordinated structure and consists of a central tetrahedron XO_4 (X=P, Si, As, B, Al,...), surrounded by 12 slightly deformed octahedra MO_6 (M=W, Mo, V, Ta or Nb) connected by common atoms oxygen. Twelve M atoms are located on twelve edges of the cube, in the center of which is the X atom. After the "demolition" of Kegin's anion by thermal treatment, bronzes are formed in which the arrangement of tetrahedra PO_4 and octahedra WO_6 is such that they form pentagonal or hexagonal channels (Roussel P, 2001). Kegin's anion from 12-tungstenphosphoric heteropoly acid, after a phase transformation at a temperature of 602 ^{O}C, passes into phosphate-tungsten bronze with composition PW_8O_{26}, while the phase transformation of iron-doped phosphate-tungsten bronze takes place at a temperature of 596 ^{O}C. Very little is known about the detailed structure of bronzes obtained by thermal treatment and there is practically no literature data. It is clear that any additional investigation, including the application of potentially new methods, contributes to a better understanding of the behavior of these bronzes.

MATERIALS AND METHODS

Materials synthesis

Bronze - method of synthesis and preparation

For the synthesis of 12-tungstenphosphoric heteropoly acid, substances p.a. purity: Na_2WO_4 x $2H_2O$, H_3PO_4, HCl and ether (Merck, Germany). The sample was synthesized according to the following procedures. a compound of the monophosphate bronze type PW_8O_{26} of the general formula $(PO_2)_4(WO_3)2m$ m=16 WPB was synthesized by programmed heating of 12-tungstenphosphorus from room temperature to 650 ^{o}C. The synthesis of the salt of 12-tungstenphosphorus heteropoly acid was carried out by ion exchange, adding an equimolar amount of iron- chloride to a solution of 12-tungstenphosphoric heteropoly acid. In the process of cooling or evaporating the solution, a heteropoly acid salt is formed . Phosphate-tungsten bronzes were obtained by thermal treatment of 12-tungstenphosphorus heteropoly acid and 12-tungstenphosphorus heteropoly acid salts, at a heating rate of 10 ^{o}C per minute, up to the temperature at which the Kegin anion transforms (breaks down). Above the breakdown temperature of the Kegin anion (650 ^{o}C), the samples were kept in the oven for 10 minutes. previous thermal analysis showed that calcination at this temperature leads to thermally stable compounds by recrystallization in the solid state of acid precursors or their salts. the obtained compounds are insoluble in water.

Materials characterization

Physico-chemical methods TGA, FTIR, XRPD.

X-ray examinations were performed on a Philips automatic powder diffractometer, model PW-1710. LFF, Cu anode with U=40 kV and I=35 mA was used, while 43 monochromatic Kα1 radiation (λ=1.54060 Å) and Xe proportional counter were used. Diffraction data were collected in the angular interval from 40 to 700 using the 2θ scanning technique, where the intensity was measured every 0.020 with a hold of 2.5 s. The base program PW-1877 was used to measure the angular positions of diffraction maxima and their associated intensities. The accuracy of the diffractometer was controlled before and after the experiment, using metallic Si powder.

RESULTS AND DISCUSSION

In this work, 12-tungstenphosphoric acid was synthesized, 12-tungstenphosphoric acid of transition metal ($FePW_{12}O_{40} \cdot nH_2O$) was obtained by ion exchange. Thermal analysis determined the temperature of the phase transition (the temperature at which the Kegin anion structure is disrupted) at a temperature (about 600 °C) to obtain phosphate tungsten bronzes doped with iron.

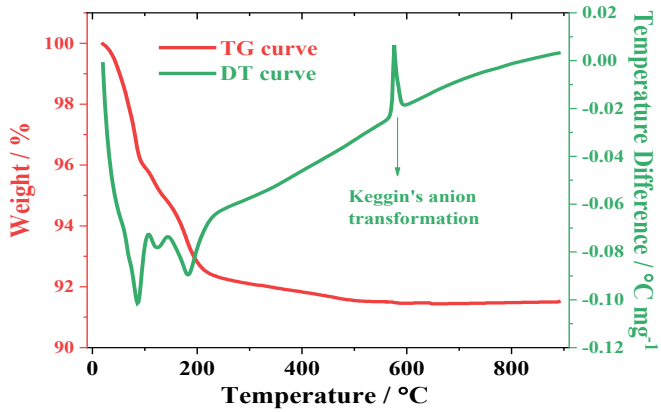

Figure 1. TGA

The collapse temperature of the Keggin anion is about 600 °C, and at this temperature, FeWPA was heated for 10 minutes in an air atmosphere to obtain iron-doped tungsten phosphate bronzes (FeWPB).

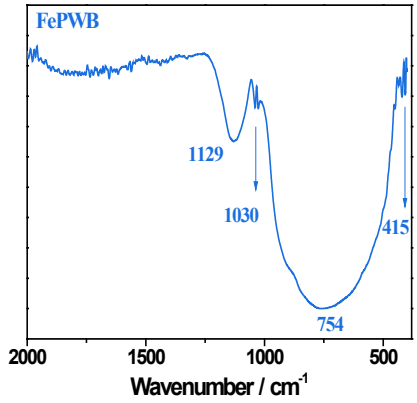

Figure 2. FTIR

A band corresponding to the ν1 vibration of the PO_4 group appears in the IR spectra, indicating that there was a significant violation of the basic symmetry of this group. The main reason for this symmetry breaking is the coordination of the PO_4 tetrahedron with the WO_6 octahedron.The transformation of the heteropoly acid into bronze is confirmed by the characteristic bands for the PO_4 group at 1129 cm^{-1} and a very broad band at 754 cm^{-1} for WO_3, while the band at 415 cm^{-1} corresponds to W-PO_4 vibrations.

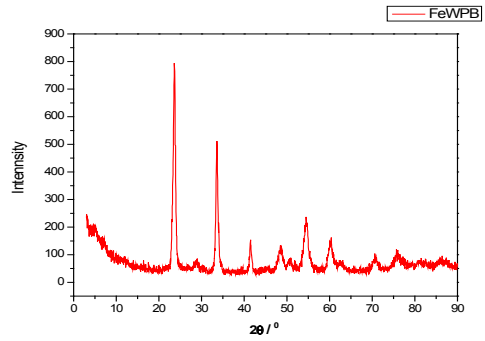

Figure 3. XRDP

CONCLUSION

The structural transformations of the crystal lattice of the solid skeleton and the presence of different proton species in WPA during the calcination/dehydration process were investigated. When studying the system, thermal, XRPD, FTIR, measurements were used with the aim of better understanding the global picture of structural transformations and the dynamics and balance of proton species in different crystal hydrates of WPA in a wide temperature interval.Infrared and Raman spectra recorded at the temperature of liquid nitrogen show a series The transformation of the heteropoly acid into bronze is confirmed by the characteristic bands for the PO_4 group at 1129 cm^{-1} and a very broad band at 754 cm^{-1} for WO_3, while the band at 415 cm^{-1} corresponds to W-PO_4 vibrations.

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MONITORING OF AIR QUALITY AND METEOROLOGICAL PARAMETERS BY IoT DEVICE AT CARA DUŠAN STREET IN BELGRADE

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Abstract

Air pollution is one of the most important problems today. To achieve quality living conditions and a sustainable environment, special attention is paid to air quality monitoring. The paper presents measurements from an IoT device for environmental monitoring owned by the University of Union-Nikola Tesla in Cara Dušana Street, Belgrade. Pollution parameters and meteorological parameters were measured. Monitoring station ekoNET-AIR with a new generation of IoT devices that enables monitoring of air quality and environmental parameters in real time was used for measurement. This type of result provides the possibility of examining the dependence of pollution parameters on meteorological conditions, and other living conditions at the location.
Key words: sir pollution; monitoring; meteorology.

INTRODUCTION

The Republic of Serbia (Serbia) is one of the European countries with the poorest recorded air quality in the recent years (IQAir, 2022). Due to the increasingly rigorous regulations, air quality in Europe is slowly improving, but pollutants in particular continue to have a serious impact on human health. Among the most significant pollutants are SOx, NOx, and PM particles. (Malinovoć et al., 2015)

Gas SO_2 is one of the most important precursors of secondary aerosols in the atmosphere. It has a significant role in air pollution, leading to degraded visibility, changes in the radiation budget, and acid rain. Many studies have shown a dependence of SO_2 concentrations in the ambient air on meteorological parameters, particularly the wind speed and direction, air temperature, humidity, and atmospheric pressure. SO_2 is the most widely distributed and important air pollutant originating from industrial and domestic emissions. This substance is formed upon the combustion of sulfur-containing fuels, e.g., coal, oil, and diesel. In the chemical industry, this gas is produced in the contact process for the production of sulfuric acid and occurs in the form of residual SO_2. SO_2 as an air pollution indicator is a gas of strong smell, colorless, suffocating, irritating, and its toxicity increases with humidity, adversely affecting the health of people, animals, and plants. It may cause increased respiratory diseases, reduced pulmonary function, low birth weight, and mortality. The varying coefficient models illustrated that the temporal (yearly) variation of SO_2 concentration was more influenced by human-related factors, especially by secondary industry share. The sulfur oxides are among the most common pollutants because sulfur can be found in various forms in most fuels and ores. The spatial variation of such concentration was more affected by meteorological indicators, especially by wind speed (Huntriesser et al , 2021; Stamenković et al., 2020).

Nitrogen Oxides (NO_x) are a family of poisonous, highly reactive gases. These gases form when fuel is burned at high temperatures. NO_x pollution is emitted by automobiles, trucks and various non-road vehicles (e.g., construction equipment, boats, etc.) as well as industrial sources such as power plants, industrial boilers, cement kilns, and turbines. NOx often appears as a brownish gas. It is a strong oxidizing agent and plays a major role in the atmospheric reactions with volatile organic compounds (VOC) that produce ozone (smog) on hot summer days. The primary pollutant, directly emitted, is nitric oxide (NO), together with a small proportion of nitrogen dioxide (NO_2). NO is oxidised by ozone in the atmosphere, on a time scale of tens of minutes, to give NO_2. In rural air, away from sources of NO, most of the nitrogen oxides in the atmosphere are in the form of NO_2. NO and NO_2 are collectively known as NO_x because they are rapidly inter-converted during the day. NO_2 is split up by UV light to give NO and an O atom, which combines with molecular oxygen (O_2) to give ozone (O_3). Therefore, during the day NO, NO_2 and ozone exist in a quasi-equilibrium which depends on the amount of sunlight. (Ulniković et al., 2020)

Carbon monoxide (CO) is a nearly ubiquitous product of incomplete combustion of carbon containing fuels. Outdoor sources include motor vehicles;

engines on motorboats, and other devices that require fossil fuel combustion; residential wood burning; improperly adjusted gas-burning and oil appliances; coal combustion; and tobacco smoking.

Extensive studies have been carried out on the impact of human activities on air pollution, but systematic investigation on the relationship between air pollutant and meteorological conditions is still insufficient.

Particle pollution includes:

- **PM_{10}** : inhalable particles, with diameters that are generally 10 micrometers and smaller; and
- **$PM_{2.5}$** : fine inhalable particles, with diameters that are generally 2.5 micrometers and smaller.
- **PM_1 : Ultrafine particles with an aerodynamic diameter less than 1 micrometers. Ultra-fine dust is the most damaging variant of fine particles because the particles penetrate directly through the lungs into the bloodstream and are thus spread to the organs.**

Particulate matter contains microscopic solids or liquid droplets that are so small that they can be inhaled and cause serious health problems. Some particles less than 10 micrometers in diameter can get deep into your lungs and some may even get into your bloodstream. Of these, particles less than 2.5 micrometers in diameter, also known as fine particles or $PM_{2.5}$, pose the greatest risk to health. Fine particles are also the main cause of reduced visibility.

The concentration of most air pollutants is affected by meteorological conditions, but the level of impact depend on the type of pollutants. To effectively control air pollution, it is further urgent to reveal the relationship between air pollution and meteorological conditions based on long-term daily or real-time data. For example, the concentration of air pollutants significantly negatively correlate with wind speed, precipitation and relative humidity, but positively correlate with atmospheric pressure. As the latitude increases, the impact of temperature on the concentration of air pollutants becomes more obvious. Temperature has a negative correlation with PM_{10}. Relative humidity affects the natural deposition process of PM, whereby moisture particles adhere to PM, accumulating atmospheric PM concentration. With increasing humidity, moisture particles eventually grow in size to a point where 'dry deposition' occurs, reducing PM_{10} concentrations in the atmosphere. It can be concluded that systematic understanding on the relationship between air pollutant concentration and meteoro-

logical conditions is the prerequisite and basis for scientifically formulating air pollution prevention and control policies. (Mrazovac Kurilić et al., 2019; 2020)

MATERIALS AND METHODS

The monitoring station ekoNET-AIR for air quality and meteorological parameters was installed in Cara Dušana Street 62-64, one of the busiest streets in the center of Belgrade.

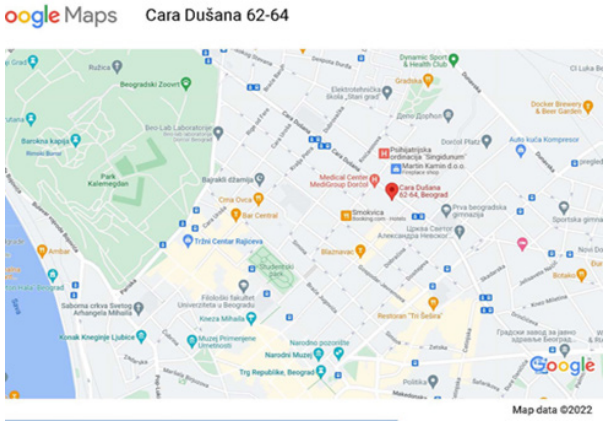

Figure 1 Map of location

Figure 2 Appearance of device AQ10x

Monitoring station ekoNET-AIR service is designed to provide an affordable end-to-end solution for air quality monitoring leveraging IoT and cloud technologies. The service combines portable devices and cloud-based functionality to enable air quality monitoring (indoors and outdoors) in a very granular manner.

The system is comprised of : Device (AQ- Air Quality), Cloud server, Web and mobile app

Device AQ10x represents a new generation of IoT devices that enables monitoring of air quality and environment parameters in real time. It is a portable device that can be installed both indoors and outdoors as well as on the vehicles to enable larger coverage.

The device is built on a flexible hardware platform which enables easy adaptation of the device to specific customer requirements, i.e. selection of different sensors and inclusion of new functions.

AQ10x contains the following components:

- Sensors for measurements of environmental parameters

- Optional GPS positioning module
- Robust industrial housing (vandal proof)

Mains power supply available. In addition, optimal power consumption is supported with rechargeable solar battery supply.

Real time data transfer (via GPRS/3G/4G/NB-IoT, LoRa/Sigfox, WiFi, BLE)

ekoNET-AIR applications are available to provide monitoring of the concentration of PM, CO, CO_2, SO_2, NO, NO_2, ozone, temperature, humidity in real time. The value of air quality index is calculated.

Web and mobile application provide data visualization (map, list, graph), notifications/alarms when values out of defined range, algorithms for data processing, export to CSV file (RAW, calibrated values, time, GPS …). By applying Device AQ10x in the period 1.03.2022-30.06.2022. at the location of Cara Dušana Street number 62-64, Belgrade, a recording was made of changes in meteorological parameters (P, T, RH), changes in the concentration of gases in the atmosphere (CO, CO_2, SO_2, NO, NO_2, O_3), as well as changes in the concentration of PM particles (PM_1, $PM_{2.5}$ and PM_{10}) in real time.

RESULTS AND DISCUSSION

The results of measuring the values of air pollution parameters and meteorological parameters are shown in Figure 3-6. Of great practical importance is the fact that this device measures pollution parameters and meteorological parameters at the same point.

Given that the period from March as the winter month to the end of June as an introduction to the summer period is covered, the analysis and comparison of both meteorological and polluting parameters and their mutual relationship and influence is very interesting.

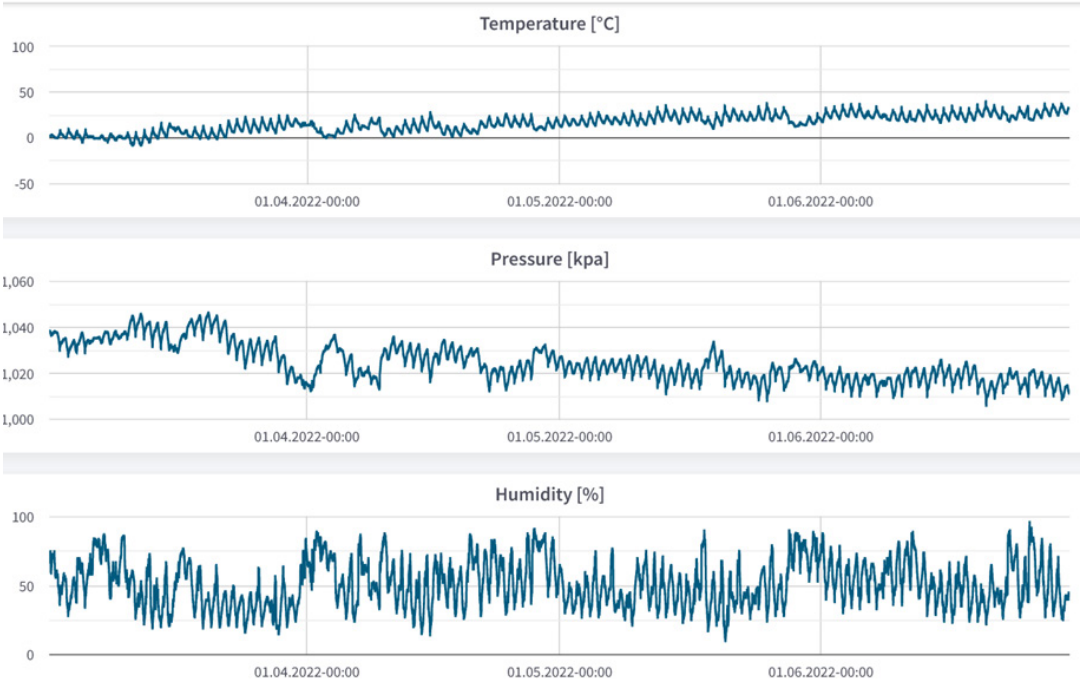

Figure 3 The values of the meteorological parameters measured by the AQ10x device at the site Cara Dušana 62-64 Belgrade in the period 1.03.2022-30.06.2022.

The Figure 3 shows the results for the period March 1. to June 30. 2022. Based on measurements for the observed period at Cara Dušana 62-64, Belgrade, the temperature was in the range of -7-38 °C, pressure 1008-1046 kPa, and humidity 11-96%.

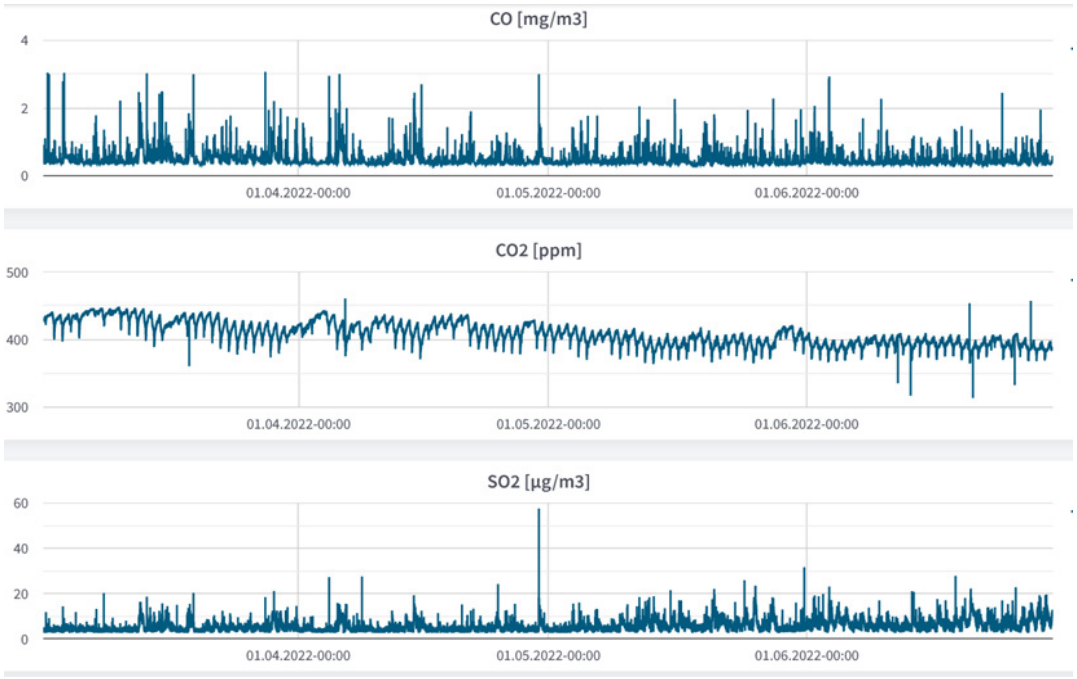

Figure 4 Concentration values of the CO, CO_2, SO_2, measured by the AQ10x device at the site Cara Dušana 62-64 Belgrade in the period 1.03.2022-30.06.2022.

Concentration values of the CO, CO_2, SO_2, measured by the AQ10x device, are shown in Figure 4, show that CO values remain approximately at the same values during the entire four-month measurement. The same cannot be said for the concentration of CO_2, which decreases with warmer weather, from 446 ppm in March to 370 ppm at the end of June, and we find the reason in the end of the heating season. The concentration of SO_2 is slightly increasing by 5-15 µg/m^3 in a four-month period.

Concentration values of the NO_2, NO, O_3, measured by the AQ10x device, are shown in Figure 5, show larger concentration oscillations of NO2 with increasing temperature and UV radiation, which contributes to an increase in NO concentration by 67% from an average of 60 µg/m3 1.04. 2022. to an average of 100 µg/m3 30.06. 2022. O_3 concentration increases due to increased UV radiation in this period. An increased concentration of O_3 is also observed on days of low pressure and markedly high humidity values, which leads to the assumption of bad weather conditions with the presence of electrical discharges, which was confirmed by looking at the weather reports of that period. For example, 1.04

2022. (P= 1011 kpa, H= 98%), 10.05.2022. (P=1010 kpa, H=75%), 8.06.2022 (P=1010 kpa, H=70%).

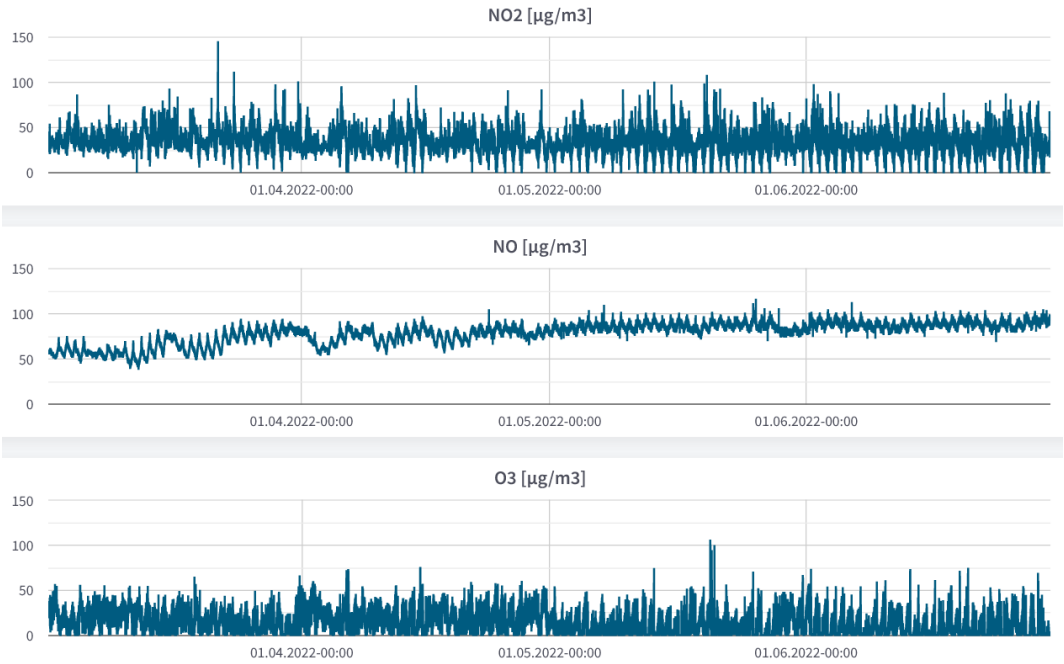

Figure 5 Concentration values of the NO_2, NO, O_3, measured by the AQ10x device at the site Cara Dušana 62-64 Belgrade in the period 1.03.2022-30.06.2022.

Concentration values of the NO_2, NO, O_3, measured by the AQ10x device, are shown in Figure 5, show larger concentration oscillations of NO_2 with increasing temperature and UV radiation, which contributes to an increase in NO concentration by 67% from an average of 60 µg/m^3 1.04. 2022. to an average of 100 µg/m^3 30.06. 2022. O_3 concentration increases due to increased UV radiation in this period. An increased concentration of O_3 is also observed on days of low pressure and markedly high humidity values, which leads to the assumption of bad weather conditions with the presence of electrical discharges, which was confirmed by looking at the weather reports of that period. For example, 1.04 2022. (P= 1011 kpa, H= 98%), 10.05.2022. (P=1010 kpa, H=75%), 8.06.2022 (P=1010 kpa, H=70%).

The European Union and the World Health Organization have prescribed limit values for the PM particles they emit: EU – PM10 40µg/m3; PM2.5 25µg/

m3; WHO – PM10 20µg/m3; PM2.5 10µg/m3. According to recorded data at Cara Dušana 62-64 Belgrade in the period 1.03.2022-30.06.2022. multiple higher values of all three types of PM particles were measured, figure 6. It is easy to see a significantly higher concentration of PM particles in March when the heating season is still in progress.

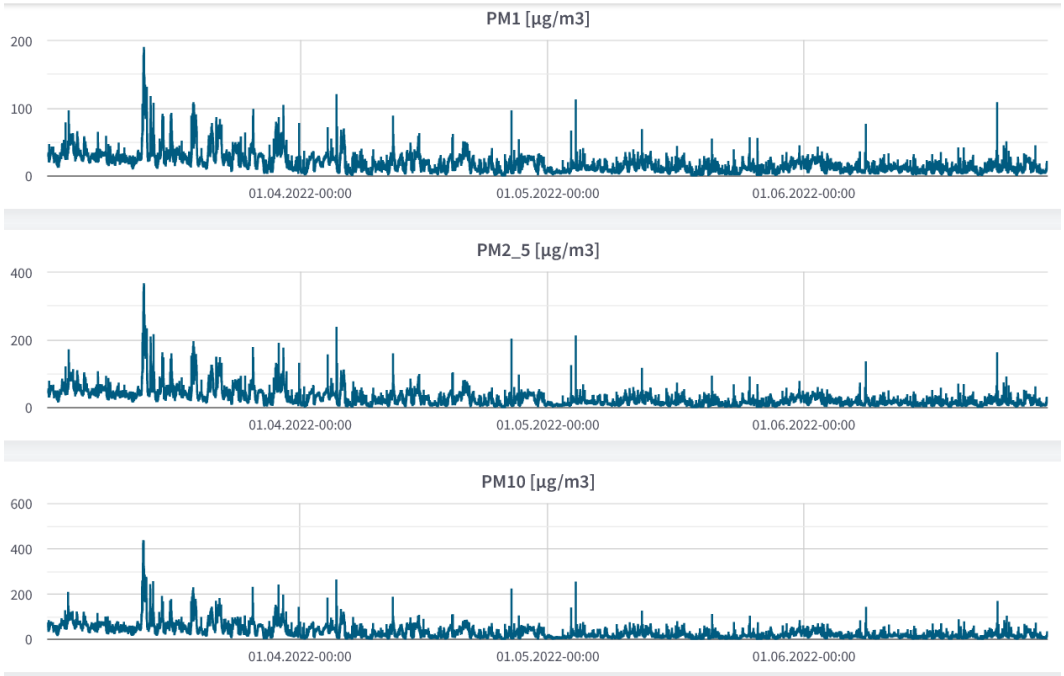

Figure 6 Concentration values of the PM_1, $PM_{2,5}$ i PM_{10} µg/m3, measured by the AQ10x device at the site Cara Dušana 62-64 Belgrade in the period 1.03.2022-30.06.2022.

Recorded values for PM_1 ranged from 20 to over 100 µg/m^3, but the Regulation on conditions for monitoring and air quality requirements ("Official Gazette of the RS", no. 11/2010, 75/2010 and 63/2013) as well as the EU and WHO do not define maximum allowed values for PM_1 (MAC). In the same period, the concentrations of $PM_{2.5}$ and PM_{10} particles increased many times over the permitted ones. $PM_{2.5}$ concentrations were from 20-200 µg/m^3 (the tolerated value according to the Regulation is 20 µg/m^3), while PM_{10} concentrations were measured from 10-250 µg/m^3 (the tolerated value according to the Regulation is 48 µg/m^3). The continuation of this trend can also be seen in the first half of April when, with the end of the heating season, the concentration of PM particles decreases and there is much less daily oscillation. On most days, the con-

centrations are around the limit values, although they are still slightly elevated compared to the MAC.

CONCLUSION

The installation of the AQ10x device at the location of Cara Dušana 62-64 Belgrade proved to be very significant in order to monitor air pollution and connect the obtained data with meteorological and other living conditions at the location. The use of the device in the future and the collection of data on the presence of pollutants at this location over a period of several years can more precisely indicate the cause-and-effect relationship of various factors that affect air quality, as well as lead to some potential solutions for reducing air pollution at this location.

ACKNOWLEDGEMENT: The work was financially supported by Union Nikola Tesla University Belgrade as part of the project under the Public Call 2021/2022

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ECOLOGICAL ASPECTS OF VEHICLE RECYCLING IN PUBLIC TRANSPORT, CASE STUDY BELGRADE

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Abstract

Vehicles used in public urban passenger transport in Belgrade (buses, trams, trolleybuses) in all their life stages, which include: the production, operation, and scrapping of vehicles, generating waste material that needs to be processed, and given the possibility of reuse. A special aspect is the treatment of hazardous waste, which poses a significant environmental risk. The paper will present general principles, and legal regulations related to vehicle recycling, with special reference to the procedures, applied in Public Transport Company Belgarde (JKP GSP Beograd).

Keywords: Vehicle recycling, Regulations, Procedures for recycling vehicles

INTRODUCTION

Recycling is the reuse of used or discarded materials, parts, or products for the same or different purposes with or without prior processing (Pešić et al., 2009). Vehicle recycling can be analyzed in the phase of production, exploitation, and disposal of the vehicle. Recycling in the production phase is carried out in factories and creates the least difficulties since it is simple to collect, sort, transport, and process in plants intended for recycling (Pešić et al., 2009).

Recycling during the lifetime (operation) refers to the waste generated during regular servicing and corrective maintenance of the vehicle. The most favorable solution is the reuse of replaced parts and assemblies without prior regeneration. Another possibility is the re-installation of parts or assemblies that have undergone repair and regeneration, after which they can be used again as

spare parts for vehicles if the vehicle maintenance technology allows it. Replaced parts, assemblies, and light bulb filters that are generated as waste during the vehicle exploitation phase are mostly processed as secondary raw materials.

After the intended life of the vehicle, recycling is the removal of the worn-out vehicle as a whole. The largest amount of various materials on the vehicle (steel, light metals, plastic...) are subject to recycling, which is carried out in specialized facilities.

In the world, the principles of recycling that apply to vehicles as a whole are known as 3R Reduce-Reuse-Recycle) which means (Reduce, Reuse, Recycle)

Reduction implies the least amount of energy and raw materials used in the vehicle production process and the longest possible lifetime of the vehicle in operation. Reuse should enable as much reuse of replaced parts or assemblies on the vehicle with or without prior regeneration (repair). Processing (Recycle) is the stage when parts, assemblies, and equipment on the vehicle are processed into the materials from which they were originally made, which can be used again as raw materials in the production of the same or different products. The latest vehicle recycling concept in the world is known as 5R, which combines the aforementioned 3R procedures and additionally increases the efficiency of the recycling process through processes of more detailed selection and purification of materials for reuse. Also in this phase, energy recovery from waste that cannot be reused as raw material for new production is sought. The latest requirements for the automotive industry regarding recycling, apply to new vehicles manufactured from 1/1/2015. require that 95% of the material be returned (Gruden, 2014).

REGULATIONS

The treatment of vehicles after the end of their useful life is regulated by international directives and regulations that are also applied in the Republic of Serbia through various laws, regulations, and procedures. The most important international regulations related to the issue of vehicle recycling are:

• Directive 2000/53/EC, ELF-End of life vehicle at the end of their life.

This directive, Annex 6, Article 1 stipulates that before the recycling procedure, the removal of hazardous materials and fluids from vehicles that may endanger the environment (Depollution process) must be carried out (Pešić et al., 2009).

- removing the battery, fuel tank
- removal or neutralization of potential explosive components

- removal, separation, collection of fuel, working fluids
- removal of components containing mercury

This directive defines that all vehicles at the end of their life, and not later than January 1, 2006. year, the degree of renewability and reuse must be at least 85% of the average weight of the vehicle, while the degree of recyclability should be at least 80% of the average weight of the vehicle. In the second phase for all vehicles at the end of their life, not later than January 1, 2015. year, the degree of renewability and reuse must be at least 95% of the average weight of the vehicle, while the degree of recyclability should be at least 85% of the average weight of the vehicle (Mitić, 2018).

• Standard ISO 22628:2002, Calculation method for road vehicles - recyclability and reusability

The standard defines several terms related to the process of vehicle disposal at the end of the vehicle's life, as well as the calculation methodology for calculating the degree of recyclability and renewability (Mitić, 2018).

The degree of recycling (recyclability rate) R*cyc* - refers to the mass share of a new vehicle expressed in percentages that can be recycled and reused (Mitić, 2018).

Recoverability rate R*cov* - refers to the mass share of a new vehicle expressed in percentages that can be recovered and reused .

$$R_{cyc} = \frac{m_p + m_d + m_m + m_{tr}}{m_v} \quad (1.1)$$

$$R_{cov} = \frac{m_p + m_d + m_m + m_{tr} + m_{te}}{m_v} \quad (1.2)$$

Wherein:
R_{cyc}– degree of recyclability [%]
R_{cov}– degree of reproducibility [%]
m_p - mass of material taken into account in the stage of preliminary preparation [kg]
m_d - mass of material taken into account in the disassembly phase [kg]
m_m - mass of metal taken into account in the stage of metal separation [kg]
m_{tr} - mass of material that is taken into account in the stage of treatment of non-metallic residues and that can be considered recyclable [kg]

m_{te} - - mass of material that is taken into account in the stage of treatment of non-metallic residues and which can be considered energy renewable [kg

m_v - vehicle mass [kg]

Directive 2005/64/EC, Vehicle type approval in relation to component re-use, renewability, and recyclability.

The directive stipulates the obligation of vehicle manufacturers and competent state institutions in the country where the homologation is carried out to control and fulfill the provisions of the directive. It prescribes which components must not be reused in vehicle production:

- Airbags, pyrotechnic actuators, and sensors
- Automatic or non-automatic safety belt assemblies
- Seats (only in the case when seat belt connectors and/or airbags are installed in the seat)
- Steering wheel locks
- Immobilizers
- Catalysts, particle filters
- Mufflers in the exhaust system

• UN Regulation No. 133 (UN ECE 133) from 2014. Uniform requirements for motor vehicles for component reuse, recyclability, and renewability.

The requirements of Regulation No. 133 are completely identical to the requirements of Directive 2005/64/EC .

RECYCLING OF BUSES, TROLLEYBUSES AND TRAMWAYS IN CITY PUBLIC TRANSPORT COMPANY "BELGRADE"

In CPTC ''Belgrade'' (JKP GSP "Beograd"), buses, trolleybuses, and trams, viewed from the aspect of recycling, are included in phases 2R and 3R. During the service life (phase 2R) refers to the treatment of replaced parts and working fluids. Buses, trolleybuses, and trams whose life cycle has expired (phase 3R) from the moment of withdrawal from regular traffic go through the following phases (JKP GSP ''Beograd'', 2014).

- Minutes of the technical committee on the condition of the vehicle with a proposal for disposal
- Decision on scrapping the vehicle
- Removal of working fluids in prescribed containers and places: fuel, engine oil,

- hypoid oil, antifreeze...
- removal of parts and assemblies that can be reused (doors, glass, covers, engine equipment, fans, signaling, seats, handrails...) (Figure 1)
- removal of aggregates: engine, gearbox, axles...
- public auction for the sale of the remaining part of the bus (Figure 2)
- purchase by an individual or company
- cutting, crushing, and grinding in the recycling plant

Figure 1. phase 3R - removal of parts

Figure 2. phase 3R - sale of the remaining part

Handling of waste materials generated during phases 2R and 3R is regulated by the Rulebook on handling waste materials in JKP GSP "Beograd" (JKP GSP ''Beograd'', 2020).. This rulebook regulates the collection, sorting, and storage of waste generated in vehicle maintenance workshops. Waste in the sense of this regulation means waste sheet metal up to 5 mm thick, waste iron over 5 mm thick, waste gray cast iron, iron shavings, waste copper, waste cables, waste coolers, waste bronze, waste brass, waste aluminum, aluminum cables, waste glass, waste wood, waste rubber (tires, cushions, cedars), waste plastic packaging, scrap vehicle chassis, scrap IC engines, scrap electric motors, scrap

retarders, scrap electric assemblies, scrap gearboxes, and drive axles. Hazardous waste must have a special treatment, which is also prescribed by the regulation (JKP GSP ‘’Beograd’’, 2020).. The most important directives and regulations related to electronic and hazardous waste are:

Directive (WEEE-Waste Electrical & Electronic Equipment, EC/249/2004) which refers to electrical and electronic waste. Directive 2002/95/EC or cocoa is often called RoHS - Restriction of the use of hazardous substances complements the WEEE Directive by defining maximum quantities of potentially hazardous materials contained in electronic and electrical devices, which primarily refer to lead, mercury, cadmium, hexavalent chromium, polybrominated biphenyl, and polybrominated biphenyl ethers.

Hazardous waste includes:

- Waste motor oils
- Spent lead accumulators and batteries
- Used nickel-cadmium accumulators and batteries
- EE waste - from electrical and electronic products (monitors, air conditioners, IT equipment, printers, etc.)
- EE-waste-from electrical and electronic products (fluorescent tubes and bulbs containing mercury)
- Metal contaminated packaging (from oil, lubricant, antifreeze)
- Plastic contaminated packaging (from oil, lubricants, antifreeze)
- Oily brushes and rags
- Waste oil and fuel filters
- Oily sand and sawdust
- Waste from the fat and oil separator
- Waste antifreeze
- Waste dust

According to the aforementioned Rulebook on the handling of waste materials in the PUK GSP “Belgrade”, the articles related to special streams of hazardous waste management are particularly important (JKP GSP ‘’Beograd’’, 2020)..

Article 10 - Management of hazardous oils (waste motor oils, which are produced when oil is replaced in the process of vehicle maintenance, are collected at the point of origin and stored in special tanks through the system of underground installations. It is prohibited to discharge or spill waste oils into/on the ground, surface and underground water and sewage) (JKP GSP ‘’Beograd’’, 2020).

Article 11 - Management of spent batteries and accumulators (spent lead accumulators and batteries and spent nickel-cadmium accumulators and batteries are stored in a special container and handed over to an authorized operator) (JKP GSP ''Beograd'', 2020).

Article 12 - Management of waste from electrical and electronic products EE-waste (collected at the point of generation and with a completed document for the submission of EE waste is sent to the warehouse provided for that at the Dorćol location, from where it is collected by the authorized operator according to the contract) (JKP GSP ''Beograd'', 2020). An example of the collection of waste copper from the coils of scrapped electric motors from trams and trolleybuses to the designated place in the JKP GSP "Beograd" is shown in Figure 3.

Figure 3. Collection of copper coils from scrapped electric motors of trams and trolleybuses in JKP GSP "Beograd"

It is important to highlight Article 15 of the Rules:

Article 15 - Management of scrap vehicles (bodywork with scrapped vehicle chassis, scrapped SUS engines, gearboxes, scrapped electric motors, rail brakes, actuator spools, retarder coils, and other steel assemblies with copper electrical coils) based on the decision of the director of JKP GSP "Beograd" on disposal of fixed assets and large aggregates, is collected at the place of origin, which is notified to the service of receiving, control and transport of goods, which further acts according to the Procedure "Sale of secondary raw materials, QQP-A-002" (JKP GSP ''Beograd'', 2020).

JKP GSP "Beograd" has 15 electric-powered buses (Higer KLQ6125GEV3) which are in the exploitation phase (2R) and on which all the measures prescribed by the Rulebook on handling waste materials in JKP GSP "Beograd" are implemented.

Modern tender procedures for the purchase of electric buses in Europe (UITP, 2018; Mišanović, 2021), especially buses using lithium batteries, leave the possibility for the chosen manufacturer of electric buses to be the "owner" of the batteries and to complete the treatment of the battery during its lifetime (service or replacement in the event of failure) and after the end of the service life will be under his responsibility (takeover of the used battery, storage, transport, recycling) which can be regulated by a special annex in the tender documentation with the user of the vehicle. Directive on batteries 2006/66/EC (Directive 2006/66/EC) was adopted in 2006, which requires implementation in the national legislation of EU member states. The aim of the directive is to constantly increase the recycling rate of used batteries and the recovery of rare and precious materials for re-production. This is especially important for rare materials such as lithium (Li), the largest percentage of reserves of which are located in three South American countries (Bolivia, Chile, and Peru), so the recycling of lithium batteries is gaining importance. One such plant of the company "Umicore" for recycling Li-ion, Li-polymer, and Li-NMH, batteries was opened in Hoboken (Belgium) in 2011, where a recycling rate of 50% can be achieved for this type of batteries (The European association for Rechargeable batteries, 2013).

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WASTE MINERAL OIL AND WASTE SYNTHETIC OIL MANAGEMENT IN REPUBLIC OF SERBIA

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Abstract

The paper presents activities of segregation, packaging and labelling, take-over, storage of used mineral and synthetic waste oil, export to the plant for re-refining, and the way of re-refining. Activities include: segregation and collection of waste oil according to type of waste oil (waste engine oil, gear and lubricating oils, waste hydraulic oil, waste insulating and heat transmission oils); definition of waste Oil; the impact of waste oil to environment; packaging, labelling and storage of waste Oil in accordance with ADR regulations for the transport of dangerous goods; takeover, transport and export of waste oil; re-refining of waste oil; examples of environmentally friendly collection of waste are presented through the segregation, packaging, transport, storage, export, and re-refining of waste oil (waste hydraulic oils, waste engine, gear and lubricating oils, waste insulating and heat transmission oils, bilge oils, oil/water separator contents, wastes of liquid fuels, oil wastes not otherwise specified).

Keywords: waste oil, segregation and packaging, ADR transportation, storage, export, and re-refining of waste oil.

DEFINITION OF WASTE OIL

Waste oil is mostly generated when oil is replaced in engines, hydraulics equipment, heat exchangers, compressors equipment, but also when is generated in physical and chemical purifiers of waste emulsions.

Waste oil means any mineral or synthetic lubrication or industrial oils which have become unfit for the use for which they were originally intended, such as used combustion engine oils and gearbox oils, lubricating oils, oils for turbines and hydraulic oils. (Directive 2008/98/EC of the European parliament and of the Council).

Waste oil is a complex mixture of low and high molecular weight (C15-C50) aliphatic and aromatic hydrocarbons. Because of exposure on high temperatures there is metals, additives, and sludge. Through to collection of waste oil follow components can be present: diesel, gasoline, water, and antifreeze can also be present in waste oil. Analyses of used engine oil is presented on Figure 3.

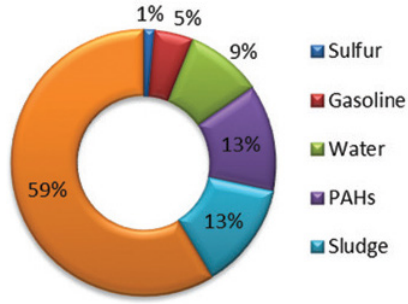

Figure.1. Chemical composition of used engine oil (reprinted PurePath Green Technology, https://www.purepathtech.com/literatures/recycling-of-used-motor-oil)

THE IMPACT OF WASTE OIL TO ENVIRONMENT

There are three ways of impact of waste oil on the environment with penetration on water, soil, and air. Waste oil have dominated impact to water environment. One litre of waste oil can contaminate one million litres of water. Groundwater contamination results when the oil absorbs through to water sewerage (places without water treatment) spill direct on Groundwater or through soil layers. When we have penetration through soil layers, waste oil can find way to underground waters and makes its way into lakes, streams, and rivers.

When waste oil spill in groundwater he is forming tiny films or sheens on the surface of the water and reduces the level of oxygen penetration needed by living organisms in water. The reduction in oxygen penetration into the water is dangerous to aquatic life system and can cause death of aquatic organism. Sometime depending on contamination level, waste oil can ruin drinking water.

Penetration through soil layers is problematic because hydrocarbons from waste engine oil can increase the toxicity level of the soil thereby reducing its fertility and productivity (Christensen and Argerbo, 1981) and Donahue et al. (1990) reported that soils contaminated with waste engine can reach temperatures of about 65-70 ºC, which are lethal to many plants that would otherwise grow in those soils at optimum temperatures of 24-32 ºC (Raven et al., 2005)

The Oil spillage leads to toxic effect on plants and seeds. Seeds do not have good germination and plants are smaller. Colour of plants are goes from green to yellow depend on contamination level.

The pollutants from waste oil also enter the air through the exhaust system during engine use or when burnt or used as a fuel in boilers, incinerators, and cement kilns. Combustion products of used crankcase oil may include metals such as lead, zinc, chromium, aluminium, nickel, copper, and iron. Others are sulphur, nitro compounds, sulphur dioxide, phosphorus, calcium, hydrochloric acid, and nitrogen oxides (Vasquez – Duhalt, 1989). PAHs formed via combustion of the oil can leave the engine via the exhaust as particulates and pollute the air (Teresa et al., 2005).

On the territory of the Republic of Serbia, one of biggest air pollution problems is use of waste oil for heating, Figure 2. Exhaust of household, with low incineration temperatures causes that exhaust gases have particulates.

Figure 2. Exhaust of household (reprinted Novosti press, https://www.novosti.rs/vesti/beograd.74.html:841537-Informacija-o-LjUBICASTOM-ALARMU-zbog-zagadjenja-izazvala-paniku-u-Beogradu-nadlezni-tvrde-Vazduh-je-cistiji-nego-prethodnih-dana*)*

SAGREGATION AND COLLECTION OF WASTE OIL

Waste oil is mostly generated in the automotive services, agriculture mechanisation, hydraulics equipment, foundry plants, metal industry and all other activities who needed lubricants.

Basically, waste oil can be mineral based, synthetics or mixed.

Second definition for segregation are from use of waste oil and it's defined by European Waste Catalogue 2014, Chapter Title No.13 Oil Wastes and Wastes of Liquid Fuels (except edible oils, and those in chapters 05, 12 and 19):

- 13 01 waste hydraulic oils
- 13 02 waste engine, gear, and lubricating oils
- 13 03 waste insulating and heat transmission oils
- 13 04 bilge oils
- 13 05 oil/water separator contents
- 13 07 wastes of liquid fuels
- 13 08 oil wastes not otherwise specified

By Serbian low and Serbian waste management act ("Off. Herald of RS", Nos. 36/2009, 88/2010, 14/2016 and 95/2018): Liability of the Waste Article 26 Producer, paragraph 2, owners of waste must obtain a waste testing report and renew it in the event of technology change. Waste testing report is prepared from certificated laboratory who take samples of waste oil and do physical / chemical analyses of waste oil. Waste testing report include EWC code, and all necessary information for future management of waste oil.

Before any packaging or movement of waste oil, workers must prepare all necessary equipment to reduce the risk of oil spillage.

Company who generated waste oil use for segregation and packaging UN (UN Recommendations on the Transport of Dangerous Goods) approved packaging like:

- steel drums 200l,
- PE drums 200l,
- IBC containers 1000l
- Special tanks for large quantities.

UN - approved packaging is designed to contain dangerous goods and is certified after testing. UN-approved packaging also carries a code indicating specifications of what the package contains. Best option is IBC container because they reduce the possibility of oil spillage.

Owner of waste oil must have hazardous waste storage and collection trays for spillage. All drums and IBC must be labelled with ADR pictogram (Accord Dangereux Routier, European regulations concerning the international transport of dangerous goods by road) and waste identification label. Waste identification label must have followed information:

- Name and address of company who generate or own waste oil

- Name of waste oil
- EWC number
- UN number (UN numbers are assigned by the United Nations Committee of Experts on the Transport of Dangerous Goods)
- Name of responsible person for waste in company
- Year of waste generation

After packaging of waste oil, all drums and IBC must be labelled.

TAKOVER AND TRANSPORT OF WASTE OIL

The transport of dangerous goods is regulated by the regulation on the transport of dangerous goods. Transportation in international traffic is regulated by international regulations:

- ADR for road traffic (European Agreement on the International Road Transport of Dangerous Goods)
- RID for rail transport (Regulation for International Transport of Dangerous Goods)
- IMGD for maritime transport (International Maritime Dangerous Goods Code/Transport by Sea)
- IATA DGR for air transport (IATA regulations on the Transport of Dangerous Goods/Air Transport)

By Serbian low and Serbian waste management act (Off. Herald of RS 36/2009, 88/2010, 14/2016 and 95/2018) owner of waste must have contract with certificate waste operators who have all necessary licence for takeover, transportation, and storage of waste oil.

Takeover of waste oil must be notified to Serbian Environmental agency two days before takeover if its local takeover and three days before transboundary movement to all countries involved in transportation of waste oil. (DIRECTIVE 2008/98/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL)

Takeover of waste oil (on territory of Republic Serbia) is performed by certificate waste operators. Most of waste oil takeover from generators is performed by ADR certificated tank truck with all necessary measures to avoid waste oil spillage. After takeover, waste oil is transported to waste operator storage and pump to tanks.

Republic of Serbia (RS) in the past, have one refinery for waste oil located in Belgrade, but refinery do not work. In this case there it not possible to do re-refining on territory of RS and its necessary export of waste oil. Export of

waste oil include all permit (from all involved country) for export, import and transit.

Export to re-refining start three days before export of waste oil with notification to all countries involved. When tank truck arrives to waste operator storage, ADR inspection is performed by ADR advisor who check truck equipment and documentation for ADR transportation, who include next paragraphs:

- The transport company must have all the necessary ADR and waste transportation permits for the country of export, the country of transit and the country of import.
- The tank truck must include ADR parameters for the specific type of hazardous waste being transported.
- The truck must have all the prescribed equipment required by ADR. (Lamps, fire extinguishers and other ADR equipment)
- The truck driver must have an ADR certificate for transporting dangerous goods.
- Before departure, the driver must be thoroughly familiar with the waste because he is transporting and secure the load together with the client.
- If necessary, a radiological examination of the truck must be carried out.
- The driver must be provided with all the necessary documents required for crossing the border and importing hazardous waste (in accordance with the Basel Convention, Document on the transboundary movement of hazardous waste, packing list, all permits for export, transit and import of hazardous waste, notification contract with the re-refining company)

RE-REFINING OF WASTE OIL

After export re-refining company start recycling of waste oils through recovery operation R9 - Used oil refining or other reuses of previously used oil, according to Regulation (EC) No 1013/2006 for above mentioned substances and recycling of waste oils collection category 1 according to German Waste Oil Ordinance.

Re-refining of waste oil have lots benefits to environment protection like: reduction in CO2 emissions, more sustainable production, avoid illegal dumping of used oils and similar REACH assessment than virgin oils.

On figure 3. Its presented benefits of re-refining versus standard production of base oil from refining of crude oil.

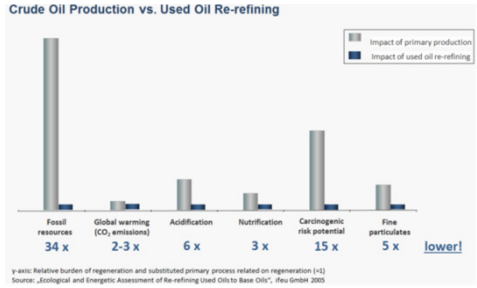

Figure 3. Crude oil production vs. used Oil Re-refining (reprinted IFEU GmbH 2005, Ecological and Energetic Assessment of Re-refining Used Oil to Base Oils)

The recycling process: (AVISTA OIL Deutschland GmbH, Reprocessing of Waste Oils,

Collection Category 1, Revision: Date: 01.01.201)

Every single delivery of waste oil is analysed and classified according to the regulations of the Waste Oil Ordinance. Waste oils of the collection category 1 are subjected to a further analytical quality control procedure and are fed to the reprocessing to base oils (recycling). This happens by several steps:

- Distillation of water and a low boiling fraction (gasoline, solvents, other volatile hydrocar-bons).
- Vacuum distillation for cutting off higher boiling petroleum-derived hydrocarbons (diesel, light fuel oil or the like).
- Flash distillation - gentle multi-stage distillation by applying high vacuum to achieve the lubricant distillate fraction with a final boiling point of about 560°C (thin film evaporation).
- Fractionation - distillate separation of the lubricant distillate (raw distillate) obtained by the flash distillation step into several viscosity / boiling cuts (fractions).
- Selective refining - the individual raw distillate fractions will be purified (refined) in an extraction process by using a highly selective solvent. The so obtained base oils are to be characterized by highest quality properties amongst others because of amounts of synthetic oils and the absence of polycyclic aromatic hydrocarbons (PAH, PNA). The base oils are used in sub-sequent mixing units for the production of about 120 finished lubricants (engine, gear, hydraulic and industrial oils) by adding different additives.

- Resulting by-products (co-products) / residues:
- Wastewater from the first distillation unit - approx. 5 - 10 % relating to the waste oil input. This is pre-treated by multi-stage distillation and is terminally cleaned in the factory's own wastewater treatment plant (precipitation/flocculation, biological treatment).
- Low boiling fraction (gasoline, solvents, etc.) - approx. 1 - 1.5 %. They are used in the company's own thermal utilization facilities for the energy supply of the refinery resp. its distillation units.
- Gas oil fraction from the first vacuum distillation stage - approx. 10 - 15 % The diesel and light fuel oil fractions (Heizoel R-LS according to DIN 51603-4) are used as a co-product of the waste oil reprocessing for the energy production (steam production, hot oil kilns) of the factory. Excess amounts are delivered as a high-grade fuel oil equivalent (Destillat F10) to factories with appropriate permissions.
- Bodenprodukt (residue from the flash distillation) - approx. 8 - 12 % Together with heavy fuel oils of the refinery this is processed to an oil for the reduction pro-cess in the steel industry. Furthermore, it can be delivered directly to the bitumen industry. Here it can be used as a mixing component for the production of regenerated bitumen, asphalts etc.
- Raw distillate (lubricant fraction for base oil production) - approx. 65 - 70 % After fractionation of the raw distillate into several boiling cuts they are purified by selective extraction. The solvent which is used therefor is redistilled completely so that nearly no losses occur i.e., this procedural step runs totally free of waste.
- Base oils (Kernsolvates®) from the Selective Refining - approx. 58 - 63 % The Kernsolvates® are marketed directly or are internally used for further processing of lubricants.
- Extract (residue from the extraction) - approx. 7 % This is marketed as a fuel oil.

Resulting Waste

- Residues from the cleaning of storage tanks and pre-filtration of the used oil prior to distillation are disposed in external facilities.
- Prior to the extraction process there is a filtration step by the use of clay (0.2% relating to the amount of raw distillate fraction) to remove least particles. The used clay with approx. 40% oil adhesion is disposed in external facilities.

The specified recycling process of the AVISTA OIL Deutschland GmbH for waste oils of the col-lection category 1 is directed to generate high quality

products at absolutely minimized waste production. This state-of-the-art reprocessing technology for the production of base oils (re-raffinates) from waste oil therewith demonstrates an excellent example of circular economy and a recycling process in terms of an integrated environmental protection.

CONCLUSION

In consequence of the chemical composition, mode of disposal and overall impacts on the environment and health, waste oil is considered to pose serious environmental and health problem.

The main problems with waste oil on territory of Republic of Serbia is use of waste oil for heating. Only ten percent of used oil finish to Re-refining or other treatment. From approximately 50000t oil per year, who are used on market of Serbia only 5000t of waste oil is taken to Re-refining and other treatment.

Re-refining process are one of the best examples of circular economy. Its strongly recommended to recycling waste oil with operation R9 - Used oil refining or other reuses of previously used oil, because it reduces CO_2 emission, there is no need for crude oil refining,
and finally energy consumption of re-refining are lower.

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DOCUMENTATION SUSTAINABILITY ACCORDING TO ISO 9001 AND ISO/IEC 17025 STANDARDS: EXPERIENCE IN THE LABORATORY - MMI BOR, SERBIA

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Abstract

The application of ISO 9001:2015 is the key to quality control in modern enterprises. With the help of this standard, it will be easier to implement ISO / IEC 17025:2017, and this is necessary for every laboratory that strives to be accredited and to implement a quality system in its work. One of the important factors for the implementation of ISO 9001:2015 is the documentation management of a company. The established system of document management enables efficient control of work in the laboratory, since the system is sustainable and can be updated and supplemented without disturbing the system of marking existing documents. Applying these standards minimizes possible errors and improves the efficiency of the laboratory service, thus contributing to sustainable business.

Keywords: ISO 9001:2015, ISO/IEC 17025:2017, Quality control, Documentation Management, Laboratory.

INTRODUCTION

International Standard ISO 9001:2015 gives wide possibilities of use and in combination with other standards can greatly facilitate the management of the company, if implemented appropriately. But many companies, due to lack of experience, in implementing ISO 9001:2015 and ISO 14001:2015 start marking records consecutively, by ascending numbers, and such a system very quickly gets out of control so companies find themselves in a situation where it is impossible to find the desired document or for their localization is needed too much time. Then the application of ISO 9001:2015 is becoming a burden for the company

because it makes functioning harder rather than easier. In this way, the essence of documentation follow-up is lost and implementation of ISO 9001:2015 becomes a real burden for the company.

Nowadays industrial development is usually accompanied by laboratory development. Quality control in laboratories in the food industry, agriculture, metallurgy, electronics, medicine and biology, at universities and institutes is unimaginable without adequate standards. All these activities have needs for implementation of ISO 9001:2015 and/or ISO/IEC 17025:2017 in addition to other standards that are applied to each individual area. Jovanovic in his works has a historical overview and progress of the implementation of ISO/IEC 17025 in the countries of Eastern Europe and Russia, Jovanović, 2004, 2005 and 2006.

Various problems that many companies have encountered during the implementation of ISO 9001 and/or ISO/IEC 17025 were the subject of much research (Yoo, et al. 2006; Walker, 1998; Gingele, et al. 2002; Martinez-Costa, et al. 2009; Krstić, et al. 2010 and 2011; Aldowaisan and Youssef, 2006; Karapetrovic and Casadesus, 2009; Pascal and Beyerle, 2006; Guzel and Guner, 2009) but the problem of document management like the sustainable quality system was not yet researched, although this aspect of ISO 9001 and/or ISO/IEC 17025 and ISO 14001 is very important for the successful functioning of the whole company.

ISO/IEC 17025:2017, together with ISO 9001:2015, ISO 14001:2015 related to environmental protection and ISO 45001:2018 related to occupational safety, form an integral quality system by which one testing laboratory can and should be accredited. Together, these standards contribute to sustainable business, through process optimization and the prevention of contamination. The MMI Bor is a complex Institute composed of different sectors and different types of laboratories and this paper will give the possibility of monitoring quality control laboratory of coal like the example to other laboratories of the MMI Bor from Serbia, and ensure the sustainability of a quality system conducted at the level of all laboratories in MMI Bor. In this way, we can ensure easy management of documents in MMI Bor, as an accredited institution, according to ISO 9001 and ISO/IEC 17025.

LABORATORIES

Today, institutions that include one or more laboratories in their structure, and wish to compete and to come to the market, must be accredited to ISO/IEC 17025 standard. The requirements of this standard are related to laboratories for testing and/or calibration.

Coal laboratory in MMI Bor in Serbia

MMI Bor is an institution accredited according to ISO 9001 since 2005, and the coal laboratory within MMI Bor is further accredited to ISO/IEC 17025 since the middle of 2010. In addition to these important organizational and generalized standard norms, specific standardized methods for accurately predicted activity in the laboratory are means that allow repeatability and reproducibility of results. Other standard methods for coal laboratory (Singh, et al. 2011; Kirsch, et al. 2010; ASTM D3302/D3302M 2017; ASTM D3173 2017; ASTM D3174 2012; ASTM D3175 2017; ASTM D5865 2013; ASTM D5373 2016) are using according to ISO/IEC 17025. According to the ISO/IEC 17025 documents which are mostly related to the monitoring of instrumental techniques are cardboard equipment, device handbook, basic characteristics of the device, control charts, estimation of measurement uncertainty, work equipment records, and documents withdrawn from use and etc.

Coal laboratory (CL), as shown in Figure 1, consists of three sub-laboratories: sample preparation laboratory (CL-PS), technical analysis (CL-TA) and silicate analysis or analysis of ash (CL-SA). Work in each of the laboratories is based on standard international norms (methods) depending on the needs of each individual laboratory. Each of these standard methods is based on ISO/IEC 17025, and by document management through ISO 9001.

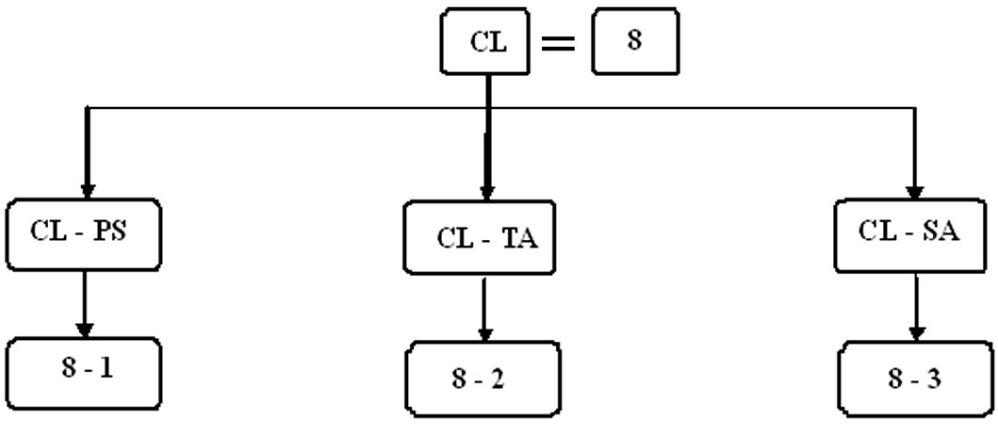

Figure 1 Schematic view of a Coal Laboratory, CL tag, which consists of three laboratories: CL-PS, laboratory for sample preparation; CL-TA, laboratory for technical analysis of coal and CL-SA, laboratory for testing of ash.

Laboratory for technical analysis of coal, CL-TA

Technical analysis of coal contains a determination of moisture in the analytical sample (ASTM D3302/D3302M 2017; ASTM D3173 2017), determination of ash (ASTM D3174 2012), determination of the volatile matter content (ASTM D3175 2017), carbon residue, C-fix, total sulfur (ISO 334 1992), and determination of gross calorific value by the calorimetric bomb method (ASTM D5865 2013; ASTM D5373 2016). For technical analysis of coal, the analytical sample prepared in the laboratory for sample preparation, CL-PS, according to appropriate standard norms was used. In the laboratory for technical analysis of coals, CL-TA, using analytical sample, obtained in CL-PS, ash is prepared, which will be tested in the laboratory for silicate analysis, CL-SA.

The tag system adopted in the coal laboratory is shown in Figure 2. The coal laboratory initially implemented a quality system control independently of other laboratories, as shown in Figures 1 and 2. Tag CL identifies the laboratory of coal, within a system of multiple laboratories in MMI Bor Serbia. As the CL is divided into three sub-laboratories CL-PS, CL-TA, and CL-SA, as shown in Figure 1, this means that the position of the other two letters determines the division within the CL, and together they make a part code in Figure 2.

The next position is determined by Roman numbers and represents a unit for themselves, so it is separated by a slash from the previous sections, and by the following unit from the dash (/II-). Roman numerals in the technical laboratory of coal indicate instrumental techniques used in the laboratory, CL-TA, so number one (I) is referred to the electronic balance, (II) on the dryer in the stream of nitrogen, (III) on the annealing furnace, (IV) on calorimeter and (V) on the elemental analyzer. The next Roman number will correspond to the new instrumental technique which is added to the laboratory.

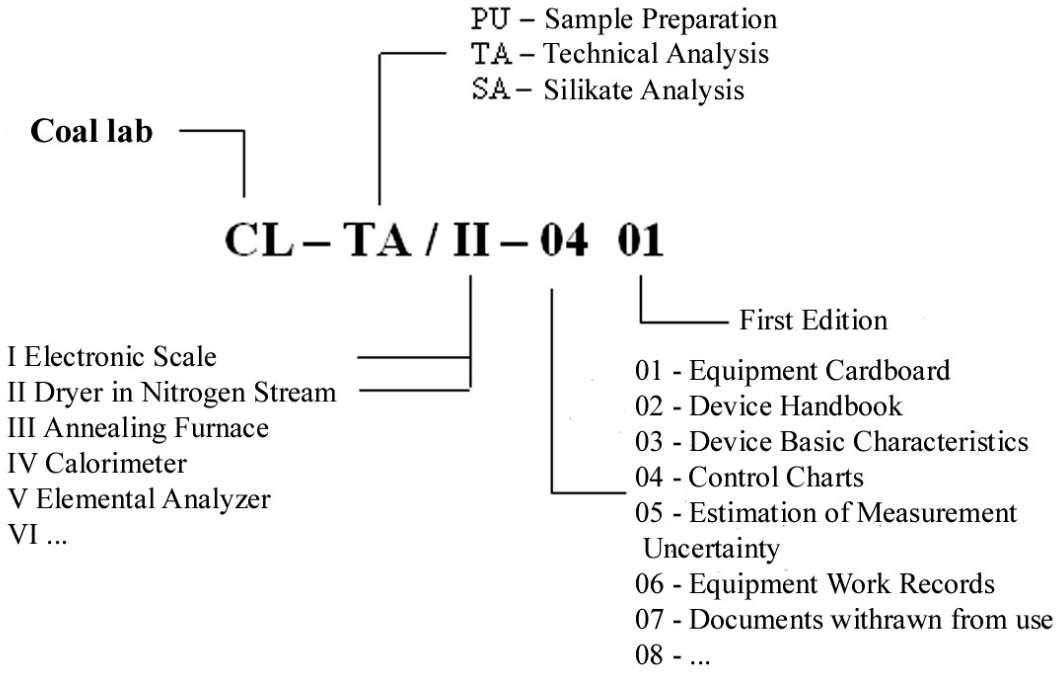

Figure 2 Documents which used in the tecnical laboratoryof coals.

The next position, 04, according to Figure 2 refers to the control charts from the defined series of documents from 01 to 07. The documents are defined as 01 - equipment card, 02 - device manual, 03 - basic characteristics of the device, 04 - control charts, 05 - uncertainty assessment, 06 - records of equipment operation and 07 - decommissioned documentation. Names of certain documents according to ISO/IEC 17025, and CL-TA defines the corresponding numbers from 01 to 07, as already mentioned. The number 04 is the same and defined control chart for all instrumental techniques, yet it is a different number for each technique, as it refers to different devices defined by Roman numerals, Table 1.

The following positions are defined by the last two digits, 01, according to Figure 2, refers to the first edition of the document. If the document has been changed, so it is necessary to actualize it, then the label of the new document is the same, except for the last two digits which will change from 01 to 02. Then number 02 will mark an updated document that has undergone a change, and the old document, marked with 01, would be transferred to the group of withdrawn documents where it would be archived, and easily accessible when needed.

If the new document was added to an existing series of documents from 01 to 07, it is defined by the following number (08 or 09), and according to Table 1, it would simultaneously be valid for each instrumental technique and will not disturb the existing system. Also, if the laboratory was equipped with a new instrumental technique or techniques, they would occupy the position of VI or VII in Table 1, which would not disturb the quality system related to the documentation of previously existing instrumental techniques. In this way, the quality system is protected both horizontally and vertically, which ensures the sustainability of the created system of marking documents within a laboratory.

Table 1. Application of ISO 9001 to instrumental techniques of laboratory documents for technical analysis of coals, precisely defined according to the ISO/IEC 17025

	ISO 17025:2017	ISO 9001:2015			
N	**Nazivi dokumenata**	**I**	**II**	**III**	**IV...**
01	Equipment Cardboard	CL-TA/I-0101	CL-TA/II-0101	CL-TA/III-0101	CL-TA/IV-0101
02	Device Handbook	CL-TA/I-0201	CL-TA/II-0201	CL-TA/III-0201	CL-TA/IV-0201
03	Basic characteristics of the device	CL-TA/I-0301	CL-TA/II-0301	CL-TA/III-0301	CL-TA/IV-0301
04	Control Charts	CL-TA/I-0401	CL-TA/II-0401	CL-TA/III-0401	CL-TA/IV-0401
05	Assessment of Uncertainty	CL-TA/I-0501	CL-TA/II-0501	CL-TA/III-0501	CL-TA/IV-0501
06	Equipment Work Records	CL-TA/I-0601	CL-TA/II-0601	CL-TA/III-0601	CL-TA/IV-0601
07	Documents Withdrawn from Use	CL-TA/I-0701	CL-TA/II-0701	CL-TA/III-0701	CL-TA/IV-0701

N – definid number of documents, I – the electronic balance, II – the dryer in stream of nitrogen, III – the annealing furnace, IV – the calorimeter C5000 and V – the elemental analyzer, CHSN.

DOCUMENTS MANAGEMENT OF INSTRUMENTAL TECHNICES OF CL-TA

Section 2.2 is given a detailed description of the document management system in the laboratory for technical analysis of coals according to ISO 9001 and ISO/IEC 17025. This system will serve as a model for managing documents in other IRM Bor laboratories.

If the laboratory for technical analysis of coal, CL-TA, was eighth of 11 as in our case (Table 2), which will be implemented a quality system in the same way, then the number 08 replaced the initial two letters of the selected model shown in Figure 2 and CL is equal to 08. Because the coal laboratory consists of three sub-laboratories (CL-PS, CL-TA, CL-SA), they can be represented numerically as 1, 2 and 3, respectively, as can be seen from Figure 1. This means that

the TA in the CL, we can replace with the number 2 (TA=2). Then label in Figure 2, CL-TA/II-0401, can be shown, in accordance with the previously explained, as follows, 082/II-0401. For the laboratory, which is not divided into sub-laboratories, that position corresponds to division within the laboratory, which will be zero.

For example, as shown in Table 2, all laboratories except CL (Lab 8) were shown as if consisted of one laboratory which is indicated by the number 0 at the TA position (Figure 2). Also, by Roman number (I) is marked that each laboratory has only one instrumental technique, for example, electric balance (to simplify labelling). This simplification will not affect the accuracy of the system. Each electric balance in each laboratory has its own documentation relating to cardboard equipment, device handbook, basic characteristics of the device, control charts, estimation of measurement uncertainty, equipment records and documentation work withdrawn from use. Any such document has the same number in each laboratory, for each defined record from 01 to 07, but it has a different initial number which defines each laboratory from 1 to 11, Table 2.

Table 2 Title od documents according to ISO 9001 and ISO/IEC 17025 for laboratories within the MMI Bor Serbia using the example of technical analysis of coals

	ISO/IEC 17025:2017 / ISO 9001:2015					
Lab	**01**	**02**	**03**	**04**	**05**	**06...**
Lab 1	010/I-0101	010/I-0201	010/I-0301	010/I-0401	010/I-0501	010/I-0601
Lab 2	020/I-0101	020/I-0201	020/I-0301	020/I-0401	020/I-0501	020/I-0601
Lab 3	030/I-0101	030/I-0201	030/I-0301	030/I-0401	030/I-0501	030/I-0601
Lab 4	040/I-0101	040/I-0201	040/I-0301	040/I-0401	040/I-0501	040/I-0601
Lab 5	050/I-0101	050/I-0201	050/I-0301	050/I-0401	050/I-0501	050/I-0601
Lab 6	060/I-0101	060/I-0201	060/I-0301	060/I-0401	060/I-0501	060/I-0601
Lab 7	070/I-0101	070/I-0201	070/I-0301	070/I-0401	070/I-0501	070/I-0601
Lab 8	081/I-0101	081/I-0201	081/I-0301	081/I-0401	081/I-0501	081/I-0601
	082/I-0101	082/I-0201	082/I-0301	082/I-0401	082/I-0501	082/I-0601
	082/II-0101	082/II-0201	082/II-0301	082/II-0401	082/II-0501	082/II-0601
	082/III-0101	082/III-0201	082/III-0301	082/III-0401	082/III-0501	082/III-0601
	082/IV-0101	082/IV-0201	082/IV-0301	082/IV-0401	082/IV-0501	082/IV-0601
	082/V-0101	082/V-0201	082/V-0301	082/V-0401	082/V-0501	082/V-0601
	083/I-0101	083/I-0201	083/I-0301	083/I-0401	083/I-0501	083/I-0601
Lab 9	090/I-0101	090/I-0201	090/I-0301	090/I-0401	090/I-0501	090/I-0601
Lab10	100/I-0101	100/I-0201	100/I-0301	100/I-0401	100/I-0501	100/I-0601
Lab11	110/I-0101	110/I-0201	110/I-0301	110/I-0401	110/I-0501	110/I-0601

In Table 2 laboratory for coal has been marked with the number 8 which corresponds to the CL title. TA within the CL from the same table is presented in its entirety by the contents of instrumental techniques (I, II, III, IV and V) and thus shows all defined documents related to the instrumental technique of the laboratory of coal, CL-TA, or 08-2 using ISO/IEC 17025.

In all other laboratories from Lab 1 to Lab 11 (Table 2), the documents management system can be developed on the same principle as in Lab 8.

CONCLUSION

The quality system described in this paper was successfully applied in the laboratory for technical analysis of coal at MMI Bor in Serbia. The applied quality system of the laboratory for technical analysis of coal can serve as a model for other laboratories in MMI Bor. Considering that the model of the document management quality system of the coal laboratory is also applicable to other laboratories in MMI Bor of Serbia, it can provide useful information and give an idea to other companies that consist of one or more laboratories and want to be accredited according to requirements of the ISO/IEC 17025 standard and supporting standards such as ISO 9001, ISO 14001 and ISO 45001. The introduction of the mentioned standards contributes to determining responsibility, reducing defects, non-conformities, enabling process optimization and eliminating unnecessary activities. Also, the application of these standards leads to savings in time and money due to the reduction or elimination of the need for re-testing of laboratory equipment, which is one of the important aspects of sustainable business.

ACKNOWLEDGEMENTS

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ANALYSIS OF WILDFIRE OCCURRENCE IN NATIONAL FORESTS AT THE TERRITORY OF THE REPUBLIC OF SRPSKA PRESENTED THROUGH GIS

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Abstract

This research paper shows the analysis of wildfires at the territory of the Republic of Srpska, where the user of forests and forest land is the Public Forest Enterprise "Forests of the Republic of Srpska" JSC Sokolac. The analysis was performed at the level of organizational units of the Public Forest Enterprise and the analysis was mapped using geographic information systems covering the period from 2010 to 2021. In addition to the spatial distribution, various types of wildfires were taken into consideration such as crown fire, surface and ground subsurface fire. The purpose of the analysis is to show the spatial distribution of wildfires, its frequency and presentation of damage caused to each organizational unit of the Public Forest Enterprise.

Key words: wildfire, analysis, GIS, Republic of Srpska

FORESTS OF THE REPUBLIC OF SRPSKA

Beneficiary of the state owned forests in the Republic of Srpska is the Public Forestry Company "Forests of the Republic of Srpska" JSC Sokolac (hereinafter referred to as „Public Company"). Total forested land of Republic of Srpska covers 1,311,491 hectares, out of which 1,010,510 hectares are state owned forests, which is 77% of all forests in Republic of Srpska.

The Public Forestry Company of the Serbian Republic of Bosnia and Herzegovina was established by the Decision of the Government of the Serbian

Republic of Bosnia and Herzegovina No. 03-599 dated June 08th 1992. ("Official Gazette of the Serbian People in B&H", number 9/92) and registered at the Municipal Court in Banja Luka on February 3rd, 1993., together with registration amendments dated July 02nd 1997, June 07th 1998., November 02nd 1999., April 09th 2001. and May 09th 2001. Transformation of the form of organization of the Public Enterprise into a joint-stock company was performed on the basis of the Law on Amendments of the Law on Forests (Official Gazette of the Republic of Srpska, number: 53/05) and was registered with the Municipal Court in Sokolac on September 26th 2005, (Forests of RS, 2020). The main activity of the Public Enterprise is the cultivation and protection and exploitation of forests. Public company performs its activities through various organizational units.

The following units operate as part of the Public Enterprise:

- 28 forestry authorities
- Center for karst management
- Center for seed and plant nursery
- Research-development and project center
- Public Enterprise Directorate
- Forestry authority "Ognjište"

METHODOLOGY

In this work, the data of the Public Enterprise, through forms of forest fire records in organizational units, were used. At the end of each business year, the Public Enterprise creates a unique overview of recorded forest fires by type and organizational unit in whose area the forest fire occurred. In this paper, the period from 2010 to 2021 was analysed.

ANALYSIS OF FOREST FIRES

Forest fire represent the greatest danger within forested area due to the speed of its spreading and the enormous proportions they can reach. Almost immediately, huge forested areas vanish, which leads to a change in the appearance of the habitat where the forest fire occured. Forested areas and green space are transformed into burnt and bare areas, and in economic aspect this represents a huge financial loss. The occurrence of forest fire is influenced by many factors, which are mainly the result of global warming, while the main cause is the human factor, i.e. humans without developed awareness of the importance of forests as a common good (Živojinović, 1967). Forest fires occur despite the implemented preventive measures, and therefore their occurrence can be observed as a regular phenomenon that we must reckon with. According to the location

and characteristics of the burning material, forest fires can be divided as ground, surface and crown fires (Ljubojević, Stanković, 2021).
Further on, analysed period shall include the number of forest fires occured and each forest fire shall be presented according to year of its occurence including the amount of damage caused (expressed in damage quantity and by value of damage caused), as well as an overview of the spatial distribution of the occurrence of forest fire by each organizational unit of the Public Enterprise and the number of forest fire and its type.

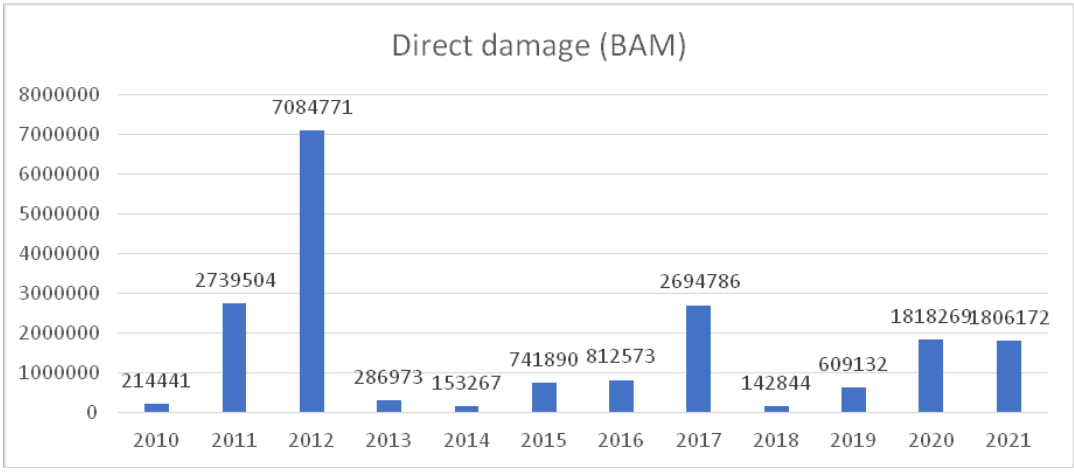
Within the observed period, 2,383 forest fires were recorded - table 1 shows a detailed overview of the number of forest fires and damage caused per each year (PCF „Public Company Forests of the RS", 2010 - 2021).

Table 1: Overview of the number of forest fires and damage value

Year	Number of forest fires	Burnt area	Totally destroyed forests	Direct damage	Firefighting costs
		hectares	m^3	BAM	BAM
2010	79	1.523	2.802	214.441	32.713
2011	298	14.970	79.268	2.739.504	174.298
2012	546	25.508	83.491	7.084.771	743.485
2013	94	422	741	286.973	48.199
2014	83	428	362	153.267	20.390
2015	179	6.067	21.654	741.890	149.757
2016	117	3.388	17.317	812.573	47.598
2017	260	18.886	254.598	2.694.786	138.833
2018	45	599	3.361	142.844	13.227
2019	206	3.654	13.722	609.132	77.207
2020	326	6.076	25.081	1.818.269	212.079
2021	150	12.173	57.340	1.806.172	159.576

When we analyse the data from Table 1, we notice that massive damages were recorded within the observed period. The total burnt area is 93,694 ha, while the total destroyed wood mass is 559,737 m^3. When we observe the economic aspect of recorded forest fires, we can conclude that total damage amounts to 19,104,233 BAM for the analysed period, which represents significant financial damage. The financial consequences are also reflected through the total firefighting costs which are 1,817,362 BAM.

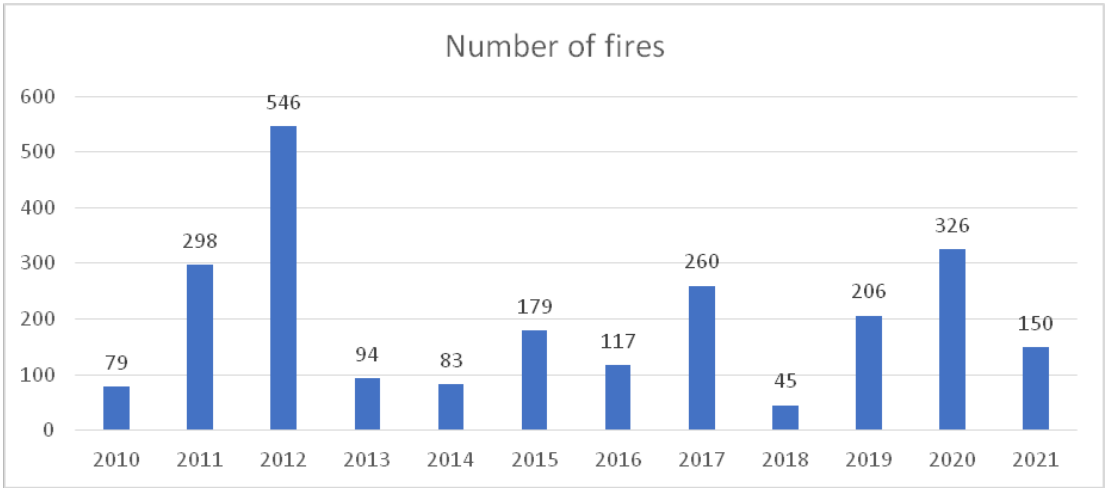
From the data shown in graph 1, we can see that the largest damage was recorded in 2012.



Graph 1: Direct damage (BAM) for the period 2010-2021

On graph 2, we can see that within the observed period, the highest number of forest fires was recorded in 2012, due to extreme temperatures and an extremely dry period during the mentioned year. The average annual number of recorded fires in this period was 199. In order to be able to analyse the number of forest fires and their spatial distribution in high quality way, the best way is to display it by using geographic information systems. Geographic information systems enable the spatial display of data that needs to be analysed, which provides a clearer view of the analysed data (Jovanović, Đurđev, Srdić, & Stankov, 2012).

Image 1 shows the spatial distribution of forest fires within each of organizational units.



Graph 2: Number of forest fires for the period 2010-2021

By analyzing the total number of forest fires within the observed period, we can see that the highest number of forest fires was recorded in the eastern part of Republic of Srpska. Due to the specificity of the terrain and its climate which is characterized by extremely dry periods, the Trebinje Karst Management Center is the organizational unit with the highest number of recorded forest fires.

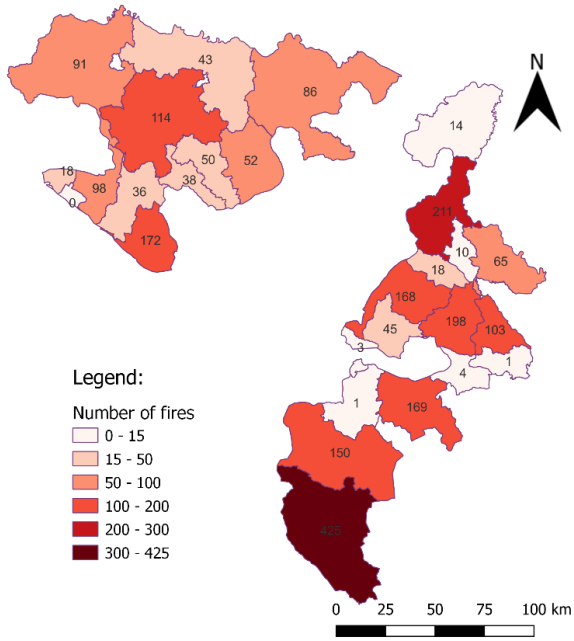


Image 1: Number of forest fires within organizational units

Table 2 shows the recorded types of fire during the observed period. Analysing the recorded fires, we can see that the most frequent fire was surface type fire which occured 2,292 times, while, on the other hand, there was a small incidence of crown fires which occured 71 times and ground type fire which occured 20 times.

Table 2 – Number of forest fires for the period 2010-2011

Year	Crown Fire	Surface Fire	Ground Fire
2010	1	78	0
2011	4	293	1
2012	23	517	6
2013	1	89	4
2014	0	83	0
2015	6	170	3
2016	1	116	0
2017	12	247	1
2018	3	42	0
2019	2	203	1
2020	9	317	0
2021	9	137	4
Total:	71	2292	20

After analysis of the tabular data, we can distinguish the number of forest fires, its type and location, as well as data of the damage caused. However, in order to have more complete overview, it is necessary to add a spatial component, and the best way to do so is to use geographic information systems. GIS provide better and more comprehensive representation of the forest fire occurrence, which afterwards enables further analyses and thus collection of additional data on fire occurence. When there is an adequate amount of data which are collected using geographic information systems, such data can be further processed for greater efficiency during fire extinguishing activities, and also to reach more specific decisions during the process of preventive activities planning.

CONCLUSION

This paper analysed data regarding the number of fires recorded in state owned forests at the territory of the Republic of Srpska, whose beneficiary is the Public Forestry Company "Forests of the Republic of Srpska" JSC Sokolac. The

period from 2010 to 2021 was analysed, covering 2.383 recorded forest fires. Out of the total number of fires, the most common were ground fires in total number of 2.292. During analysed period, 199 forest fires was an average number of recorded fires occuring annually spanning through average area of 7,808 ha. When analysing the damage caused, an average annual amount of destroyed wood mass was 46.646 m^3, which amounts to 1.592,052 BAM of direct damage, and the average annual firefighting costs were 151,447 BAM. According to all mentioned in this paper, it is obvious that forest fires represent enormous problem, both for the ecosystem due to its large number, and for the economics due to extensive damages. The presentation of forest fires occurrence using geographic information systems enables a better and more accurate presentation of the occurrence of forest fires, which, on the other hand, enables more effective implementation of preventive measures, as well as exact pinpointing for more effective firefighting activities.

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REDUCTION OF AIR POLLUTION IN UŽICE DUE TO ENERGY EFFICIENCY MEASURES APPLIED TO SINGLE-FAMILY HOUSING

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Abstract

Single-family houses in Serbia mostly have inadequate thermal characteristics and use heating systems based on low-quality energy sources. This problem causes poor ecological image of cities and an increased concentration of pollutants in the air. Therefore, the improvement of energy performance is becoming an increasingly common principle of design, both within the new and the existing buildings. This paper is based on the assumption that use of more than sixteen thousand individual fireplaces within single-family households in Užice is one of the biggest air pollutants in the city. Poor quality of energy sources and improper combustion process release toxic substances into the atmosphere, but the cause of increased emissions of pollutants can be identified in the poor characteristics of thermal envelopes. This research is trying to discover if there was the right solution for a single-family house in Užice, when it comes to reducing the air pollution by changing the thermal envelope and heating system.

Key words: air pollution, single-family housing, thermal envelope, individual heating system

INTRODUCTION

Buildings in economically less developed countries, such as Serbia, mostly have low energy performances which lead to poor environmental picture and negative health impact of the entire population. Some of the first regulations affecting the thermal issue of buildings appeared at the end of 1960s in Serbia. However, their following development was not in line with the development of regulations in European Union countries. This is the reason why Serbia is lagging far behind them. Another problem is inadequate implementation of regulations, especially when it comes to family housing. This behavior shows that there is not enough concern for energy in Serbia.

The subject of the research is the impact of energy improvement measures on single-family residential buildings on reducing air pollution in the city of Užice. There is a variety of applied measures either connected to construction or

thermal engineering. The goal is to find an environmentally friendly model that would be suitable for the city of Užice and its pollution problem.

ANALYSIS OF AIR POLLUTION PROBLEM IN UŽICE

Air pollution in Užice

There are noumerous air pollutants that can be classified into pollutants of natural and artificial origin. The leading artificial pollutants are created in the processes of extraction and processing of mineral raw materials, the operation of communal and industrial facilities, the consumption of traffic and the operation of heating systems and devices that primarily use fossil fuels (Vallero, 2014).

Air quality measurements in Serbia show that the concentration of polluting particles exceeded all European standards, and according to data from the Institute of Public Health, Užice is one of the most polluted cities in the country.

Factors affecting air pollution in Užice

There are many different factors that cause great air pollution; some of them are related to the natural origins, such as terrain configuration and climatic characteristics, but most of them happen because of artificial use of heating systems, excessive traffic and industry.

Užice has a particular position; it is located in the river Djetinja's valley and surrounded by several hills. This hole-like relief caused present appearance of the city; the city center is the only part that is not hilly (Figure 1).

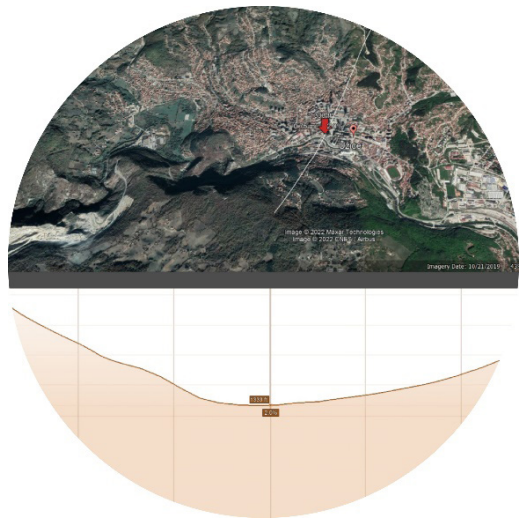


Figure 1. Review of the city morphology through the section across the city center (Source: made by author using Google Earth - earth.google.com)

The specific location and high buildings disturb the ventilation and lead to accumulation of harmful particles. In the central streets, ventilation is difficult and pollutants vortices are created. Considering the valley position and the dense street network, traffic in Užice represents a significant environmental problem. The overload of vehicles has caused the narrow and steep streets and sidewalks to turn into parking lots. In the winter period, there is a radiation temperature inversion, where cold air remains trapped in the ground layers of the atmosphere, while a front of warmer air forms above. In these conditions, vertical air circulation is disabled, so all emitted pollutants accumulate in the lowest layer of the atmosphere (Figure 3).

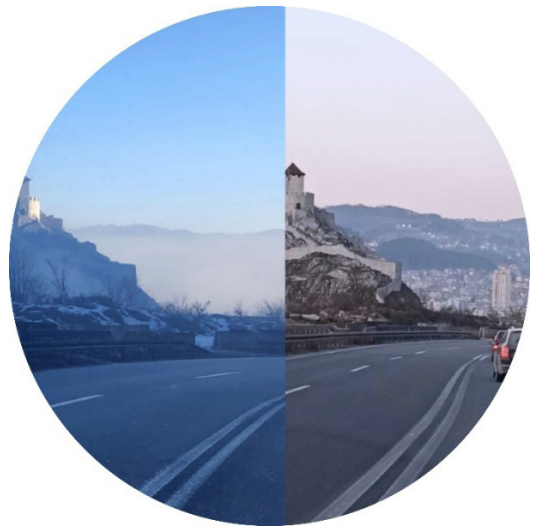


Figure 3. City views with and without temperature inversion (Source: made by author – photographed in December and March)

However, one of the most influential factors of air pollution in Užice is the use of individual fireplaces in households that use fossil fuel as the main source of heating energy.[1]

According to the Report of air quality from 2018, it is estimated that there are more than sixteen thousand individual fireplaces in Užice. Due to relatively low chimney positions, specific terrain configuration and disadvantageous flow of air masses, products of individual fireplaces mostly stay in the lowest part of the atmosphere. Another issue is bad quality of energy sources; according to Report of air quality from 2018, more than 70% of household use wood and coal,

[1] Službeni list grada Užica (br. 8/2019). *Izveštaj o kvalitetu vazduha* za 2018. godinu (in Serbian). Užice: Službeni list grada Užica.

but sometimes poor economic situation results in waste materials use. Increased emission of air pollutants can also be identified in low energy performance of individual buildings. Poor characteristics of thermal envelopes usually cause higher energy consumption. Therefore, in order to reduce energy consumption and reduce air pollution, there is a great need for the implementation of energy improvement measures.

ANALYSIS OF SUBJECT LOCATION OF SINGLE-FAMILY HOUSING IN UŽICE

Methodology of data collection for the analysis

Using the methodology for data collection and analysis carried out in Atlas of Family Houses of Serbia, the typology is based on architectural-urban parameters, thermal performance and construction period, as well as the heating systems.

The first step of the research is the determination of the existing condition; direct contact with residents allowed an adequate insight into the various characteristics of the buildings. The survey was possible with the residents of 30 houses. Certain similarities were noticed among houses, so the research work was reduced to three representative types.

Using the principles from the National Typology of Residential Buildings of Serbia, each type of the house was improved with basic and advanced improvement and six variants were created for each house: basic and advanced improvement of heating system without changing the envelope, basic and advanced improvement of the envelope with the existing heating system and two improvement levels with both envelope and heating changed. According to the Regulation on Energy Efficiency of Buildings, the calculation of carbon dioxide emission is substantial. It is assumed that the emissions of other pollutants that affect air pollution are reduced as well.

Analysis of the current state of the site

Due to the specific morphological position of Užice, subject location was selected in the area near city center, at an altitude that is lower than surrounding hills. The emission of harmful gases in this part of the city, due to the temperature inversion during the heating period, remains trapped and directly affects the atmosphere. Selected area is representing a single-family housing that is placed close to the city center, but still in the valley. The subject location is surrounded by streets of low intensity. Parking is mostly aranged within the limits of indi-

vidual lots and there are no sidewalks for pedestrians. Built structures prevail comparing to green areas.

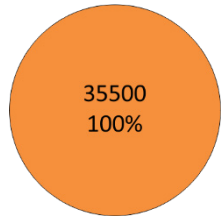
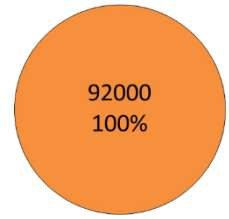
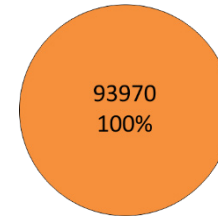
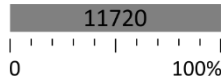
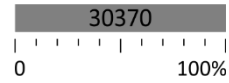
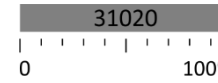
Analysis of the selected houses of the site

The first two types are freestanding rectangular base houses on a sloping terrain that is typical for Užice's region. The first type is built between 1919 and 1945 and the other one between 1946 and 1970, both with solid brick walls and gable roof. Single-paned wooden windows are small and glazed with single-paned glass. Houses have less than 50% of openings on the façade that are between 30 and 40 years old. The slope was used for creating the basement that is not heated and roof is suitable for having the loft but the attic space is not adapted for use. The façades have no thermal insulation. The entire residential part of the first house is heated by local coal stoves located in each room, while in the second house, the ground floor and the first floor are heated by local coal heating system, while basement and attic are not heated. The third type is a freestanding house with a square base built between 1981 and 1990. Unlike the previously mentioned ones, this house is located on a flat surface, with no basement floor and attic space. The façade walls are made of bricks and insulated with a 5-centimeters thermal insulation. The entire facility is heated using a central heating system with solid fossil fuel. According to the results obtained by using the software for testing energy performance of buildings according to the current regulatory framework in Serbia (KnaufTerm), all house types belongs to G energy class.

CONCLUDING REMARKS

Carbon dioxide emissions are a direct consequence of primary energy needs. According to the Rulebook on Energy Efficiency of Buildings ("Službeni glasnik RS", 61/2011), primary energy represents energy from renewable and non-renewable energy sources that has not undergone a conversion or transformation process; primary energy is contained in the energy source. It can be concluded that the emission of carbon dioxide depends on the energy used for heating (Table 1).

Table 1. Comparison of primary energy and carbon dioxide emissions for three house types (Source: made by author)

	Type 1	Type 2	Type 3
Energy required for heating [kWh]			
Annual energy required for heating [kWh/m^{2}a]			

Analyzing the results of the research, it can be seen that the change in the heating system does not affect the energy needs of the house so, accordingly, the first step towards prosperity would be the implementation of building improvement measures. On the other hand, when it comes to the emission of carbon dioxide, switching the use of fossil fuels to natural gas reduces the emission of carbon dioxide almost three times in each of the selected examples. The best results are shown by advanced improvement, where primary energy needs are reduced by up to five times, and carbon dioxide emissions by more than ten times. For the proposed varieties, it can be concluded that, in terms of carbon dioxide emissions, it is best to carry out a basic construction improvement with a change of the heating system to a natural gas condensing boiler. However, if renewable sources were to be used for the production of electricity, in that case the best solution would be non-conventional heating systems, such as a heat pump.

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RADON IN NATURAL WATERS AND ITS IMPACT ON HEALTH IN THE AREA OF SOKOBANJA

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Abstract

In this study, radon concentrations in natural water were measured at 9 locations in the area of Sokobanja, using RAD-7 radon monitoring system (DURRIDGE Co., USA). The interval of measured values is from 1.2±0.6 Bq/l to 111.1±8.0 Bq/l, with average value of 19.6±4.5 Bq/l. The range of total annual effective dose for all water samples was from 3.3±1.6 μSv/y to303.2±21.8 μSv/y, with average value of 53.4±12.2 μSv/y. When the results of this study were compared to the internationally recommended reference levels of radon concentrations (World Health Organization limit 100 Bq/l) and the recommended effective annual dose for radon in drink water (100 μSv/y), there were no indications of existence of radon problems in the water sources in this survey.

Key words: radon, water, annual effective doses of inhalation and ingestion, health risk

INTRODUCTION

Due to the great importance of drinking water and the increased consumption of mineral waters, it is very important to carefully and systematically control their quality. It is known that numerous mineral springs contain significant concentrations of natural radionuclides (mainly radium and radon) in higher concentrations (Najeeb et al, 2014) than usual drinking water (Moldovan et al, 2009), which is the result of natural processes of decomposition and dissolution of rocks

from surrounding geological environment (Moreno et al, 2014; Fonollosa et al, 2016). Radium is more chemically active, and as such can easily be absorbed by plants from the soil and transported up the food chain to humans when it can affect tissues (bone marrow that produces red blood cells) and can also cause bone cancer. Radioactive gas radon, as a direct product of the decay of radium, is an inert gas with a half-life of 3.82 days and is characterized by its high solubility in water. Presence of radon in groundwater is greatly influenced by numerous factors: its emission from the surrounding rocks, temperature, pressure, precipitation and earthquake activity (Ilani et al, 2006; Sannappa et al, 2006). Due to greater contact of groundwater with igneous and sedimentary rocks, the concentration of radioactive contents in these waters can be higher than surface water sources (Todorovic et al, 2012; Akawwi, 2014). Numerous studies have shown that the consumption of water containing high concentrations of radon would increase the received effective dose, because by the emission of alpha particles during its decay, it can cause lung, blood and stomach cancer in the long term usage (Colmenero Sujo et al, 2004; Nagaraja et al, 2003; Smith et al., 2007). Reference level of radon in drinking water according to the decision of the World Health Organization is 100 Bq/l (WHO, 2004), while the reference level set by the United States Environmental Protection Agency is 11.1 Bq/l (USEPA, 1999). The World Health Organization and the European Committee have proposed that the annual received effective dose from both inhalation and ingestion of radon exposure is 0.1 mSv/y (WHO, 2004; EURATOM, 2013). This paper presents the results of testing the presence of radon in natural mineral spring waters at 9 locations in the Sokobanja area, in order to assess whether its level in the water can have a negative impact on public health.

RESEARCH AREA

Research was conducted in 9 selected localities, figure 1. The area of Sokobanja, the so-called Sokobanja basin), geographically, is characterized by a complex structural and tectonic assemblage dominated by the presence of numerous faults and fault zones that cross complex geological formations in different directions, figure 1. (Komatina, 2015) The complex tectonic evolution of the Sokobanja basin has resulted in its composition containing rocks of different geological formations and compositions (Joksić et al, 2007).

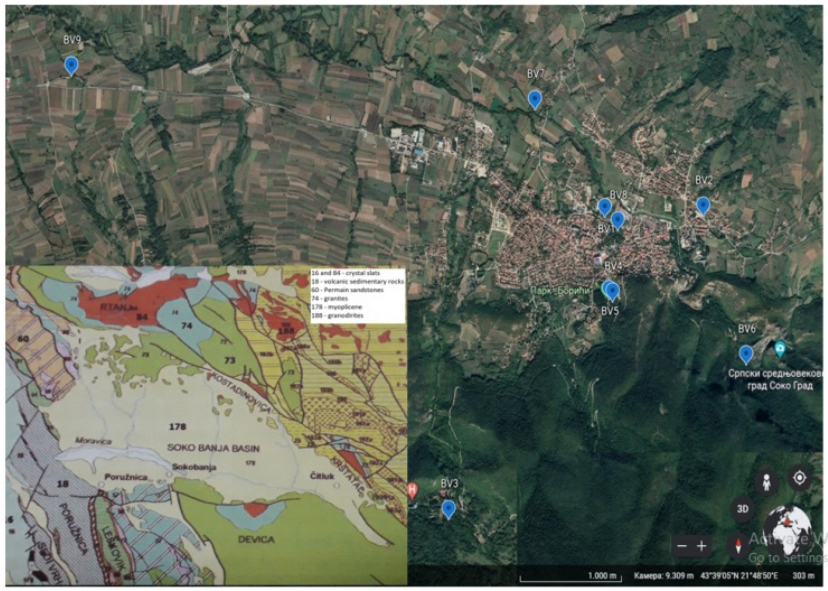

Figure 1. Map of selected localities in the area of Sokobanja

Volcano-sedimentary formations are the most represented, followed by crystalline schists, granodiorites and Permian sandstones, whose age is estimated at more than a billion years. Sokobanja basin belongs to the group of radioactive spa areas of Serbia, with several springs of mineral water of different temperatures which erupt along the faults described above. Mineral waters in the Sokobanja basin originate mainly from great depths, but there are also springs from shallower layers. According to the temperature range, they belong to the group of akratopega-cold mineral waters. Based on the pH value, they are classified as slightly acidic (5.5-6.8), neutral (6.8-7.2) and slightly alkaline (7.2-8.5), (Filipović, 2007).

MATERIAL AND METHODS

Radon concentration in mineral water samples was determined using the RAD H2O system (Durrige Co.). Recommended method of the manufacturer of the measuring system was followed during sampling in this study. Water from mineral springs was sampled in original glass bottles with a volume of 250 ml. The bottle was filled under a small jet and closed while the water poured over the opening, in order to avoid the accumulation of radon released from the water under the cap.

Basis of the RAD7 alpha spectrometer itself is a hemispherical chamber with a volume of 0.7l, the inner side of which is coated with a material that is a good conductor. As radon is chemically inert and electrically neutral in the chamber, positive Po-218 ion is what accelerates the electric field in the chamber and directs it towards the detector. Deposited Po-218 emits α-particles that enter the active medium with a probability of 50% and produce an electrical signal whose intensity corresponds to the energy. Sampled water was aerated with a RAD7 pump so that radon was squeezed out of the sample and transferred to the measuring chamber. Air circulates through the water in cycles and continuously extracts radon from it. The efficiency of radon extraction from water into the air that circulates to the measuring chamber depends slightly on the temperature, but is always greater than 90%. This system reaches equilibrium very quickly, and after 5 minutes there is no more radon that could be extracted from the sample. The RAD7 pump was used to aerate the sampled water so that the radon was squeezed out of the sample and transferred to the measuring chamber. Air circulates through the water in cycles and continuously extracts radon from it. The efficiency of radon extraction from the water into the air that circulates to the measuring chamber depends slightly on the temperature, but is always greater than 90%. This system reaches equilibrium very quickly, and after 5 minutes there is no more radon that could be extracted from the sample. The lower detection limit of the device is 0.37 Bq/l. Following values were measured during water sampling: water temperature with a digital thermometer (Testo Se & KGaA, Germany) and pH value with a pH-meter with a combined electrode HI 1131 (Microcomputer pH-vision 6071, JENCO Electronics. Ltd, Taiwan). The value of the ambient dose equivalent of gamma radiation was measured with a RADEX RD1503+ device (PCE Instruments Ltd, UK). The measurement was made at a height of 1 m above the source itself. Indication that there is a radionuclide in a higher concentration at the selected location would be the value of the ambient dose equivalent of radiation above 0.20 μSv/h.

RESULTS AND DISCUSSION

Radon

Since the concentration of radon in the water samples was not determined at the sampling site, the value of the radon concentration was determined in the laboratory. So, as the true value of radon concentration in water samples, its corrected value is used according to the formula (Todorovic et al, 20012) - $C_{corr} = C_o \cdot \delta$, where: $\delta = e\lambda t$, where for radon decay $\lambda = 0.00756$ h-1, and t defines the time elapsed from sampling to laboratory analysis. In addition to the corrected

value of the radon concentration, table 1 also includes: temperature T (oC), pH value of the water sample and the value of the ambient dose equivalent of radiation at the sampling sites D (μSv/h).

Table 1. Summarized results of this research in the area of Sokobanja

No of location	T (°C)	pH	D (μSv/h)	C_{corr} (Bq/l)
1	15	7.0	0.16	111.1±8.0
2	14	7.4	0.15	17.6±3.4
3	10	7.7	0.12	1.2±0.6
4	12	7.4	0.14	7.0±2.3
5	13	7.8	0.09	3.3±0.0
6	14	7.5	0.09	8.8±5.3
7	12	7.3	0.13	13.9±6.8
8	13	7.8	0.09	3.1±0.0
9	13	7.4	0.15	10.2±5.0
Min	10	7.0	0.09	1.2±0.6
Max	15	7.8	0.16	111.1±8.0
Average value	13	7.5	0.12	19.6±4.5

Values of radon concentration in water from 9 selected locations are in the interval from 1.2±0.6 Bq/l to 111.1±8.0 Bq/l and the mean value is 19.6±4.5 Bq/l, which is below the recommended value of 100 Bq/l. Only at site 1 was measured a radon concentration in the water sample of 111.1 Bq/l, which may be a consequence of the geological structure of the terrain. On its way to the source, underground water probably comes into contact with rocks rich in radionuclides, which it dissolves and thus conditions the increased presence of radon. At all other locations, the radon concentration is low, far below the recommended value for natural mineral waters of 100 Bq/l, so it can be said that radon at location 3 is found in traces - 1.2±0.6 Bq/l. Only in two locations (2 and 7) is the concentration of radon in the water close to the recommended value for drinking water of 11.1 Bq/l. Based on these measured radon concentration values, it can be said that the water is radiologically safe for use. Figure 2 shows the values of radon concentration in water in relation to the recommended values.

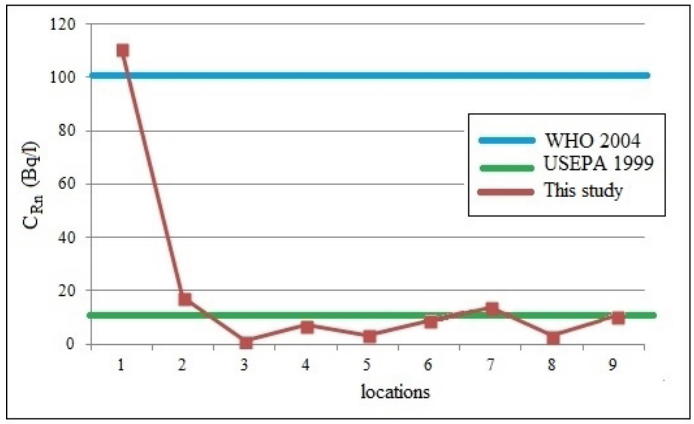

Figure 2. Range of radon concentration in mineral water in Sokobanja

According to the temperature range, they are classified as cold mineral waters, and according to the pH value, they belong to the group of neutral and weakly alkaline waters. Measured values of the ambient radiation dose equivalent correspond to the natural radiation background (UNSCEAR 2000), the mean value of the measured values is 0.12 μSv/h. Mutual dependence of the measured parameters is determined by the Pearson coefficient, the values of which are: radon concentration in water and pH value - 0.60, radon concentration in water and ambient dose equivalent of gamma radiation - 0.36, and radon concentration in water and temperature - 0.30.

Estimation of total annual effective doses of irradiation

To calculate the annual doses of inhalation and ingestion, the authors used the equations from UNSCEAR 2000 which are presented in table 2. Exposures to radon come mainly from the inhalation of the decay products of radon, which deposit in homogeneously within the human respiratory tract and irradiate the bronchiale pithelium (Todorovic et al, 2012). The annual effective inhalation doses from radon in water were calculated by using the parameter established in the UNSCEAR 2000 as:

$$E_{inh}\left(\frac{\mu Sv}{y}\right) = C_{wRn} \times C_{aw} \times DCF \times F \times t \qquad (1)$$

where E_{inh} is the effective dose for inhalation, C_{WRn} is the radon concentration in water (Bq/l), C_{aW} is the radon in air to the radon in water ratio (10^{-4}), F is the equilibrium factor between radon and its progenies (0.4), t is the average indoor

occupancy time per individual (7000 h/y) and DCF is the dose conversion factor for radon exposure [9 nSv (Bq h m^{-3})$^{-1}$].

The ingestion of water was estimated in the UNSCEAR 1993 to be 100 l/y by infants, 75 l/y by children, and 50 l/y by adults. Assuming the proportion of these groups in the population to be 0.05, 0.3, and 0.65, the weighted estimate of consumption is 60 l/y. For the ingestion part, radon and its progenies in drinking water impact a radiation dose to the stomach. The committed annual effective dose contribution of citizens, taking radon concentrations in account, was calculated according to following formula:

$$E_{ing}(\frac{\mu Sv}{y}) = C_{wRn} \times C_w \times EDC \quad (2)$$

where E_{ing} is the effective dose for ingestion, C_{wRn} is the radon concentration in water (Bq/l), C_w is the the weighted estimate of water consumption (60 l/y) and EDC is the effective dose coefficient for ingestion (3.5 nSv/Bq), respectively.

Table 2.Annual effective doses and radiation doses to organs

No of location	E_{inh} (μSv/y)	E_{ing} (μSv/y)	E_{tot} (μSv/y)	Doses to organs (μSv/y)	
				Lungs	Stomach
1	279.9±20.1	23.3±1.7	303.2±21.8	33.6	2.8
2	44.4±8.6	3.7±0.7	48.1±9.3	5.3	0.4
3	3.0±1.5	0.3±0.1	3.3±1.6	0.4	0.03
4	17.6±5.8	1.5±0.4	19.1±6.2	2.1	0.2
5	8.3±0.0	0.7±0.0	9.0±0.0	0.9	0.08
6	22.2±13.3	1.8±1.1	24.0±14.4	2.6	0.2
7	35.0±17.1	2.9±1.4	37.9±18.5	4.2	0.4
8	7.8±0.0	0.6±0.0	8.4±0.0	0.8	0.07
9	25.7±12.6	2.1±1.0	27.8±13.6	3.1	0.3
Min	3.0±1.5	0.3±0.1	3.3±1.6	0.4	0.03
Max	279.9±20.1	23.3±1.7	303.2±21.8	33.6	2.8
Average value	49.3±11.3	4.1±0.9	53.4±12.2	5.9	0.5

The mean value of the total annual equivalent dose of ingestion and inhalation of radon released from water is 53.4±12.2 μSv/y, which is below the recommended level of 100 μSv/y (UNSCEAR 2000). Only the annual effective exposure dose is significantly above the recommended - 303.2±21.8 μSv/y, which is understandable because the concentration of radon in the water sample is 111.1±8.0 Bq/l.

The radiation dose contribution from this source to lungs and stomach is calculated by multiplying the inhalation and ingestion dose by coefficient of 0.12 for lungs and stomach, respectively. The mean lungs and stomach radiation dose values are 5.9 μSv/y and 0.5 μSv/y, respectively.

CONCLUSION

The main goal of the authors was to examine and record the amount of radon present in natural mineral spring waters in this very visited area. The values of radon concentration in water from 9 selected locations are in the interval from 1.2±0.6 Bq/l to 111.1±8.0 Bq/l and the mean value is 19.6±4.5 Bq/l, which is below the recommended value of 100 Bq/l. Only at site 1 was measured the radon concentration in the water sample of 111.1 Bq/l, which may be a consequence of the geological structure of the terrain. Based on these measured radon concentration values, it can be said that the water is radiologically safe for use. Radon is the least represented in the water at location 3, only 1.2±0.6 Bq/l, while at two locations: 2 -17.6±3.4 Bq/l and 7 - 13.9±6.8 Bq/l radon is within the limit of the recommended USEPA value for drinking water . Based on these measured radon concentration values, it can be said that the water is radiologically safe for use. The mean value of the total annual effective dose of exposure to radon released from water is 53.4±12.2 μSv/y, which is below the recommended level of 100 μSv/y. This is another indication that the waters from these nine localities are safe to use. According to the average temperature value of 13 oC, the investigated mineral waters belong to the acratopeg group, and according to the average pH value, they belong to weakly alkaline waters. The mean value of the ambient radiation dose equivalent of 0.12 μSv/h is within the limits of the natural background.

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EXAMPLES OF PHYTOREMEDIATION AND BIOFORTIFICATION AS TWO SIDES OF THE SAME COIN

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Abstract

The work presents findings from our and other researcher investigations, carried out on different cultivars using some non-standard fertilizers (preferentially based on plant phytohormones, amino acids ant plant and other extracts). The work demonstrates that these non-standard fertilizers is highly effective in biofortification (increasing the nutritional value of food of plant origin) in different crops. Also, natural origin of these non-standard fertilizers makes it suitable for use in organic agriculture. Furthermore, it also contributes to improving yield and different plant physiological and growth parameters. Additionally, that non-standard fertilizers induce excellent resistance crops to abiotic stresses connected with heavy metals and other toxic elements, which makes them suitable for the program of phytoremediation of polluted soil.

Key words: non-standard fertilizers, biofortification, crop yield and physiology, phytoremediation

MATHERIAL AND METHODS

The conditions for growing plants are stated in the works Waisi et al. (2015, 2017), Dragičević et al. (2016) and Đurović et al. (2019), while the conditions of chemical, biochemical and microbiological analyzes are stated in the papers Waisi et al. (2015, 2017), Dragičević et al.(2016) and Đurović et al. (2019).

RESULTS AND DISSCUSIONS

From results presented in Table 1 we see that fertilizers based on plant and other extracts (Zircon, Chitosan) have a significantly greater impact on the yield, than fertilizers based on phytohormones (Epin extra, Benzyladenine, Propikonazole: an antagonist of brassinosteroid phytohormones) and antitranspirants (Siliplant), but their influence on 1000 grain weight yield component characteristic is not unambiguous. In Table 2, we have shown the availability of different nutrients in food of plant origin treated during the growing season with the mentioned fertilizers. The availability of various nutrients (inorganic P, *β*-carotene, Mg, Ca, Fe, Zn and Mn) for human and domestic animal consumption depends on their relationship with phytic phosphorus, which can immobilize these nutrients and make them unavailable. Lower values of the ratio of phytic phosphorus to the mentioned nutrients indicate their greater availability, so in that sense we can conclude that fertilizers based on phytohormones (Epin extra, Benzyladenine) and plant and other extracts (Zircon) Chitosan have a favorable effect on availability inorganic P, *β*-carotene and Mg, but their influence on availability Ca, Fe, Zn and Mn is not unambiguous.

In Tables 3 and 4 we presented influence of different concentrations of a fertilizer based on brassinosteroid phytohormones (24-EBL) on seedling and whole mature plants of a corn hybrid.

Table 1 Grain yield and 1,000 grains weight of barley (cv. Apolon) influenced by the different foliar fertilizers (Dragičević et al., 2016).

Treatment	Grain yield (kg ha^{-1})			1000 grain weight(g)		
	2013	2014	Average	2013	2014	Average
Control	*3231.7*	*922.3*	*2077.0*	*37.80*	*29.09*	*33.44*
Epin extra	*3113.0*	*1043.1*	*2078.0*	*39.30*	*36.64*	*37.97*
Zircon	*3752.0*	*623.7*	*2187.9*	*38.69*	*32.84*	*35.77*
Chitosan	*3856.3*	*1098.8*	*2477.6*	*39.14*	*31.55*	*35.34*
Benzyladenine	*3244.3*	*1107.5*	*2175.9*	*40.01*	*30.49*	*35.25*
Siliplant	*3194.3*	*933.3*	*2063.8*	*39.40*	*32.63*	*36.01*

Propikonazole	3328.7	653.1	1990.9	40.67	33.78	37.23
Average	3388.6	911.7		39.29	32.43	
LSD 0.05*	Treatment	Year	T X Y	Treatment	Year	T X Y
	1462.0	532.5	569.4	4.03	1.95	1.05

**Least significant difference, P = 0.05 (n = 4)*

Table 2 The effect of different foliar fertilizers on relations between phytic and inorganic P, phytate, β-carotene, Mg, Ca, Fe, Zn and Mn in barley (cv. Apolon) grain (Dragičević et al., 2016).

Treatment	Pphy/Pi	Phy/β-carot.	Phy/Mg	Phy/Ca	Phy/Fe	Phy/Zn	Phy/Mn
Control	5.10	5356.60	2.15	2.86	107.34	40.22	74.1
Epin extra	4.58	5242.48	2.11	2.68	100.90	27.52	60.0
Zircon	4.62	5411.22	2.14	3.11	103.15	37.21	71.0
Chitosan	4.60	5088.97	2.14	4.21	72.38	34.10	70.1
Benzyladenine	4.60	5349.25	2.03	2.36	62.91	31.81	69.1
Siliplant	4.47	5610.72	2.05	2.96	51.13	28.70	76.1
Propikonazole	4.74	5828.46	2.16	2.96	55.46	35.80	80.3
LSD 0.05*	0.8	2397.6	0.11	0.58	262.7	15.66	104.3

**Least significant difference, P = 0.05 (n = 4)*

From Table 3 we concluded that 24-EBL is affecting redistribution of elements in different parts maize seedlings, which entails some consequences for the phytoremediation of polluted soils.

Table 3 Effect of different concentrations of 24-EBL on content of micronutrient and heavy metals (mg/kg) in different seedling parts of ZP 434 hybrid. Results are expressed in percentage (%) Sum of shoot, root and RoS is 100% for every trial combination. (Waisi et al., 2017).

Concentrations of 24-epibrassinolide												
	Control shoot	Control root	Control RoS	10^{-9} shoot	10^{-9} root	10^{-9} RoS	10^{-12} shoot	10^{-12} root	10^{-12} RoS	10^{-15} shoot	10^{-15} root	10^{-15} RoS
Mn	38	19	43	34	18	48	34	19	48	33	16	51
Na	38	46	17	45	30	25	25	61	14	33	43	24
Zn	50	34	16	44	24	32	39	31	30	38	32	30
Cu	56	33	12	41	27	32	38	32	30	37	34	29
Cr	50	32	17	38	26	35	45	22	34	32	43	25
Pb	55	32	13	46	32	23	33	34	33	12	34	54
Ni	34	35	31	34	30	36	37	31	32	37	30	33
Mo	32	33	35	34	25	41	34	32	34	35	30	34

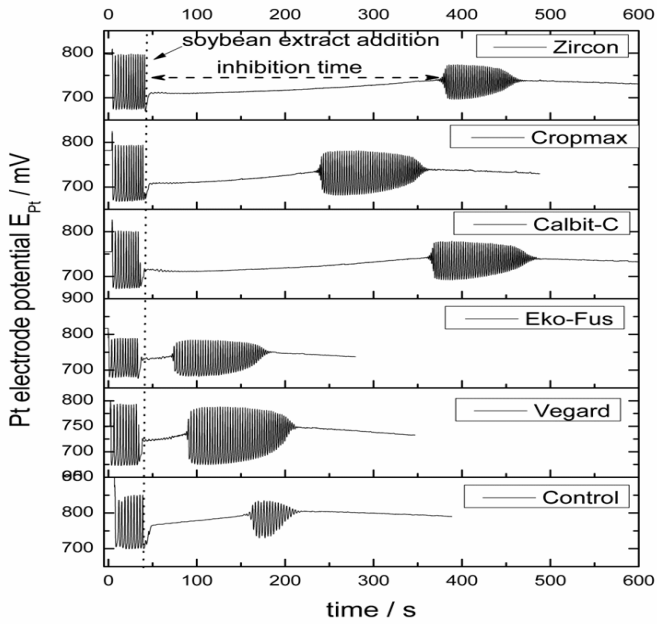
Ca	44	27	29	34	24	41	34	32	34	32	29	39
Mg	27	12	60	28	12	60	23	13	63	27	12	61

Table 4 Average (of 2 or 4 measurements) values of relative content (% against control) of different chemical and biochemical parameters in crude extract of ZP434 maize grain. Absolute values of control of different parameters: 1. starch: 74.60%; 2. total phenols: 260.05 μg/g; 3. moisture: 9.95%; 4. total proteins: 7.16%; 5. total oil: 3.45%; 6. Pphy: 3.22 mg/g; 7. Pi: 0.36 mg/g; 8. GSH: 1053.63 nmol/g; 9. K: 3185.12 mg/g; 10. Ca: 36.38 mg/g; 11. Mg: 384.64 mg/g; 12. Fe: 5.08 μg/g; 13. Zn: 6.10 μg/g; 14: Si: 23.88 μg/g. Max values in a series of measurements is signed by bold, but minimal values in that same measurements series signed by italic. 24-EBL: 24-epibrassinolide; PZR: propiconazole. (Waisi et al., 2015).

Relative content of different compounds (% against control)	Treatments during trial							
	Control	5.2 X 10^{-7} of 24-EBL	5.2 X 10^{-9} of 24-EBL	5.2 X 10^{-11} of 24-EBL	5.2 X 10^{-13} of 24-EBL	5.2 X 10^{-15} of 24-EBL	10^{-6} PZR	10^{-7} PZR
starch	**100**	98.19	99.60	98.86	95.51	98.39	*95.17*	98.86
Total phenols	100	99.73	94.51	**148.63**	95.88	114.01	*92.03*	96.98
Moisture	100	**111.06**	*96.48*	104.52	108.04	108.04	110.05	105.02
Total proteins	*100*	108.72	101.19	105.58	**118.42**	102.51	115.42	107.47
Total oil	100	101.45	95.65	97.10	**105.80**	102.90	98.55	*94.20*
Pphy	100	100.73	95.62	*95.25*	99.03	102.31	103.16	**108.03**
Pi	100	**111.59**	100.29	96.01	107.98	98.10	97.44	*77.01*
GSH	100	122.21	*87.11*	110.69	**130.92**	107.73	104.02	117.43
K	100	99.33	95.76	98.25	96.19	**100.67**	97.99	*93.82*
Ca	100	79.90	122.53	145.37	478.45	89.92	*68.50*	**2755.82**
Mg	100	95.62	*78.81*	100.80	93.66	96.95	108.98	**112.02**
Fe	*100*	103.57	111.33	156.34	208.87	322.84	319.21	**384.17**
Zn	100	73.04	*49.26*	55.97	49.31	91.75	62.74	**118.40**
Si	100	118.65	88.89	80.20	88.01	99.16	*77.66*	**127.72**

Table 4 we see that low concentration (influence of 5.2X10^{-13} mol of 24-EBL and 10^{-7} mol of PZR antagonist of 24-EBL) of phytohormone based fertilizers has significant impact on the content of various nutrients (total proteins and oils, GSH, Ca, Mg, Fe, Zn, Si) in corn grains.

Figure 1 The Briggs-Rauscher oscillograms (as a measure of whole antioxidative capacity) obtained with particular soybean extract addition (100 μl) after 30 s from oscillatory reaction beginning. The initial concentrations of reactants for BR reaction were $[CH_2(COOH)_2]_0$ = 0.0789 mol/dm³, $[MnSO_4]_0$ = 0.00752 mol/dm³, $[HClO_4]_0$ = 0.0300 mol/dm³, $[KIO_3]_0$ = 0.0752 mol/dm³ and $[H_2O_2]_0$ = 1.2690 mol/dm³. (from: Đurović et al., 2019).



From Figure 1 we se that different aminoacid and plant and other extract non-standard fertilizers induced different antioxydative capacites in extract of soybean grain meal.

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ANALYSIS OF THE GREEN GROWTH INDEX OF SERBIA AND ENVIRONMENTAL COUNTRIES

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Abstract

The Green Growth Index (GGGI) is an index that measures the effect of countries in achieving sustainability goals. This index includes the Sustainable Development Goals (SDG), the Paris Climate Agreement, and the Aichi Biodiversity Goals (Strategic Plan of the Convention on Biological Diversity) for four dimensions of green growth - efficient and sustainable use of resources, protection of natural capital, green economic opportunities and social inclusion. The index takes into account the existing green industry of each region base, innovation activity, relevant skills, training, infrastructure as well as the use of renewable energy, to determine the assessment "Opportunity for Green Growth." Today, it is used as the first index of the green economy by many international organizations, civil society, the private sector, and policymakers. This index is used by many countries that aim to achieve sustainable development goals by reducing emissions. This paper aims to analyze Serbia and the surrounding countries' Green Growth Index to see the possibilities for improving the position of Serbia and its "green growth."

Keywords: Green Growth Index (GGGI), sustainability, green economy, green growth

INTRODUCTION

The sustainable development concept considers a turning point in the global approach to environmental protection and development because the impacts on the environment are significant and greater awareness of environmental protec-

tion leads to notable and turbulent changes (Ilić et al., 2022). Sustainable development can be defined as "development that meets the needs of the present without jeopardizing the ability of future generations to meet their own needs."[2] "Achieving national and equitable economic development is the greatest challenge facing the human race."[3] The sustainable development concept is based on the aspiration to achieve a "healthy" growth rate (Milenović, 2000). This implies a harmonious relationship between economic development, natural resources use, and healthy environment preservation (Vujičić and Nikolić, 2021, Milošević et al., 2022). When defining sustainable development, the problem of conflict between the environment and development goals arises. This problem also can be seen from the definition "Sustainable development is the development that meets the current needs of society without jeopardizing the ability of future generations to meet their needs." It represents a framework for societies that strive to protect and preserve natural resources, ensure the economic valuation of the ecosystem of services and goods, reduce poverty, and move the world towards development with reduced carbon dioxide emissions. Green economy development in modern society is one of the key instruments for achieving sustainable development. The increasing pressure on the environment requires taking the necessary preventive measures and finding ways to balance the economic growth paths with potential problems, such as environmental pollution and depletion of natural resources. Governments of countries can have three primary roles in mobilizing investments in green growth: (Amin et al., 2014)

- Creating a favorable environment for long-term green investments;
- Effective use of public budgets and investments, including dedicated funds and/or financial intermediaries to encourage green growth;
- Adapted application of financial risk reduction instruments to mobilize private green investments

The role of Public Policy and Finance in Unlocking Private Investment in Green Growth is illustrated in Figure 1 based on

[2] World Commission on Envirnomental and Sustainability, 1987
[3] World Bank, World Development Report, 1992.

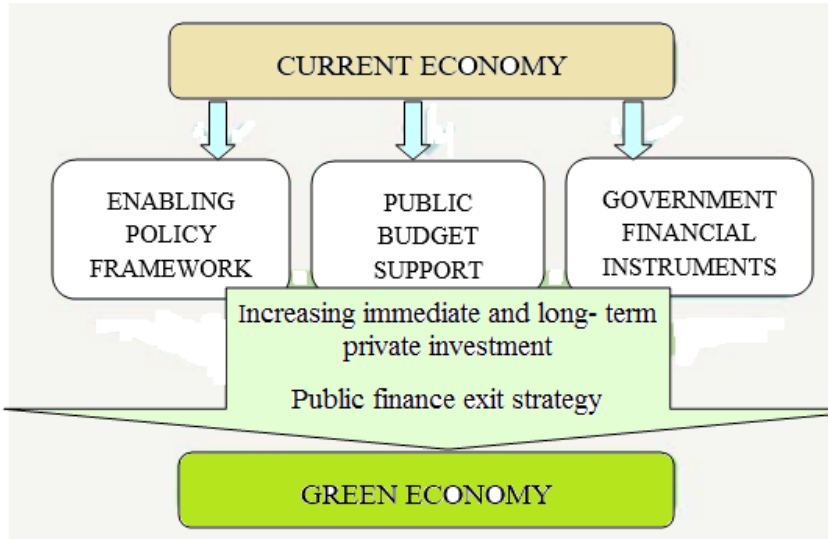

Figure 1: Role of Public Policy and Finance in Unlocking Private Investment in Green Growth

MATERIALS AND METHODS

Green growth and green growth index

A green economy is a concept that found itself the focus of interest in the second half of the 20th century, both at the national and international levels. The green economy is the result of an effort to make the economy more environmentally responsible and, at the same time, more advanced, creating a balanced and positive impact on society and the environment. There is no single and generally accepted definition of the green growth economy concept, but it is the result of efforts to make the economy more environmentally responsible and, at the same time, create a balanced and positive impact on the economy, society, and the environment.

Different countries have adopted alternative approaches that emphasize weak, moderate, or strong versions of green growth (Huberty et al. 2011), as in Figure 2:

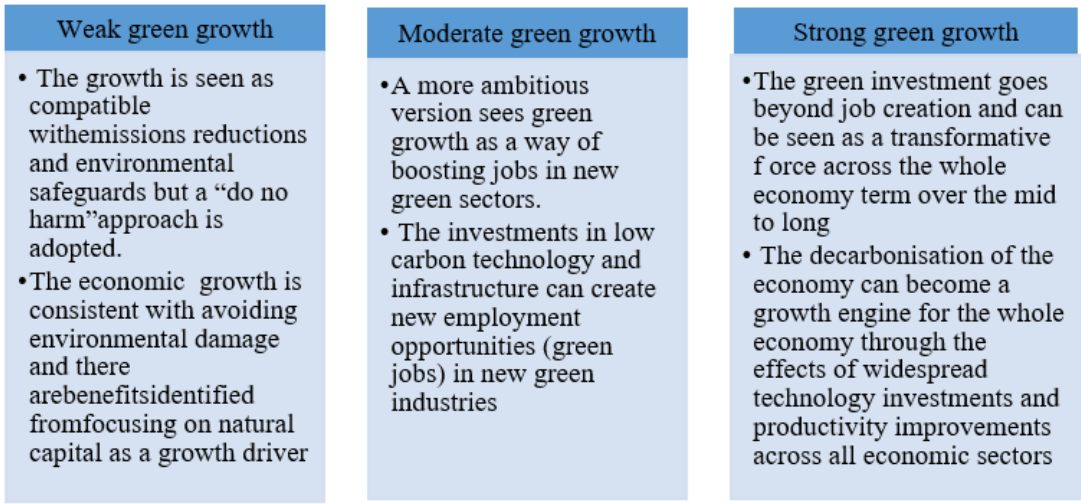

Figure 2: An overview of different approaches to green growth

The four dimensions of green growth are shown in Figure 3.

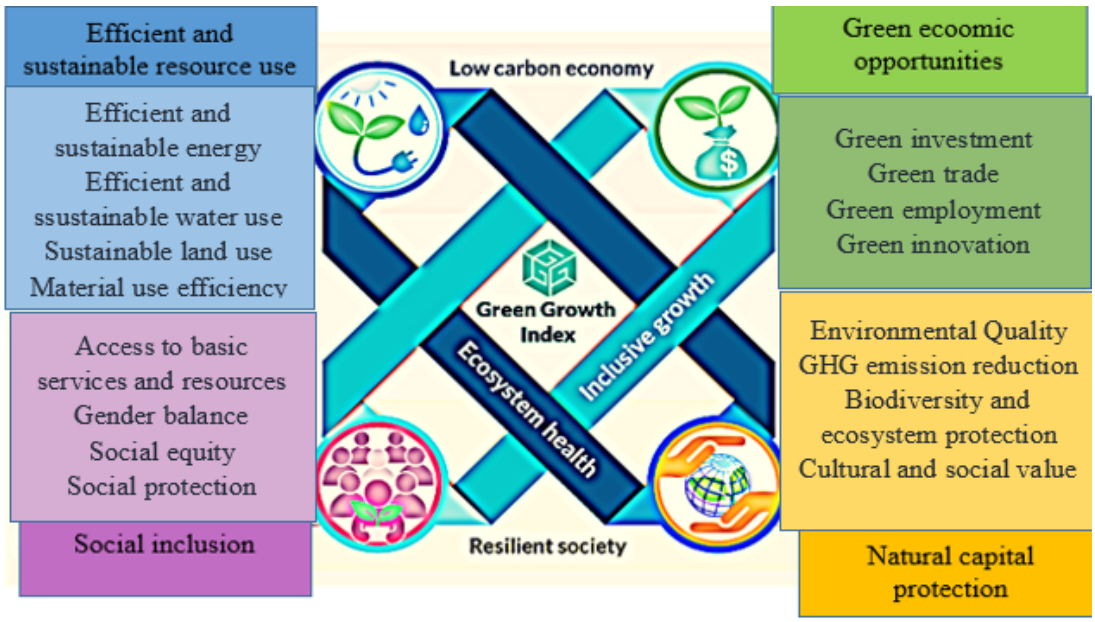

Figure 3: The four dimensions of green growth

The Green Growth Index is a composite index that measures a country's performance in achieving sustainability goals, including the Sustainable Development Goals (SDGs).

RESULTS

The indicators considered within the four dimensions are given in Table 1:

Table 1. Indicator Framework for the Green Growth Index

Main dimension	**Indicator**	**Denotation**
Efficient and sustainable resource use (ESRU)	Efficient and sustainable energy Efficient and ssustainable water use Sustainable land use Material use efficiency	EE EW SL ME
Green economic opportunites (GEO)	Green investment Green trade Green employment Green innovation	GV GT GJ GN
Social inclusion (SI)	Access to basic services and resources Gender balance Social equity Social protection	AB GB SE SP
Natural capital protection (NCP)	Environmental Quality GHG emission reduction Biodiversity and ecosystem protection Cultural and social value	EQ GE BE CV

Since Serbia is still a developing country moving towards the more developed countries of Europe, the environment has been neglected for several decades (Vujičić et al. 202). Serbia is an upper-middle-income Europe country with a Green Growth index of 63.13, as in Figure 4 left. Data availability is given in Figure 4 on the right.

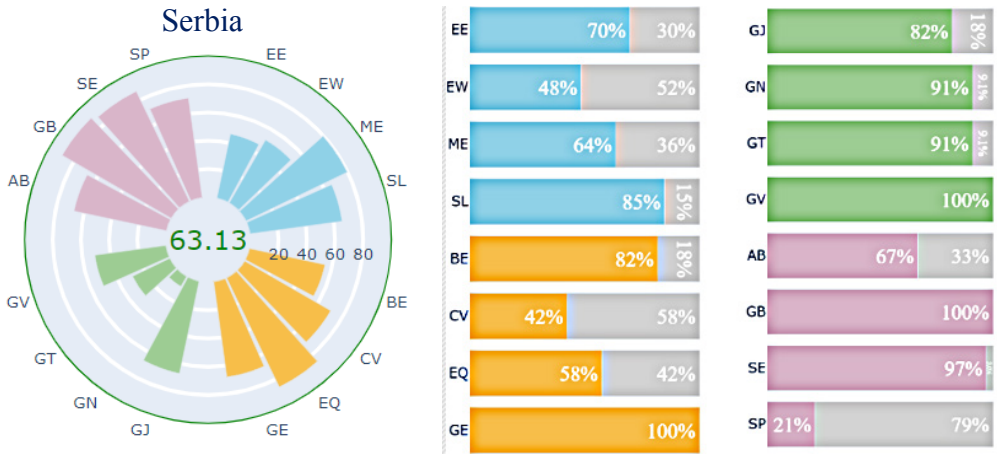

Figure 4. Green Growth index of Serbia in 2020 and Data availability

For the period 2010-2020, about 71.6% of all possible values are available. In 2020, there are 119 countries with scores on the Green Growth Index, There are 41 countries that reached a high score between 60 and 80, and many of them are in Europe. Sweden has the highest Green Growth Index with a score of 78.87, which is still away from reaching the sustainability target of 100. In 2020, with an index of 63.13, Serbia took 28th place. The ranking for Bosnia and Herzegovina has not been determined for 2020, nor has North Macedonia. Croatia had a better Green Growth Index than Serbia and took 16th place.

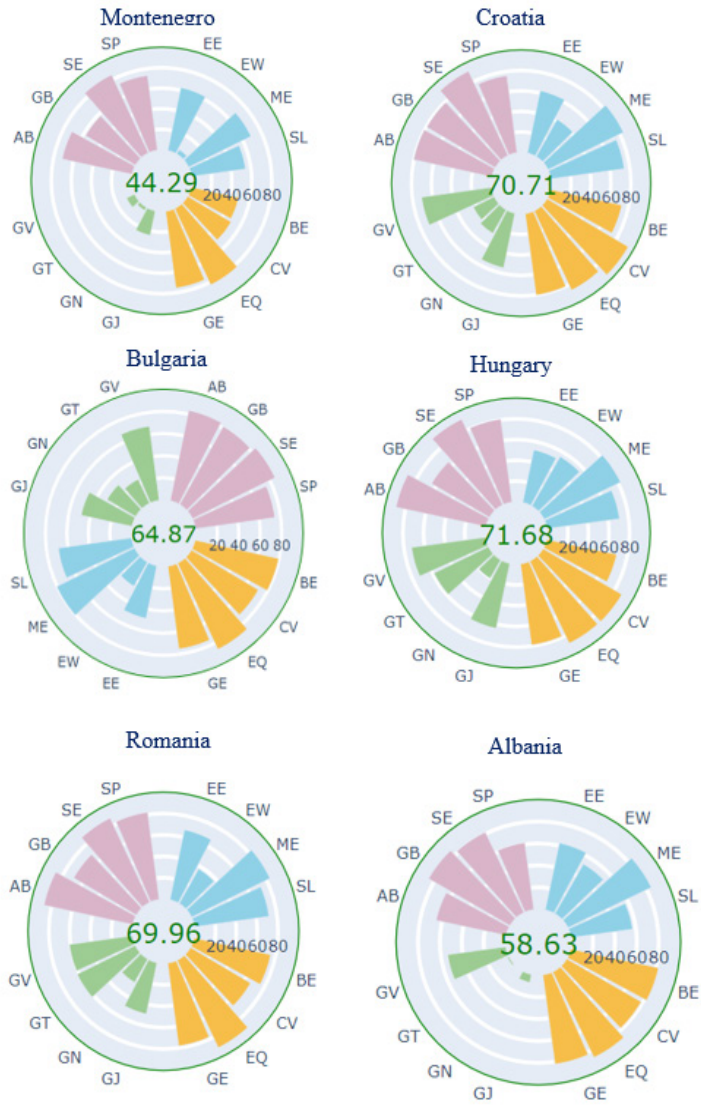

Figure 5. Green Growth index of environmental countries (based on GGI Report)

Table 1. The dimensions of green growth and the green growth index of Serbia's neighboring countries

	Dimension - 2019.				**2018**		**2019**	
Country	*ESRU*	*NCP*	*GEO*	*SI*	*Index*	*Rank (43 countries)*	*Index*	*Rank (41 countries*
Serbia	57.31	69.51	40.91	76.7	52	30	59.46	28
Croatia	72.71	84.04	45.91	75.48	64.49	15	67.84	21
Bosnia and Herzegovina	58.70	61.76	9.54	69.05	35	37	39.31	37
North Macedonia	59.70	74.72	-	72.71	-	-	-	-
Montenegro	66.06	60.91	12.75	71.65	40	35	43.78	36
Albania	65.05	82.62	9.44	80.69			44.98	35

	Dimension -2020.				**2020**	
Country	ESRU	NCP	GEO	SI	Index	Rank
Serbia	59.63	69.03	30.3	78.07	63.13	28
Croatia	63.54	83.03	39.4	81.43	70.71	16
Bosnia and Herzegovina	-	-	-	-	-	-
North Macedonia	60.36	74.78	-	73.82	-	--
Montenegro	33.05	62.44	9.22	71.06	44.29	35
Albania	63.02	82.4	8.86	72.86	58.63	30

CONCLUSION

The paper presents the numerical parameters of the green index of Serbia and its surroundings. The green growth index is based on four dimensions: For each of the four dimensions listed, calculations and numerical expressions can be monitored because each dimension is based on selected indicators. It is possible, in this way, to facilitate the monitoring of countries not only in terms of achieving green growth but also in sustainable development. With the observed countries, in 2020., Serbia has 28th place out of 43 observed countries.

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SUSTAINABLE GROWTH BASED ON THE DEVELOPMENT OF DYNAMIC ENTREPRENEURSHIP

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Abstract

Dynamic entrepreneurship is an effective instrument that increases the sustainability of growth, competitiveness and resistance of economies to recessionary impacts and external shocks. Dynamic companies are fast-growing companies with growth potential, they are the generator of sustainable development of any economy.

The focus of the research in the paper is aimed at looking at the overall and regional effects of dynamic entrepreneurship in Serbia in the period of economic growth 2015-2020. The results of the research directed the economic messages in the work in several directions: the need to review the existing institutions, policies and incentive mechanisms in order to solve the key problems of the development of companies in the phase of growth and development; direct the regulatory reform, not only to the removal of obstacles to the establishment of new companies, but also to the creation of favorable conditions for the growth of dynamic companies; as well as the need to redesign the SME financing model. In the coming period, economic transformation towards a dynamic entrepreneurial economy and dynamic company structures, with an emphasis on innovation and smart specialization, will be key.

Key words: dynamic entrepreneurship, gazelles, sustainable growth.

INTRODUCTION

Entrepreneurship develops most dynamically in those market economies that were the first to recognize its development potential with all the positive effects on the overall development of the country. The systemic-institutional framework of the entrepreneurial infrastructure is focused, in addition to open-

ing as many start-up companies as possible, on the creation and implementation of specialized incentive measures for the further development of fast-growing companies with growth potential.

The paper presents the basic results of research into dynamic entrepreneurship in Serbia 2015-2020. Serbian companies have been identified that in the last five years, despite the global recession of 2020, recorded above-average growth and thus contributed to the economic growth of the entire economy, the creation of new jobs and the generation of new value.

The research of dynamic entrepreneurship in Serbia aims to test the hypothesis, on the example of the Serbian economy, that less than 5% of companies in an economy, in the course of five years, can at least double their growth, income and create new jobs (modified setting of Birch, 1987). Also, the research indicates the degree of development of the entrepreneurial sector in Serbia, as well as the basic sectoral and regional performances of dynamic entrepreneurship in Serbia.

THE DEVELOPMENT OF SMEs SECTOR IN SERBIA

During the two-decade transition of the Serbian economy, the sector of small and medium-sized enterprises (SMEs) grew into a dominant sector of the economy. The entrepreneurial sector contributes 1/3 to Serbia's GDP, but the participation of the SMEs sector in the economy is greater than the participation of large enterprises: in 2020, the SMEs sector with 105 thousand enterprises (without entrepreneurial shops) and about 700 thousand employees, created 53% of newly created value, 62% of income and 2/3 of the economy's profit. However, its participation in the total losses of the economy in 2020 was 70%, and in liabilities 68%, which indicates that its business is more illiquid than the sector of large enterprises.

Table 1 The impact of the 2020 recession on the structural performance of the Serbian economy

	No. enterprises	*No. employees*	*Income*	*Profit*	*Loss*	*Net result*	*GVA*	*Capital*	*Cumulative loss*	*Total Liabilities*
	Structure 2020									
SMEs	*99.4*	*57.0*	*61.7*	*66.4*	*70.2*	*64.0*	*52.7*	*50.4*	*71.5*	*68.0*
Micro	*85.4*	*13.8*	*15.6*	*17.9*	*40.1*	*3.6*	*10.6*	*15.9*	*51.2*	*35.3*
Small	*11.5*	*20.3*	*21.7*	*22.3*	*12.4*	*28.7*	*18.6*	*16.0*	*8.6*	*13.5*
Medium	*2.6*	*22.9*	*24.4*	*26.2*	*17.8*	*31.7*	*23.6*	*18.5*	*11.7*	*19.1*

Large enterprises	*0.6*	*43.0*	*38.3*	*33.6*	*29.8*	*36.0*	*47.3*	*49.6*	*28.5*	*32.0*
	Rate of growth/decline 2020/2019									
SMEs	*0.1*	*3.1*	*-1.4*	*10.3*	*-12.3*	*34.6*	*5.7*	*7.7*	*9.0*	*10.5*
Micro	*-0.6*	*1.3*	*-1.8*	*7.3*	*-15.7*	*-214.3*	*5.7*	*5.4*	*13.5*	*14.0*
Small	4.7	5.1	-3.3	6.7	-3.3	9.9	5.9	8.4	-8.9	-5.3
Medium	2.4	2.5	0.5	15.8	-9.7	28.9	5.5	9.1	6.0	17.6
Large enterprises	3.2	4.5	-0.9	7.3	27.7	-1.1	6.9	-0.7	2.5	6.1

Source: Author's calculation based on BRA (Business Registers Agency) data.

During the 2020 pandemic, the SMEs sector in Serbia, in general, managed to cope with the recession without major turbulence, however, in its structure, the recession hit the segment of micro-enterprises hard, where the negative business result doubled (Jakopin & Cokorilo, 2021, pp. 27-31; Paunovic & Anicic, 2021, p. 80). All three segments of the SME sector increased the number of employees, medium (30%) and small enterprises (10%) performed positively, but the segment of micro enterprises, due to large losses (-15.7%), recorded a negative financial result (-114%). GVA growth was even in all SME segments (close to 6%). In the structure of liabilities, they decreased only in small (-0.8%), while they increased in micro (14%) and medium enterprises (17.6%).

RESEARCH OF DYNAMIC ENTREPRENEURSHIP

Theoretical context

The beginning of systemic research into dynamic entrepreneurship is linked to Edith Penrose's well-known research on the theory of the growth of the firm (Penrose, 1959, p. 5), later called the resource-based view of the firm, which experienced a true renaissance at the beginning the last decade of the last century (Prahalad & Hamel, 1990). The core of the resource theory lies in the claim that a competitive advantage is acquired through resources that are valuable and scarce but that are hard to imitate and substitute.

The catalyst for the growth of dynamic entrepreneurship is resource management (Kor, et al., 2005). Resources are cognitive drivers of growth (Itamiand & Numagami, 1992). The factors of dynamic entrepreneurship are '*intimate and tacit knowledge about the company's resources, capabilities, organizational structure, standard operating procedures, historical conditions and personnel specificities*' (Williamson, 1996). The theory of resources is upgraded by the proposal of a dynamic theory of organizational knowledge creation, through

interactions between individuals (Sveiby, 2001). '*The dynamic properties of knowledge are the most important for managers*' (Sveiby, 2001, p. 344)

Basic researches into dynamic entrepreneurship show a high degree of correlation between growth factors and overall economic growth. A usual division of growth factors to of motivation, (2) abilities, and (3) opportunities (Stenholm & Toivonen, 2009), while others suggest that growth of a company is primarily influenced by the following factors: (1) company's exterior and interior setting, (2) the entrepreneur or the entrepreneurial team itself, (3) innovativeness and realization of changes, (4) growth and the strategic access, (5) the business model and the management system, (6) human resources, and (7) growth of financing (Roure, 1999, p. 10).

Over the past few decades some business researchers have devoted ever more time to the study of ecological factors that impact on the development of entrepreneurship and growth of companies and vice versa (the impact of a company's growth on living environment). Numerous European researches have proved the link between the success of European gazelles and economic development by studying a set of stimulating measures: financial, fiscal, legal and other incentives for starting a business, the attitude to entrepreneurship, tolerance of business failure, readiness to take a risk, an overall entrepreneurial climate, and favorable legislation for companies' growth.

Methodological framework

Coverage of dynamic companies in Serbia in the period 2015-2020. it was done based on the following criteria:

- Enterprises that operated in the research period (2015-2020);
- In the last year (2020), more than 2 employees were working in the enterprises;
- Revenue from sales (of products and services) per employee in the enterprise in the last year exceeded the average revenue from sales per employee in the economy (78,600 EUR);
- Positive GVA in the initial and final year;
- In the last year compared to the beginning, an increase in employment was registered;
- The enterprise is in the period 2015-2020. achieved two or more times higher sales revenue growth than the average of the economy in the same period;
- The enterprise had a profit in the initial and final year;
- Public non-financial enterprise are excluded;

- Sectors excluded: L-Real estate; O-Public administration and defense; S-Other services; T-Activities of households; U- Activities of extraterritorial organizations;
- Subsidiary enterprises (those that are part of the economic entity) are excluded.
- Criteria for Gazelles:
- Dynamic companies that have a Birch indicator >100;
- Birch's indicator is the product of the difference and the ratio of employees in the final and initial years (Birch, 1987).

RESULTS OF THE RESEARCH

Research on dynamic entrepreneurship in Serbia has shown that fast-growing companies with growth potential in Serbia in the period 2015-2020, in terms of all performance, are the healthiest tissue of the economy, the driver of overall and regional growth, in a word, these enterprises are the connection of the Serbian economy to developed economic markets .

By applying the previous, rather strict, criteria, on the basis of which similar researches of dynamic entrepreneurship are conducted in developed economies in the EU, in the period 2015-2020, in Serbia. 1,527 dynamic enterprises operated, of which 10% (153) were gazelles (the most dynamic companies). These enterprises withstood the recessionary shocks during 2020, they represented the strongest recessionary economic dam. The potential for growth of dynamic enterprises in Serbia is above average.

Basic performance of dynamic enterprises (DEs) in Serbia 2015-2020:

- DEs (1,527) almost doubled employment, created 21.6 thousand. of new jobs in the economy (3.3% of total employment in the economy, 1.8% in 2015), with a 5.2 times higher employment growth rate than the average in the economy (118.2% versus 22.7%);
- DEs tripled the sales revenue in the economy (from 3% to 8.8% in 2020), achieved a 12.2 times higher growth rate of sales revenue than the average growth rate of sales revenue in the economy;
- DEs increased their participation in the economy's profit by 2.5 times (from 4% to 10%);
- DEs generated a 5 times higher GVA growth rate than the average in the economy, which more than doubled the participation of DEs in the economy (from 3% to 6.6%).
-

Table 2 Dynamic enterprises and gazelles in Serbia 2015-2020 (growth rates)

	No. employees	*Sales revenue*	*Net profit*	*GVA*
Economy	*22.7*	*20.7*	*38.4*	*43.7*
DE (1,527)	*118.2*	*254.9*	*238.6*	*214.0*
Gazelles (153)	*159.3*	*252.6*	*181.2*	*187.6*

Source: Author's calculation based on BRA data.

Gazelle's basic business performance (153):

- 153 gazelles increased employment by 2.6 times (from 7,896 in 2015 to 20,477), i.e. by 12.6 thousand new employees;
- Revenue from sales of gazelles increased by 3.9 times;
- Gazelle's net profit increased by 3.1 times;
- Gazelle's GVA increased by 3.2 times.

The sectoral structure of DEs shows a concentration in three sectors: *Wholesale and retail trade* (30% in employment, 26% in profit and GVA), *Manufacturing industry* (29%, 36% and 32%) and *Construction* (25%, 23% and 24%). The sectoral structure of the gazelle shows an even greater concentration in the above-mentioned three sectors in all indicators: in the total number of DEs they participate with 3/4, in employment and income from sales and profits with 85%, and in GVA with 82%.

Table 3 DEs sector structure (%)

Sectors		No. enterprises 2020		No. employees		Sales revenue		Net profit		GVA	
		Structure	%	2015	2020	2015	2020	2015	2020	2015	2020
C	*Manufacturing industry*	247	16.2	34.4	28.8	33.7	27.6	50.0	35.5	44.7	32.4
F	*Construction*	216	14.1	24.0	24.6	17.3	20.6	15.7	22.9	18.6	23.9
G	*Trade*	687	45.0	25.7	29.7	35.6	36.5	19.2	25.7	21.9	25.5
	Others	377	24.7	15.9	16.9	13.4	15.3	15.1	15.9	14.8	18.2
	Total DEs	1,527	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Source: Author's calculation based on BRA data.

The regional distribution of DEs shows a huge concentration in the Belgrade district (51% of all DEs, 51% of employees, 53% of sales revenue, 49% of profit and 51% of GDP), followed by South Backa district (with 10-11% in all indicators) and the Pirot district (with 13-15% in all indicators):

- Contribution of DEs to the growth of their regional districts in 2015-2020. is very different, but what they have in common is the growing influence of DEs in their regional districts;

- The exceptional growth of DEs is in Sremska district (10% of the GVA of the district`s economy), South Backa (from 1.6% in 2015 to 6% of the GVA of the district`s in 2020), Kolubarska (from 3% to 8%), Raska (from 2 % to 7%), Macvanska (from 4% to 8%), etc.

DEs increased their contribution to economic growth in all dimensions of the survey. The increase in influence of 1,527 fast-growing companies and 153 gazelles 2015-2020, despite recessionary shocks in 2020, increased 2-2.5 times in all relevant economic indicators:

- Growth in the share of DEs employment from 1.8% to 3.3% of total employment in the economy in 2020, and gazelle from 0.8% to 1.7%;
- Increase in share of sales revenue in DEs from 3% to 8.8%, in gazelles from 1.3% to 3.8%;
- Profit growth in DEs 4.1% to 10%, in gazelles from 2.4% to 4.8%;
- Growth of VAT in DE from 3% to 6.6%, in ghazals from 1.6% to 3.2%.

Table 4 Growth in the participation of DE and gazelles in the economy 2015-2020. (%)

	No. employees		Sales revenue		Net profit		GVA	
	2015	2020	2015	2020	2015	2020	2015	2020
DEs (1,527)	1.8	3.3	3.0	8.8	4.1	10.0	3.0	6.6
Gazelles (153)	0.8	1.7	1.3	3.8	2.4	4.8	1.6	3.2

Source: Author's calculation based on BRA data.

CONCLUSION

Fast-growing companies with growth potential in any economy represent one of the key drivers of growth, whether the economy is in a phase of expansion or a phase of recession (Jakopin, et all., 2021, p. 168). Their potential is different from country to country, their maximum number ranges from 3-5% of all companies, they show above-average growth in income and employment, they are carriers of smart specialization, innovation and sustainable development. The research on dynamic entrepreneurship in Serbia confirmed the initial hypothesis, i.e. it identified 1.4% of fast-growing companies with the potential for further growth, which managed to make their contribution, for the last five years, to overall economic growth, new employment and creation of new value, more than doubled. Those companies should be in the permanent focus of the creators of economic policy, because they represent a support for their own strengths, a flywheel of economic growth, they change the overall and regional economic structure and contribute to strengthening competitiveness.

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CREATING SUSTAINABLE SUPPLY CHAINS FROM SOCIAL PERSPECTIVE

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Abstract

The aim of this paper is to explore the possibilities of creating and modeling sustainable supply chains from a social perspective. The purpose of this paper is to promote social sustainability. The research results are based on the mathematical method of dynamic programming. The main finding of this paper is that social sustainable supply chains in the long-term produce interest for all supply chain participants, their stakeholders and society at large.

Key words: sustainability, supply chains, social sustainability, dynamic programming

INTRODUCTION

Despite significant progress and numerous examples of good practice, the concept of sustainable development, which includes improving economic and social well-being while protecting the environment, may not have achieved the desired global sustainability. Global supply chains can be helpful in promoting and realizing this great idea in practice. In the trefoil of economic, environmental and social sustainability, social sustainability has gained less attention from researchers and managers. Business world has focused, mainly on economic sustainability. Numerous scandals (sexual harassment, retaliation by supervisors, hazardous labor conditions, child labor, environmental destruction) have been revealed in which global corporations such as Apple, Dell, HP, Adidas, Nike, Nestle, and others have been implicated (Vilena & Gioia, 2020**)**. Such a practice can seriously jeopardize a company's operations. Accordingly, the main hypothesis of this work is: The incorporation of social sustainability into supply chains is a critical step toward achieving sustainable development. The methods of analysis and synthesis, comparative method, and the dynamic programming method were used to prove the hypothesis.

LITERATURE REVIEW

Supply chains

A supply chain consist of all stages involved, directly or indirectly, in fulfilling a customer request. A typical supply chain consists of: customers, retailers, wholesalers/distributors, manufactures and component/raw material suppliers. Success in the supply chain is measured in terms of supply chain profitability. The higher the supply chain profitability, the more successful the supply chain (Chopra & Meindl, 2001). For many companies, sustainability is gaining a new dimension. Sustainability has become increasingly important not just from economic but also from ecological and social perspective. While traditional supply chain management focuses on operational speed, cost, and reliability, sustainable supply chain management incorporates the goals of environmental and societal values. This includes dealing with global issues like climate change, water security, deforestation, human rights, fair labor practices, and corruption.

Sustanibility

Sustainability refers to the long-term maintence of systems according to environmental, economic and social perspecitve (Crane & Matten, 2010., 34). The incorporation of sustainability into supply chains is a critical step toward achieving sustainable development, as supply chains consider the product from the time raw materials are first processed until it is delivered to the end user.

Economic Sustainability

Economic sustainability, sometimes known as the "profit" pillar, is correlated with economic development, growth, productivity, profitability, and the stability of prices and markets (Elkington, 1994; Kuhlman and Farrington, 2010). This pillar in business relates to a company's short- and long-term profitability, which may be assessed using metrics like revenues and market capitalization (Zarra, et al, 2019). Economic sustainability refers to a company's ability to compete fairly in a given industry. It includes respect for copyright, prevention of counterfeit goods (OECD-EUIPO, 2016), and avoidance of anti-competitive practices (Yang and Ji, 2016).

Environmental Sustainability

Environmental sustainability, the most researched pillar of sustainability, focuses on how we use raw materials to meet human needs and the environmental damage that this causes. Environmental sustainability is the „planet" pilar

(Elkington, 1994; Kuhlman and Farrington, 2010). Environmental sustainability promotes recycling, resource reuse, and environmental damage mitigation.

Social Sustainability

Social sustainability has a critical importance for human life. Social sustainability lacks a broadly accepted definition (Cope, Keman, Sanders & Ward, 2022). Social responsibility can be defined as ability of local community to create a life from itself for itself. It is a „people" pilar. Sociial sustainability is a complex concept that include topics such as (Şebnem Yılmaz Balaman): health and social equity, human rights, labor rights, practices and decent working conditions, social responsibility and justice, community development and well-being, product responsibility, community resilience, and cultural competence.

Social Sustainability and Supply Chains

Social sustainability has been defined from a CSR perspective in the supply chain literature (Carter and Jennings, 2002, 2004; Ciliberti et al., 2008; Carter andEaston, 2011; Lu et al., 2012). Suppliers, manufacturers, customers, and society are all affected by social sustainability issues (Freeman, 1984; 2004). Upstream social sustainability can be achieved by addressing social challenges in supplier sites (Krause, 1999; Krauseet al., 2000, 2007; Bai and Sarkis, 2010; Mani et al., 2014). In the downstream, socially conscious purchasing can aid in achieving sustainability and efficiency, such as the adoption of fair trade norms and effective governmental frameworks. Lower-tier suppliers nearly always have worse business practices, which exposes businesses to more substantial financial, social, and environmental hazards.

MATHERIAL AND METHODS

Let's say (Pupavac, Krpan, Maršanić, 2021) that for a product to be manufactured and delivered on the demand location within the supply chain, certain production and logistic activities need to be done and which can be classified in five phases (I-V): x_1 (procurement of raw materials), x_2 (production), x_3 (warehousing and land transport), $x_{4,}$ (maritime transport), x_5 (distribution), and for which within the global logistic system it is possible to engage 27 different participants: f_1, f_2, f_3...,f_{23}. (cf. Table 1).

Table 1.Production phases within the supply chain and potential supply chain participants

Phases of logistic process	Potential supply chain participants	Costs of each phase within the supply chain (in 000 €)		
1	2	3		
		Economic	Social	Total
I. Delivery of raw materials Incoterms EXW - Ex Works	f_1– Russia	11	H=11	22
	f_2 – Finland	12	N=**0**	**12**
	f_3 – Egypt	14	M=7	21
	f_4 – Bulgaria	14	L=3,5	17.5
	f_5 – Moldavia	**10**	M=5	15
	f_6 - Belarus	11	H=11	22
II. Production	f_7 – Czech	32	L=8	40
	f_8 – Romania	22	M=11	33
	f_9 – Poland	26	L=**6,5**	32.5
	f_{10} – Slovakia	24	M=12	36
	f_{11} – Serbia	**20**	M=10	**30**
III. Warehousing and land carriage (railway operator, road transport operator)	f_{12} – national railway operator	**8**	L=**2**	**10**
	f_{13} – ABC Logistics	9	L=2,25	11.25
IV. Sea shipping (ship operators)	f_{14} - Global Alliance	**7**	L=1.75	8.75
	f_{15} - Grand Alliance	8	N=**0**	**8**
	f_{16} - Maersk-Sealand	10	M=5	15
V. Distribution (distributors in North America)	f_{17} – East Coast	12	L=3	15
	f_{18} – West Coast	**11**	M=5.5	16.5
	f_{19} – Canada	14	N=**0**	**14**
I., II.	f_{20} – Austria	30	L=7.5	37.5
II., III.	f_{21} – Switzerland	36	N=0	36
I., II., III.	F_{22}– GB	42	L=10.5	52.5
II., III., IV.	F_{23} – Croatia	40	L=10	50
III., IV., V.	f_{24} – Germany	28	N=0	28
III., IV.	f_{25} – Italy	22	M=11	33
IV., V	f_{26} – USA	20	N=**0**	**20**
	f_{27} – USA	**18**	L=4.5	22.5

The assumption is that the supply chain produces and delivers 100 tons of goods per month. Economic and social costs are arbitrarily estimated. Economic costs are the cost price of each stage within the supply chain. Social costs are estimated as a percentage of economic costs depending on whether there is a high risk (H-100 %), medium risk (M-50 %), low risk (L-25 %), and no risk (N-0) of unacceptable business behaviour within any supply chain participant.

RESULTS AND DISCUSSION

Based on the data from table 1, it is evident that in order to design an optimal network from an economic, social or total cost aspect, it is not necessary to consider all potential participants, but only some of them. Once non-competitive potential supply chain participants have been eliminated, it is possible to approach the design of the appropriate supply chain network and solve the problem posed.

The following shows the supply chain network from a social aspect (cf. figure 1).

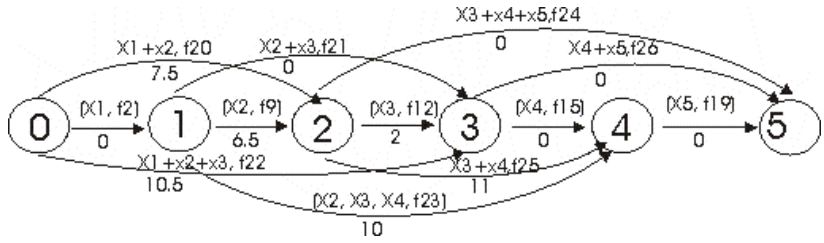

Figure 1. Logistic network of potential qualified global supply chain participants from social aspect

Above every branch of the logistic network (cf. *Figure 1*) a logistic chain phase is entered as well as potential participants for carrying out a certain activity within the global logistic chain and under the branches of the logistic network costs for carrying out a certain phase within the logistic chain are entered.

In the following, the problem of the shortest path in the network is solved from a social aspect by applying the dynamic programming method. Other problems (from economic and total costs aspects) were solved according to the same principle, and the description of their solution is omitted. By applying the recursive expression the following is obtained
f(0) = 0 i f(1) = 0, and then

$$f(2) = \min \begin{Bmatrix} f(0) + c(x1 + x2, f20 = 0 + 7.5 \\ f(1) + c(x2, f9 = 0 + 6.5 \end{Bmatrix} = 6.5$$

$$f(3) = \min \begin{Bmatrix} f(0) + c(x1 + x2 + x3, f22 = 0 + 10.5 \\ f(1) + c(x2 + x3, f21 = 0 + 0 \\ f(2) + c(x3, f12) = 6.5 + 0 \end{Bmatrix} = 0$$

$$f(4) = \min \begin{Bmatrix} f(0) + \infty = 0 + \infty = \infty \\ f(1) + c(x2 + x3 + x4, f23) = 0 + 10 \\ f(2) + c(x3 + x4, f25) = 6.5 + 11 \\ f(3) + c(x4, f15) = 0 + 0 = 0 \end{Bmatrix} = 0$$

and finally

$$f(5) = \min \begin{Bmatrix} f(0) + \infty = 0 + \infty = \infty \\ f(1) + \infty = 10 + \infty = \infty \\ f(2) + c(x3 + x4 + x5, f24 = 6.5 + 0 \\ f(3) + c(x4 + x5, f26) = 0 + 0 \\ f(4) + c(x5, f19) = 0 + 0 \end{Bmatrix} = 0$$

which means that the length of the shortest way p*, i.e. the minimum value of the function of the target z* = d(p*) = 0, and in this example we have two optimum ways p* = (0,1,3,4,5) and (0,1,3,5). If the managers choose the first solution they will have a cost of supply chain from 70 000 €. In the second case they will have a cost from 68,000 € which is the best solution if we optimize the supply chain only from a social aspect. The optimal supply chain formed from an economic aspect will have a cost in the amount of 56,000€. We can conclude that a supply chain which is optimized from a social aspect has a higher cost for 21,42 % than a supply chain which is optimized from an economic aspect. An overview of other optimal solutions from different aspects is given in table 2.

Table 2. Overview of optimal solutions

Optimization by aspects	Optimal way on network	Supply chain participants	Economic costs (000 €)	Social costs (000 €)	Total costs (000 €)
Economic	0,1,2,3,4,5 0,2,3,5	f5,f11,f12,f14,f18 f20,f12,27	56 56	24,25 9,5	74,25 65.5
Social	0,1,3,4,5 0,1,3,5	f2,f21,f15,f19 f2,f21,f26	70 68	0 0	70 68
Total costs (min)	0,2,5	f20,f24	58	7,5	65.5

Based on the data from table 2, we can see that we have two optimal solutions if we optimize the supply chain only from an economic aspect. But if we take into consideration that the first solution has potential high social costs (24,250€) we will choose the second solution which has less potential social costs (9,500€). The optimal solution from the social aspect is higher just 3.81 % than the best solution from the economic aspect which includes potential social cost. It seems reasonable to choose that solution. Social sustainable supply chains are clean from of unacceptable business behaviour and in the long-term produce interest for all supply chain participants, their stakeholders and society at large.

CONCLUSION

A growing number of multinational firms have made the commitment in recent years to only do business with suppliers who uphold social and environmental criteria. The most problem arises at first-tier suppliers. Lower-tier suppliers nearly always have worse business practices, which exposes businesses to more substantial financial, social, and environmental risk. The findings of this scientific discussion confirmed the possibility of developing more optimal supply chains in terms of social costs. The difference in economic (total) costs in the resulting supply chains is negligible. Optimizing supply chains from the standpoint of economic costs yields significantly better results only if potential social costs, i.e. potential scandals, are ignored. We can conclude that social sustainable supply chains in the long-term produce interest for all supply chain participants, their stakeholders and society at large.

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INFLUENCE OF FINANCING STRUCTURE ON BUSINESS RESULTS OF COMPANIES IN SERBIA

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Abstract

In the modern business environment, only companies that have the ability to adapt to the new conditions in the environment have a chance to survive and grow. One of the necessary preconditions for high competitiveness of a company is a flexible financial strategy that requires an adequate structure of own and borrowed sources of financing, as well as the structure of fixed and current assets of the company. The structure of financing affects profit and risk, financial flexibility, development strategy and through them the value of the entire company. The paper analyzes the trends in the business of companies in Serbia in the five-year period, from 2016 to 2020, based on the data of the Business Registers Agency from the processed financial statements. This period is characterized by macroeconomic stability, which companies have successfully used to raise their business performance, as evidenced by the business results reported in the financial statements. Thanks to the healthy financial position of a large part of the company, the negative effects of the pandemic in the last two years have left much smaller consequences on the decline in gross domestic product.

Key words: company, business results, financial reports, financial strategy, Serbia

INTRODUCTION

Doing business in modern market conditions is exposed to risks that companies must assess and manage. Business performance is presented through financial statements and all their users seek reliable, timely, complete and accurate data, which enhances the role of the audit, which in its assessment increases the credibility of the information contained in the financial statements. Thanks to

quality financial reports, information asymmetry and negative selection are reduced and thus investment and greater capital mobility are encouraged, and the result is a more efficient functioning of the capital market, which is an important determinant of economic development in each country. The globalization of business has strengthened the importance and role of international financial reporting standards, so their full implementation is an important prerequisite for the inclusion of companies in international business.

Companies in their business develop a financial strategy that includes raising funds in accordance with the requirements of the business strategy and their use in order to maximize the value of the company. Consistency between financial and business strategy is an important condition for creating and maintaining a competitive advantage of the company in the market. There is a wide range of factors that affect the structure of financing and at the same time affect the choice of business strategy. The structure of financing affects the profit and risk, financial flexibility, development strategy of the company and through them the value of the whole company. In modern business conditions, a flexible financial strategy is necessary that will ensure that companies adapt to changes in a dynamic environment, with minimal costs and maintaining high competitiveness.

The Serbian economy is fully exposed to strong international competition, both in the domestic and especially in the foreign market. In such an environment, an individual company is forced to increase its competitiveness in order to survive in the market and increase its market share in order to create preconditions for its long-term, sustainable development. The Serbian economy has recorded good business results in recent years, and has shown its vitality and resilience to external negative influences, such as the undoubted impact of the corona virus pandemic over the past two years. Significant and timely incentives by state institutions should also be highlighted, which have undoubtedly contributed to mitigating the decline in economic activity and deepening the crisis.

MACROECONOMIC ENVIRONMENT

Managing a company in a dynamic environment is a very complex process because the company represents a set of different resources and interests whose most important goal is to maximize its value. Value maximization is based on three basic principles: 1) investment principle, 2) financing principle, and 3) dividend principle (Damodaran, 2015). The principle of investment implies investing funds in projects and assets that will bring returns that are higher than the cost of capital. The principle of financing is the choice of the optimal com-

bination of debt and equity that brings the maximum value. The principle of dividends implies the distribution of dividends to owners of capital and / or the purchase of own shares, especially in situations where there are no investment options that would reject the return above the cost of capital.

Maximizing the value of the company implies that the management makes and implements only those decisions that increase the financial strength and competitiveness of the company. Strategies, business plans, projects and other decisions are divided into successful or unsuccessful, acceptable or unacceptable, depending on whether they create value or not. The assumption of value creation is a competitive advantage that is achieved at the business level, and the task of management is to translate the competitive advantage of their businesses into value (superior returns) for owners (Djuričin, Janošević, Kaličanin, 2015).

The modern business environment is characterized by high information, communication and production technology, but also by the concentration of large financial resources with a small number of entities. In such a dynamic environment, business entities strive to achieve and maintain competitive advantages because both uncertainty and risk are increased in their business. The processes of mergers and acquisitions are taking place, as well as cooperation between domestic and foreign companies, internationalization of business, etc. Decisions of global companies are significantly different from the classic way of decision-making, and most often there is a change in business rules by global companies (Novićević, 2004).

International Financial Reporting Standards are standardization instruments at the global level and facilitate international communication. A country that provides quality accounting in accordance with IAS / IFRS acquires numerous advantages (Novićević, 2004), such as:

- increasing their own opportunities to participate in the global capital market,
- encourages capital inflows into the country,
- simplifies reporting requirements,
- simplifies the possibility of international comparisons,
- reduces the costs of adjusting to the requirements of quality financial reporting and their necessary continuous improvement,
- encourages access to capital markets around the world and directly increases the efficiency of its own securities market, etc.

The business of a company is usually financed by a combination of own and borrowed sources. The capital structure of companies from developed market economies consists of ordinary and preferred shares, debt securities and hybrid financial instruments. As a rule, long-term debt is intended to finance permanent and permanent working capital, while short-term sources are used to finance temporary and occasional needs of companies for working capital. The financing structure of the company is greatly influenced by a number of internal and external factors. The most important internal factors are the size of the company, profitability, liquidity, growth opportunities, asset structure, wage volatility, etc. External factors that affect the structure of financing are divided into branch and macroeconomic. The most important of the macroeconomic factors are certainly the GDP growth rate, the level of inflation, the movement of tax rates, the level of the reference interest rate, etc.

In order to establish a market-oriented economy, Serbia, like other transition countries, has faced numerous challenges in creating an economic system, forming institutions and establishing incentives to improve economic performance. At the same time, corporate governance is recognized as an important factor for developing and improving the investment climate in the country (Denčić-Mihajlov, 2009). Although Serbia today has laws related to financial regulations, company registration, bankruptcies, taxes, customs, etc., the quality of economic legislation is still uneven, and the main problem remains in the implementation of legal provisions in practice.

In recent years, the Serbian economy has continuously recorded positive results (Table 1), which slowed down in 2020 due to the effects of the corona virus pandemic. This trend of growth of macroeconomic indicators provides a good basis for successful economic development in the future.

Table 1: Basic macroeconomic indicators in the period 2016-2020. years

DESCRIPTION	Year				
	2016	**2017**	**2018**	**2019**	**2020**
Gross domestic product (in millions of dinars - current prices)	4.200.197,1	4.754.368,4	5.059.680,8	5.417.724,9	5.463.542,3

Gross domestic product growth rate	2,7	2,0	4,3	4,2	-1,0
Industrial production	104,7	103,9	101,3	100,3	100,4
Annual inflation rate (consumer price index)	1,6	3,0	2,0	1,9	1,3
Exports (in millions of euros)	13.429,7	15.050,8	16.271,4	17.536,4	17.051,9
Imports (in millions of euros)	17.389,6	19.396,0	21.918,4	23.857,3	22.957,1
Number of employees (in thousands	1.921	1.977	2.053	2.101	2.149
Gross earnings (in dinars)	63.474	64.727	68.629	75.814	82.984
Net earnings (in dinars)	46.097	46.600	49.650	54.919	60.073
Dinar exchange rate against euro (as of December 31)	123,47	118,47	118,19	117,59	117,58

Source: Business Registers Agency

After 2014, when there was a decline in GDP of 1.8%, in the following years, GDP growth was recorded continuously, until 2020, when there was a decline of 1% (Table 1). high growth rates in 2018 and 2019 of 4.3 and 4.2 respectively. In the entire observed period, according to the data from Table 1, most other macroeconomic data show a significant upward trend in the business of the economy. Industrial production, which was drastically devastated before 2000, as well as later in the transition period, shows signs of recovery and slight growth, which is extremely important, given that economic policy in the transition period forced the growth of the service sector, at the expense of real sector, and mostly industry and agriculture.

The observed period from 2016 to 2020 is characterized by low and stable inflation and a stable exchange rate, which are elementary prerequisites for planning business activities, primarily in the field of investment and research and development activities. Macroeconomic stability in this period also contributed to the increase in the number of employees and their salaries. What spoils the picture of successful economic development is a further increase in the foreign trade deficit: thus, exports from 2016 to 2020 increased by approximately 27%, while the growth of imports in the observed period was higher and amounted to approximately 32%. This resulted in a trade deficit in 2020 of 5,905 million euros, which is a high amount given the low performance of the economy.

SOURCES OF FINANCING OF COMPANIES

Financial statements are the most basic way in which a company reports to external stakeholders on the results of its operations and financial condition. The usefulness of financial reporting should not be assessed only in relation to individual users, but also from a broader economic perspective, ie. social points of view. This is in the sense that financial reporting, in addition to a number of other relevant factors, must have in its focus the primary goals of ensuring the highest possible level of general social well-being, as the supreme strategic goal of every society. In other words, it is founded considers that the quality of financial reporting in a country is directly proportional and that in the long run it directly corresponds to the general economic well-being of a country (Milojević, 2006).

The importance of financial reporting is particularly pronounced when financial statements are used to compare the operations of different economic entities. This comparison is made from the aspect of liquidity, financial balance, profitability, etc. Based on the data from the financial statements, investors are able to invest capital in successful businesses. Comparability is provided only by information from business reports that is based on the same accounting rules. These financial statements also enable a comparison between the current and previous business periods of a business entity, which monitors its performance at the appropriate time.

For countries in transition, the harmonization of national accounting regulations with international standards is especially important because they need foreign capital for accelerated economic development. According to Mitrović (2013), international accounting regulations are a factor in the quality of financial reporting, on the one hand, and an instrument of harmonization of financial reporting, on the other hand.

Due to the numerous specifics of small and medium enterprises, it is necessary to adopt special standards for this sector, for several reasons (Sačer et. All, 2009). Financial institutions provide lending internationally, so banks rely on financial statements to make lending decisions for these companies. Suppliers want to assess the financial health of customers in other countries before delivering goods or performing appropriate services. Financial statements are the basis for assessing the creditworthiness of companies by credit rating agencies. Also, the capital of small and medium enterprises moves across borders, so the standardization of financial reporting in this sector is in their interest, as well as in the interest of other users of their data.

Companies in their business develop a financial strategy that includes raising funds in accordance with the requirements of the business strategy and their use in order to maximize the value of the company. Consistency between financial and business strategy is an important condition for creating and maintaining a competitive advantage of the company in the market. There is a wide range of factors that affect the structure of financing and at the same time affect the choice of business strategy. The structure of financing affects the profit and risk, financial flexibility, development strategy of the company and through them the value of the whole company. In modern business conditions, a flexible financial strategy is necessary that will ensure that companies adapt to changes in a dynamic environment, with minimal costs and maintaining high competitiveness.

In the modern business environment, only companies that have the ability to adapt to the new conditions in the environment have a chance to survive and grow. The flexibility of a company is its ability to quickly and with minimal costs avoid threats and take advantage of the opportunities that arise, and the management of financial flexibility is in the function of maximizing the value of the company. To this end, companies strive to create an optimal financing structure that is a combination of debt and equity in which the maximum value of the company is achieved. Decisions on the structure of financing cannot be made independently of strategic plans on investments, disinvestment, acquisitions, etc., because the financial strategy must be consistent with the business strategy.

Companies in their business usually determine the target structure of financing, and in case of deviations from the target structure, companies take measures of financial restructuring. These are changes in the ratio between equity and debt, but also changes within all sources of financing individually. Financial restructuring is a mechanism for effective management of the financing structure in accordance with the requirements of the business strategy. The strategy is to determine the long-term goals and tasks of the company, adjust the actions and

allocate resources for the realization of the set goals. The result of financial restructuring should be the strengthening of the financial structure and the growth of the value of the company.

The financial strategy includes a set of decisions that are made in order to finance the business activities of companies that have long-term consequences. The focus of financial strategy is on the financial aspects of strategic decisions, and by considering the financial consequences of available financial options, the best path is determined (Clarke, 1988). According to Bender & Ward (2009), the financial strategy includes two basic components, namely: 1) raising funds in accordance with the requirements of the business strategy; and 2) the use of the company's financial resources, including reinvestment and distribution of profits to owners, in order to maximize value. The optimal financing structure is a combination of debt and equity at which the maximum value of the company is achieved.

According to the criterion of affiliation, sources of financing are divided into own and borrowed, and according to the criterion of maturity, they are divided into short-term and long-term sources. In addition to long-term sources of financing, companies provide the necessary funds to finance growth and development from short-term sources, such as bank loans, loans, short-term securities and so-called. spontaneous sources of financing (suppliers, calculated liabilities at the expense of operating costs - salaries, taxes, etc.). To understand the financial structure of a company, the way in which these sources are combined to finance the total funds committed is crucial. The share invested by owners or shareholders is especially important compared to the amount provided from other sources - loans, credits or borrowings (Kothari, Barone, 2012).

The average funding structure at the branch level usually serves as a standard for comparison or as a targeted funding structure. Some branches have a high level of financial leverage (textile industry, steel industry, cement, aerospace industry, etc.) while others have a very low level of financial leverage, such as the pharmaceutical and food industry, internet providers, etc. Companies belonging to industries with high financial leverage tend to have higher levels of indebtedness and vice versa (Frank & Goyal, 2009).

Costs have undergone significant changes in structure as well as in their general role in recent decades (Malinić et al. 2018). Two changes are characteristic in the general role of costs. One is that costs cannot be viewed in isolation, but always with income and net result, with a view to the long term. The second change stems from the management need of market-driven companies to re-

place access to costs as determinants of market performance with the approach of adjusting costs to future market opportunities, which increases their importance and requires increasingly careful management and accounting approaches to costs.

Cost management leads to the improvement of the business process because it promotes the idea of continuously assisting the organization in making the right decisions and creating greater consumer value at lower costs. The introduction of a cost management system requires the company's full commitment to involving employees at all hierarchical levels and the introduction of a performance control system that will enhance value-added activities while reducing those that do not (Agrawal, et all, 1998).

The increased complexity of business due to rapid technological and market changes and the diversification of business and financial activities of companies has led to the growing application of accounting information in companies. The requirements of raising productivity and tight cost control conditioned by increased competition, understanding the vital role of planning and control in management, decentralization of management and establishing a flexible organizational structure of the company (Aničić et all, 2014) work in the same direction.

The Serbian economy is fully exposed to strong international competition, both in the domestic and especially in the foreign market. In such an environment, the individual company is forced to increase its competitiveness in order to survive in the market and increase its market share with the aim of creating preconditions for its long-term, sustainable development. The Serbian economy has recorded good business results in recent years, and has shown its vitality and resilience to external negative influences, such as the undoubted impact of the corona virus pandemic over the past two years. Significant and timely incentives by state institutions should also be highlighted, which have undoubtedly contributed to mitigating the decline in economic activity and deepening the crisis.

The data in Table 2 show that the total assets (assets) of companies in Serbia increased in 2020 compared to 2016 by 27%. The share of fixed assets at the end of 2020 was 58.9%, current 40.70%, and the approximate relations were during the previous five years. Within fixed assets amounting to RSD 10,118,711 million at the end of 2020, the largest part consists of real estate, plant and equipment whose value of RSD 8,163,053 million is 6% higher than last year, while investments in long-term financial investments have decreased by 4.1% compared to the previous year. In the structure of working capital, at the end of 2020, inventories (RSD 2,305,546 million), receivables from sales (RSD 2,173,850

million), cash and cash equivalents (RSD 1,064,344 million) and short-term financial investments have the largest share. of 550,512 million dinars.

Table 2: Structure of business assets of companies

in millions of dinars

DESCRIPTION	Year				
	2016	**2017**	**2018**	**2019**	**2020**
A. Subscribed but unpaid capital	21.577	21.401	21.562	20.657	37.278
B. Fixed assets	8.004.262	8.455.179	8.861.606	9.651.473	10.118.711
V. Deferred tax assets	38.983	33.338	31.128	32.220	31.660
G. Current assets	5.462.814	5.609.755	6.050.509	6.312.608	6.990.596
D. Total assets	13.527.636	14.119.674	14.964.804	16.016.957	17.178.245

Source: Business Registers Agency

Regarding the structure of corporate financing (Table 3), we see that the share of capital, as own source of financing, at the end of 2020 was 46.74%, which is a slight decrease compared to the initial observed year (2016) when 47,69%. The share of losses above the amount of capital in the total liabilities of companies at the end of 2020 is 9.4%, which is a decrease compared to the initial 2016 when it was 11.84%. Positive trends were realized in the structure of liabilities because the share of long-term liabilities increased (19.38%), and the share of short-term liabilities decreased in total liabilities (42.19%) at the end of 2020 compared to 2016. As far as borrowed sources of financing are concerned, bank loans still dominate, which are still significantly less favorable in relation to loans received by companies from EU countries, although commercial banks operating in Serbia are predominantly from EU countries.

Table 3: Structure of company financing sources

in millions of dinars

DESCRIPTION	Year				
	2016	**2017**	**2018**	**2019**	**2020**
A. Capital	6.452.000	6.841.984	7.244.187	7.669.421	8.029.451

B. Long-term provisions and liabilities	2.515.799	2.646.446	2.685.097	2.967.488	3.329.597
C. Deferred tax liabilities	169.388	192.293	191.066	183.528	180.020
D. Short-term liabilities	5.998.657	6.030.252	6.314.310	6.590.453	7.249.212
E. Loss above equity	1.608.209	1.591.300	1.469.856	1.393.933	1.610.034
F. Total liabilities	13.527.636	14.119.674	14.964.804	16.016.957	17.178.245

Source: Business Registers Agency

The successful operation of the economy in 2020 is also indicated by the growing values of profitability indicators, and the annual rates at which companies achieved a return on sales revenue, as well as a return on equity and total assets have increased. At the same time, the realized positive result enabled the settlement of interest expenses, and the fact that the return on equity was realized at a higher rate than the return on total assets indicates that the borrowing was justified. According to the data in Table 4, it can be seen that the rates of return on equity, total assets, net profit, as well as the interest coverage ratio, increased in 2020, compared to 2016. Only the operating profit rate remained the same in these two years, and in the meantime it was slightly lower.

Table 4: Profitability indicators at the level of the economy

DESCRIPTION	Year				
	2016	**2017**	**2018**	**2019**	**2020**
1. Return on equity (after tax)	4,9	7,4	9,0	6,1	6,8
2. Rate of return on total assets (after tax)	2,5	3,4	4,0	2,9	3,0
3. Operating profit rate	5,7	5,3	5,6	5,1	5,7
4. Net profit rate	2,5	3,8	4,8	3,2	3,8
5. Interest coverage ratio	4,06	5,65	8,82	6,99	8,59

Source: Business Registers Agency

CONCLUSION

In the modern business environment, only companies that have the ability to adapt to the new conditions in the environment have a chance to survive and

grow. The flexibility of a company is its ability to quickly and with minimal costs avoid threats and take advantage of the opportunities that arise, and the management of financial flexibility is in the function of maximizing the value of the company. Companies strive to create an optimal financing structure that is a combination of debt and equity, in which the maximum value of the company is achieved. The financial strategy includes a set of decisions that are made in order to finance the business activities of companies that have long-term consequences. Exposure to the effects of global competition in the domestic and foreign markets requires companies to apply international standards in various areas, of which financial reporting standards are very important.

The Serbian economy is rapidly adapting to international requirements in all areas of business. This is evidenced by the growth of GDP and the business results of companies in recent years. The economy took advantage of macroeconomic stability, which was reflected in low inflation and a stable exchange rate, and all this led to a slight increase in industrial production and an increase in the number of employees. What spoils the picture of successful economic development is a further increase in the foreign trade deficit: thus, exports from 2016 to 2020 increased by approximately 27%, while the growth of imports in the observed period was higher and amounted to approximately 32%. This resulted in a trade deficit in 2020 of 5,905 million euros, which is a high amount given the low performance of the economy.

The Serbian economy has shown its resilience to external negative influences, such as the undoubted impact of the corona virus pandemic over the past two years. Good results have been achieved, among other things, thanks to timely incentives from state institutions that have undoubtedly mitigated the negative effects of the pandemic.

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INVENTORY MANAGEMENT POLICY IN THE FUNCTION OF EFFICIENCY OF COMPANY BUSINESS OPERATIONS

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Abstract

Inventories are an important part of a company's working capital and their efficient use significantly affects the financial performance of a business from liquidity and solvency to profitability and competitiveness. On the one hand, maintaining inventory has its advantages but also causes high costs, while on the other hand, the lack of adequate inventories causes major disruptions in business and can cause a large reduction in company profits.Due to the uncertain business environment, inventory management policy is a very complex issue for company management. This paper points out the importance of inventories in the company's operations and the most important factors influencing the inventory management policy in order to optimize the amount of inventories and their contribution to profitable business operations.

Key words: inventories, enterprise, management, business efficiency

INTRODUCTION

In many manufacturing and trading companies, inventories make up a large part of their total assets, which is why they require relatively large financial investments, so the issues of their management must be given adequate attention. Numerous factors determine the necessity of keeping stocks in the company and one of the most important is the uncertainty that exists in the future business of the company.From the point of view of the company's management, the basic problems in inventory management are to determine the level and time of inventory acquisition, balancing the costs and risks of holding inventory with the benefits of the company. Many companies face problems that make it difficult to find the optimal inventory management policy: unpredictability of demand, long

delivery times, unreliable procurement process, large number of items, short demand time for a particular product, etc.

Inventory management is a significant segment of the process of reducing the company's total costs and increasing the efficiency of its business operations. When analyzing the company's business, depending on the type and form of inventory, it is necessary to use adequate methods and models, which should contribute to the optimization of inventory levels in the company.Inventory management is basically reduced to a cost-benefit analysis, i.e. an analysis of the costs caused by holding stocks and the benefits of keeping them. Poor inventory management results in a significant increase in required costs and a decrease in the company's profitability.Engaging a high level of financial resources in inventories causes a number of negative consequences for the company's operations, ranging from liquidity and solvency, through low turnover ratios to reduced profitability and declining competitiveness in the market.

THE IMPORTANCE OF INVENTORY IN BUSINESS OPERATIONS

Inventories are one of the main segments of the company's working capital. In many manufacturing and trading companies, they make a large part of their total assets, which is why they require relatively large financial investments. In order for these investments not to be unnecessarily high, inventories must be managed efficiently, which means knowing their character and the reasons for their existence in the company. Inventory management is one of the biggest challenges in every company's business, because the company's operations take place in a dynamic and turbulent environment, and large and frequent changes make efficient inventory management difficult.

In foreign literature dealing with the issue of inventories, they are most often defined as own materials used in business, ie. intended for domestic consumption or sale, and include raw materials, semi-finished products, work materials and finished products. We find a similar definition in our literature, where stocks are stored materials that are used to ensure normal production and meet customer needs. It can be said that inventories represent assets that the company has in its regular business process, and for that reason they are considered liquid assets.

The necessity of having stocks in the company arises from three main reasons (Kulić, 2004). The first is that it takes time for economic goods to go through the process of production and distribution. The second reason is the discontinuity that exists due to the mismatch between individual processes and flows of economic goods within the company, and the third is the uncertainty or

incertitude that exists in economic life. All these reasons simultaneously and in combination condition the existence of stocks in different forms. From the point of view of financial management, the basic problem is to determine the level and time of stock acquisition. Determining the appropriate amount of inventory requires balancing the cost and risk of the inventory with the benefits arising from holding it.

From the financial point of view, it would be ideal if the company does not have stocks until the moment of their consumption (materials and semi-finished products), i.e. until the moment of sale (finished products and goods). However, the goal of the business is to keep inventories at the lowest level, provided that this level does not jeopardize the normal functioning of production and sales. This level of inventories makes it easier to achieve good financial stability, and thus solvency. In addition, the costs of financing and holding stocks are then reduced to the lowest level (Ratković, 2017).

An economically motivated and controlled inventory management process is a necessity, in order to avoid unwanted negative impact on business results. Inventories, as part of working capital, are necessary for the smooth performance of both the production process and the sales process, that is, they are a necessity in every company so that all processes take place with minimal disruption. Inventory management is certainly one of the most important logistics tasks, a challenge for companies in modern business conditions. Many companies face problems that make it difficult to find the optimal inventory management policy: unpredictability of demand, long delivery times, unreliable procurement process, large number of items, short demand time for a particular product, etc.

The main challenge of the company's business in modern business conditions is to reduce costs. Inventory management is a significant segment of the process of reducing the total costs of the company. When analyzing the company's business, depending on the type and form of inventory, it is necessary to use adequate methods and models, which should contribute to the optimization of inventory levels in the company. In order to secure and hold stocks, it is necessary to engage significant financial resources, the size of which depends, above all, on the type and size of stocks, the size of the company and the industry in which it operates.

There are different opinions in economic theory and practice as to whether inventories are a good or bad characteristic of a company. As positive characteristics of the existence of stocks in the company, it is stated that they represent security in case of unexpected disruption of supply and demand, enable eco-

nomical production and supply, enable uninterrupted business in case of delays in supply and the like. As bad characteristics of stocks, arguments are given that stocks require capital investments, i.e. they bind the company's capital, cause storage and management costs, they can become obsolete, lose their quality, etc.

By keeping inventories and their efficient management in the company, appropriate benefits are achieved from inventories such as enabling continuity of production, achieving quantity discounts, reducing the cost of acquiring inventory, avoiding loss of sales revenue, achieving higher sales prices (Todorović, Ivanišević, 2017).

Costs of lack of stock can occur due to lack of raw materials, which can lead to increased costs due to urgent procurement and pressure on suppliers, but also cause interruption of the production process, which will increase the total cost of doing business. In case of lack of stocks of finished products, the company will not be able to accept orders, which means that there will be no sales. The lost profit on the sale that would be realized by accepting and executing these orders represents the opportunity cost of lack of stock (Hampton, 1989).

In practice, it is necessary to take into account all the listed good and bad properties of stocks and based on them, decide on the optimal amount of stock. Inventory management is basically reduced to the so-called cost-benefit analysis, i.e. the analysis of costs and benefits of holding inventories.In fact, determining the optimal amount of inventory requires a balance between the cost of holding inventory and the utility achieved by disposing of that inventory. The basic function of inventories is to mitigate or eliminate temporal and spatial differences between production and consumption.

Efficient management of inventories and their holding in the company, achieves certain benefits which are reflected in the following: avoiding losses on sales, achieving quantity discounts, reducing order costs, increasing production efficiency and the like. The optimal level of stocks is the amount of stocks that provides a regular flow of the production cycle with the lowest costs, and is formed in accordance with the principle of continuity and the principle of economy in the formation of inventories (Paunović, Zipovski, 2006).

If inventory management is considered as one connected system, then the following subsystems could be singled out: the optimal order size, the optimal moment for placing an order and the record of inventory levels. The key reason for inventory management is to reconcile the following potentially conflicting goals (Viale, 1996):

- Maximizing customer satisfaction,
- Maximizing supply and production efficiency,
- Minimizing investment inventories,
- Maximizing profits

The importance of inventory management in a company has often been underestimated in the sense that a superficial analysis has concluded that it is best to have as much inventory as the company's financial strength allows. Due to the possibility of cessation of production or other business activities of the company, the concept of "low level" of inventories seems intimidating, forgetting the profitability of working with inventories (Becker, 2011). Inventory management is a complex business that seeks to store, use and distribute inventory that the company owns, which can be adequately implemented with minimal financial allocation and human effort.

FACTORS AND OBJECTIVES OF INVENTORY MANAGEMENT

Many companies operate at a low profit rate, which could easily disappear if inventory is not given due attention. Poor inventory management results in significant profit reductions and even economic suicide. The choice of inventory philosophy is of great importance for the efficient operation of the company, and given the negative effects of inventory, strict control of business is necessary to minimize the level of inventory. The strategic role of inventory is embodied in supporting the improvement of five target business performance: quality, speed, dependence, flexibility costs (Schroeder, 1999).

Modern business conditions attach great importance to the inventory management system, because it is an important basis in determining business success. Inventory management involves maintaining a satisfactory level of inventory for which there is demand, as well as reducing the level of inventory of products for which there is no satisfactory level of demand. The key to inventory management is to strike a balance between products for which there is demand and products for which there is no demand.

In modern business conditions, when companies are at approximately the same level of technological equipment, inventory management is becoming one of the most important tasks of business management and profit insurance. Modern markets require high productivity as well as the ability of companies to respond to the challenges present in the market. For most industries, strong com-

petition has contributed to optimizing the production process and the structure of inventory management plans accordingly.

According to Valero (1999) the most important factors of inventory management are:

- • The level of inventory should be adequately assessed
- • Time in procurement, production and distribution function should be kept to a minimum
- • The risk of obsolescence and deterioration of inventories must be taken into account when calculating the desired inventory level
- • Inventory management involves a trade-off between the cost of holding inventory and the benefits of holding it
- • The level of inventories also depends on the short-term interest rate: when short-term interest rates increase, the optimal level of inventory holding decreases
- • Inventory management also involves the decision to sell the product at the current stage, or to sell it for further processing.

The goal of inventory management is to meet every request of the user / customer, taking care that the cost of acquisition and possession of inventory is at an acceptably low levelso that the company makes a profit from its business. One should be very careful in this, because paying attention to only one of the two opposing criteria can be disastrous for any company. Therefore, it is necessary to approach the problem of establishing the dynamics of procurement, as well as the quantity that is procured.

Inventory management in supply chains can have a great positive or negative impact on other business performance, and the main goal of management should be to reduce total costs in the supply chain and ensure uninterrupted business continuity, meaning that inventory levels are at optimal levels. Inventory management systems themselves can be based on continuous management (continuous monitoring with the renewal of inventories when their condition falls to a predetermined level) and periodic management (the situation is determined at specific intervals and then inventory is restored to the desired level).

Inventory management is influenced by the characteristics of customer requirements (stochasticity, non-stationarity, etc.), order cycle and delivery times, number of items and length of the planning period, cost structure, etc. For example, in manufacturing activities, the development of production technologies

has increased stochasticity due to shorter life expectancy and increased product range.

Among the indicators of inventory management success, the most widespread and at the same time the most significant indicator is the turnover ratio. It shows how many times the average inventory was sold during the accounting period. The higher the turnover ratio, the more profitable the business, because the assets are shorter tied. It is usually very expensive to keep large quantities of stocks for a long time, so it is better to have a slightly higher stock turnover ratio, and a low indicator usually indicates poor quality stocks (Ivaniš, 2009).

Since inventories are most directly related to the company's income, the acceleration of their turnover results in an increase in mass income, less engagement of expensive and most often borrowed funds in this form of property, and finally, results in a faster release of cash that is needed on a daily basis to settle due short-term and long-term liabilities.In a word, faster turnover of stocks results in higher liquidity and solvency of the company, while indirectly it has a positive impact on increasing the profitability of the company (Stevanović, et al, 2011).

The most complex inventory management system is a system in which the company strives to get rid of holding inventories of all stages of completion - raw materials, work in progress and finished products - known as Just-In-Time - JIT. JIT system is a holistic system that, in addition to the central inventory management system, permeates all processes and functions in the company, which was initially designed in the automotive industry and the Japanese company Toyota, and is suitable for use in other industries where the final product consists of many components. e.g. in the computer industry (Todorović, Ivanišević 2017).

CONCLUSION

Maintaining a favorable financial structure of the company and a satisfactory degree of its liquidity largely depends on the proper disposal of inventories. For this reason, it is of great importance for every company to adequately manage inventories and thus maintain their optimal level. Inventories serve to reduce risk in business, making the company flexible and able to meet the increased needs of consumers. On the other hand, one should be careful with the size of inventories because inventories bind capital, take up space, require maintenance investments, become obsolete and lose quality. Because of all this, it is

necessary to find a balance between the costs caused by keeping stocks in the company and the costs incurred due to their lack.

Efficient management of inventories and their holding in the company achieves certain benefits which are reflected in avoiding losses on sales, achieving quantity discounts, reducing order costs, increasing production efficiency and the like. In modern business conditions, when companies are at approximately the same level of technological equipment, inventory management is becoming one of the most important tasks of business management and profit insurance. Modern markets require high productivity and competitiveness, as well as the ability of companies to respond to the challenges present in the market. For most companies in the field of production, as well as trade, high competition has contributed to optimizing the business process as a whole, and thus the efficiency of inventory management as an important segment of increasing the efficiency of overall business.

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DATA FILTERING TOOLS FOR ILLUMINA RNASEQ IN ZEA MAYS L.

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Abstract

Exploration of maize (*Zea mays L.*) transcriptome is significant in molecular biology research for improving existing maize breeding programmes worldwide. Through numerous studies of maize transcriptome response to abiotic stresses (like cold, drought, etc.) researchers and breeders are looking for molecular and phenotypic clues, which would help in gaining knowledge on how to increase and stabilize maize yield under variable and unfavorable environmental conditions. There are numerous publicly available maize transcriptome datasets obtained from maize plants grown in different environmental conditions and in different developmental stages, representing a rich data vault for mining of significant molecular clues. These datasets mostly include Illumina RNAseq data, usually provided in a raw format, implying that adequate transcriptome data filtering is needed prior to any further transcriptome data analysis. There are plenty of tools intended for raw genomic data filtering, but very few are designed for RNAseq data, and only one is designed for Illumina RNAseq data. We provide comprehensive evaluation of the existing tools that can be used for Illumina RNAseq data filtering, based on the comparison of their performance on a typical Illumina RNAseq dataset that include publicly available transcriptome data for 46 maize inbred lines from Maize Research Institute "Zemun Polje" (SRA dataset SRP299841).

Key words: Illumina RNAseq data, transcriptome data filtering, genomic data filtering, Zea mays RNAseq.

INTRODUCTION

Maize is a worldwide important crop, mainly used as a source of food and feed, and also for bioethanol production. Its yield is negatively affected by a wide range of biotic and abiotic stresses, thus looking for novel ways to secure and stabilize maize yield under variable and unfavorable environmental conditions are necessary. Innovative tools, methods and techniques available from the genomics and bioinformatics area could help in the advancement of existing breeding approaches, intended for development of the superior and resilient maize hybrids. In order to develop maize hybrids that are resistant to different environmentally related challenges, maize transcriptome is extensively studied.

Transcriptome data analysis is the process of obtaining important molecular information from raw genomic datasets, usually obtained by Next Generation Sequencing (NGS) technology and is called RNAseq analysis. There are numerous approaches in RNAseq data analysis, but one general set of the main steps is common for all of them. These general steps include: raw RNAseq data collection, RNAseq data preprocessing, RNAseq data processing, exploratory RNAseq data analysis and reporting results.

The amount of available raw RNAseq data collections is rapidly increasing on a daily basis. A vast amount of raw RNAseq data collections from all kingdoms of life are publicly available through the NCBI's Sequence Read Archive (SRA) and EMBL-EBI's European Nucleotide Archive (ENA). As SRA is a part of ENA, these archives are mutually synchronized. Contained raw genomic data collections are differently labeled in these two archives, but they are interconnected. Regardless of the existing plethora of publicly available raw RNAseq datasets, plenty of RNAseq experiments are conducted in order to assist diverse nature of different molecular biology research. The available raw data obtained from RNAseq experiments consists of several to several hundreds gigabases of short sequence reads, containing 100-250 base pairs (bp) per read, but there are new technologies like Oxford Nanopore and PacBio that may produce even longer reads up to 1000bp, but their outputs are not yet visible in the NCBI database. Raw RNAseq sequence data is commonly stored in the FASTQ format, which consists of the nucleotide sequence itself and calculated quality of the data determined by the Phred algorithm. Taking into account the potential size of the raw genomic sequence datasets, these datasets are provided in compressed form, usually using GZIP format.

Leading NGS method for raw genomic data production is a method invented by Solexa, and from 2007. further developed by Illumina Inc., to which the rest

of the paper will be dedicated to, as it is currently the most popular platform for RNAseq among researchers. Illumina has developed several series of sequencers with NovaSeq, HiSeq, MiSeq, NextSeq, MiniSeq and iSeq platforms being in use today. Because of the nature of the Illumina sequencing process, which is based on the sequencing-by-synthesis approach, resulting raw genomic datasets are imperfect and need preprocessing before the main analysis step . Regardless of the RNAseq data source, RNAseq data preprocessing involves two substeps: RNAseq data quality control (QC) and RNAseq data filtering (DF).

In this paper we focus on the DF. DF implies cleaning the raw genomic data from errors and noise, and it directly depends on the results of the genomic data QC step. DF of the genomic data includes: adapter removal, low-quality bases removal, first bases bias removal, contaminant removal, duplicate removal and removal of the short nucleotide sequences below a certain threshold. Some of the aforementioned steps are mandatory for filtering all kinds of genomic data, like adapter and low-quality bases removal, while the necessity of some steps depends on the type of sequencing, like duplicate or sequence bias removal, which are useful for the DNAseq, but disadvantageous for the RNAseq data analysis. When it comes to the RNAseq data, the necessary steps of DF include adapter removal, low-quality bases removal, biological and technical contaminant removal and removal of the short nucleotide sequences below 18 bp (Dudic et al, 2022).

In this paper, we evaluate different available and widely used DF tools, based on their functionality and performance on the publicly available RNA-seq data for 46 maize inbred lines from the Maize Research Institute "Zemun Polje" (SRA dataset SRP299841) in order to determine the tool which best fits transcriptome data.

MATERIALS AND METHODS

The Dataset

Raw RNAseq data under the accession number SRP29984 were retrieved from the NCBI SRA database. This dataset contained total RNAseq data of 46 maize inbred lines from the Maize Research Institute "Zemun Polje". The NGS approach used for obtaining this dataset involved sequencing of the maize leaf total transcriptome via Illumina MiSeq platform and 150bp pair-end sequencing.

Tools

The evolution of the NGS technology has been followed by parallel development of numerous general tools for genomic data filtering like Trimmomatic (Bolger et al., 2014), FastqCleaner, FASTX-Toolkit, QC-Chain, BBDuk, FaQCs, Kraken, SeqPurge, fastp (Chen et al., 2018), AfterQC, etc. There are even more tools that display some functionalities needed for DF of RNAseq data like BioBloom, DeconSeq, VecScreen, FastQ Screen, BBSplit - for decontamination of data, SolexaQA, ConDeTri and Sicle - for trimming the reads, NGS QC Toolkit and Seqtk - for trimming read ends, PRINSEQ, HTQC - for quality trimming, and TrimGalore!, cutadapt, Scythe - for adapter removal. But, very few tools are fully designed for DF of RNAseq data in specific, and these are: prepRNA (Dudic et al., 2022), RNA-QC-Chain and FastqPuri (Pérez-Rubio et al., 2019). As a consequence, for DF of RNAseq data researchers most often use general DF tools or combine several different tools to obtain desired functionalities, which may be challenging for non-computer specialized users.

Among the plethora of available genomic DF tools, researchers have a hard time choosing the adequate one for the depicted task. For this case study we selected two tools that are declared as RNAseq DF tools, prepRNA and FastqPuri, and two broadly used general DF tools, Trimmomatic and fastp.

Measures

Tools can be generally compared using their characteristics taking into account the domain of application. In this case we focus on the level of possible adjustment of DF to RNAseq data and simplicity and completeness of the selected tools through 11 measures: used programming language, support for single end (SE) and/or paired end (PE) data, supported format, support for RNAseq, support for Illumina data, is the tool easy to install, is the tool easy to use, QF support, contaminant removal support, adapter removal support, quality filtering support.

On the other hand, the quality of the genomic DF approach can be best evaluated by the results of genomic data processing. Because of the existence, maturity and quality of the maize reference genome, it's natural to use data mapping measures in order to determine the DF quality like percentage of mapped reads and number of reads mapped to the reference genome. The need to use both mapping quality measures rises from the generality of the percentage as a measure and uncertainty of the number of reads mapped to the reference genome as a measure. For the mapping task we used the STAR tool, v2.7.10a in PE mode and with default parameters.

Another quality measure is execution time but it must be taken into account that as the number of steps included in DF increases, execution time must be increased, too.

RESULTS

Aforementioned selected tools: prepRNA, Trimmomatic, trimFilterPE modul from the FastqPuri tool and fastp, are compared according to their characteristics and performance.

Tools characteristics

From a plethora of DF tool characteristics we selected those which reflect user friendliness, scope of possible application and completeness of DF tools observed from the RNAseq domain. Comparison of selected tools characteristics are given in Table 1.

Table 1. Comparison of characteristics for selected tools: prepRNA, Trimmomatic, trimFilterPE modul from the FastqPuri tool and fastp

Alat	prepRNA	Trimmomatic	FastqPuri	fastp
Programming language	C, java	java	C, R	C++
SE/PE	SE, PE	SE, PE	SE, PE	SE,PE
Format	fq.gz	fq*	fq*	fq*
RNAseq	+	-	+	-
Illumina	+	+	-	-
easy to install	+	+	+/-	+
easy to use	+	-	-	+
QF	-	-	+/-	+/-
contaminant removal	+	-	+	-
adapter removal	+	+	+	+
quality filtering	+	+	+	+

Tools performance

In order to benchmark selected tools three measures are used: execution time - measured with UNIX time command, mapping percentage and number of mapped reads - as calculated and presented in the STAR report. All filtering was done using PE mode and adjusted to the selected RNAseq dataset (SRP29984). Obtained tools performance is given in Figures 1-3.

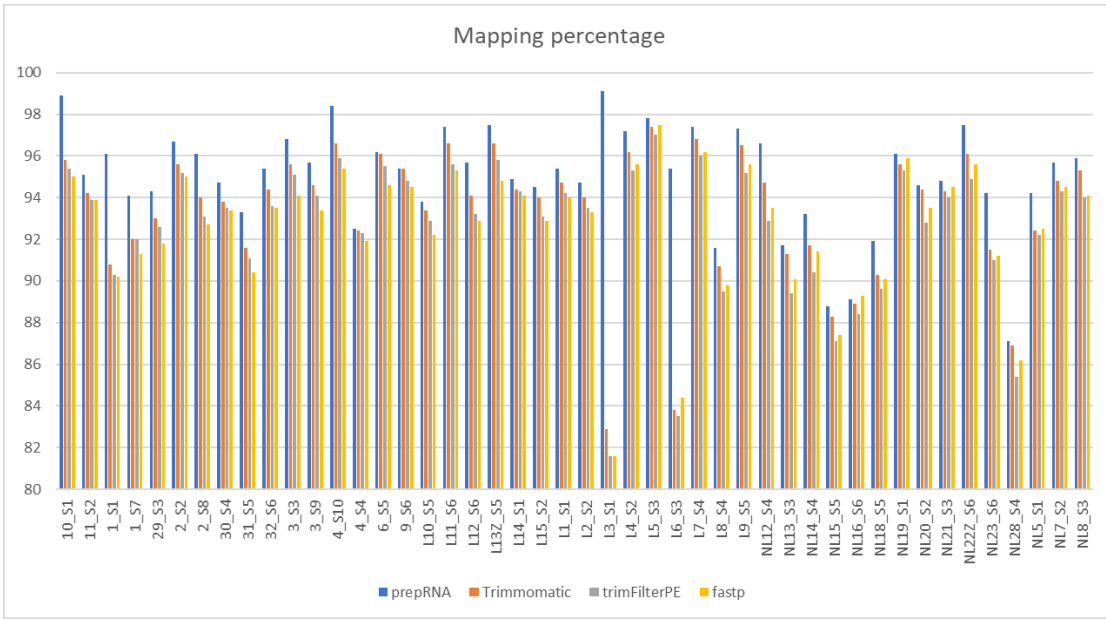

Figure 1. Mapping percentage comparison for the four selected tools for RNAseq data filtering

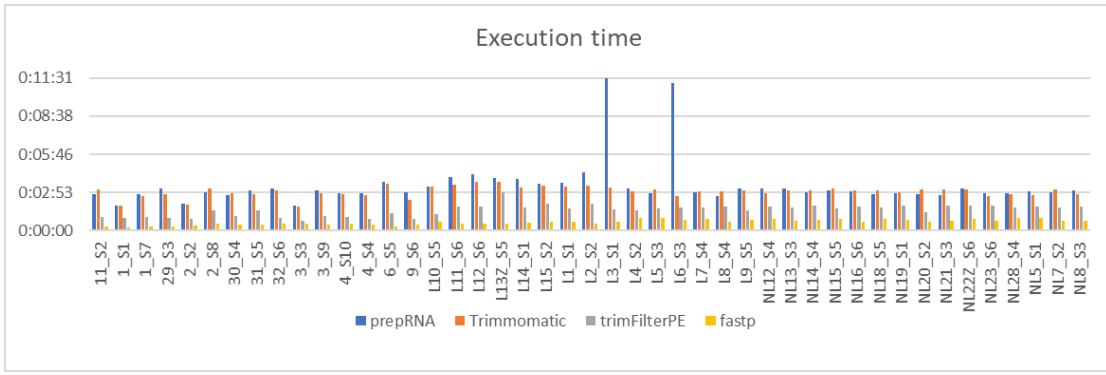

Figure 2. Execution time comparison for four selected tools for RNAseq data filtering.

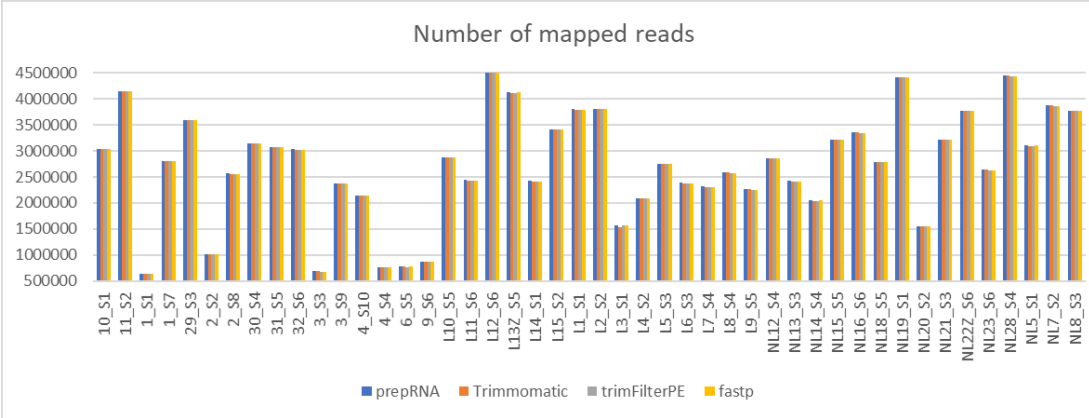

Figure 3. Comparison of mappability for four selected tools for RNAseq data filtering.

DISCUSSION AND CONCLUSION

Biological contaminant removal, technical contaminant (adapter) removal and quality trimming are three main tasks needed for adequate data filtering for Illumina RNAseq data. Although there are many bioinformatic tools designed for one or two of the aforementioned Illumina RNAseq data filtering tasks, there is a lack of tools designed for all three of them and therefore intended for Illumina RNAseq data filtering at all. Usually, the excluded task from bioinformatics data filtering tools is biological contamination removal with the explanation that if reads do not belong to the sequenced organism they will not map to its reference genome. In theory, this is true, but there are similarities between organisms and in order to preserve validity of results it is better to remove any ambiguity.

We compared four existing tools for bioinformatics data filtering: prepRNA intended for Illumina RNAseq data, Trimmomatic intended for Illumina data, FastqPuri intended for RNAseq data and fastp intended for general purpose. According to comparison of tool characteristics we conclude that among compared tools only prepRNA is a user-friendly tool that provides full and comprehensive filtering of Illumina RNAseq data. Also, based on tools performance we conclude that prepRNA tool has the best performance. Two out of three metrics, mapping percentage and number of mapped reads, showed that prepRNA outperforms other bioinformatics data filtering tools. The prepRNA tool execution time is significantly higher for several elements of the dataset, but these reads are more contaminated than others and the decontamination process takes more time. To

support the aforementioned, we can take a look at the number of mapped reads that is gratter for the prepRNA tool than others.

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THE CONNECTION OF THE MANAGEMENT OF ZANJA WITH MODERN MODELS OF EDUCATION OF EMPLOYEES IN COMPANIES IN INDUSTRY 4.0. AND 5.0.

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Abstract

The modern way of doing business brings with it an increasing need for the training of employees. The development of technology conditions the education of employees in one continuity. The focus is placed on the education of human resources. Intellectual capital is becoming one of the most important resources that companies have at their disposal at a given moment. Modern models of education are gaining more and more importance even though they significantly increase the total costs of doing business. Additional training improves the quality of human resources, increases the efficiency of employees and, therefore, the entire production process. By improving knowledge at all levels in business, a concrete advantage in the market is achieved. Employees in additional education should see additional motivation and stimulation for progress and thus higher earnings and satisfaction at the workplace.

Key words: education, knowledge, management, efficiency, human potential, motivation

INTRODUCTION

Technological development and innovation result in changes in productivity, the labor market and education. Accordingly, through a literature review, Motta Reis et al. attempted to identify research gaps. The result of their efforts is reflected in the formation of five groups with similar characteristics of education 4.0 (Nuñez S. & Padilla J, 2020). In today's global economy, technology and innovation are key elements of sustainable economic growth. Successful examples include China and several other Asian countries, such as Korea, Taiwan and Singapore, which have played a significant role in economic development through the efficient use of technologies in production processes and their research and development (R&D) capabilities (Cavdar & Aydin, 2015). In order to achieve success and ensure their long-term survival in a market characterized

by various factors related to globalization, digitalization, technology intensity, knowledge transfer and emerging new business models, companies are no longer able to work innovatively in isolation, but a constant scanning of the business environment is necessary. development of their absorptive capacities, motivation for external acquisition of knowledge and its integration with internal activities (Lazarenko, 2019).

Technologies are constantly changing and are of great importance in turbulent markets. They influence the development of special competencies and thus make a difference between companies. A firm's technological choices are usually clarified in its technological strategy, a plan that leads to the accumulation and application of technological resources and capabilities (Dasgupta et al., 2011). Ivanova et al. (2019) state that "specialized technological knowledge plays a leading role in ensuring the income and profitability of the company". They single out companies that are able to manage a sufficient amount of R&D investment and use the results to create new products, services and technologies as companies that will provide far more significant advantages in technology advancement than their competitors.

The importance of knowledge management comes to the fore when looking at a certain market with an increase in the rate of innovation; the need to replace informal knowledge with formal methods and ways of saving and retaining knowledge within the collective memory of the company, all because of the ever-present trend of permanent reduction of the workforce, the possibility of losing human potential as a result of workforce mobility, workforce reduction or changes in strategic business directions. Knowledge management is a chance for a company to undertake certain activities based on knowledge, intellectual capital and thus achieve efficiency and quality in business processes, thereby creating employee satisfaction.

THE IMPORTANCE OF HUMAN POTENTIAL AND MODERN BUSINESS METHODS

Modern ways of doing business increasingly require the economical use of resources. The newer economy bases its resources on human potential. The application of the concept of human resources is gaining more and more importance in all business processes. Without an adequate distribution of human resources, business loses both efficiency and effectiveness. Therefore, profitability decreases in this way. By increasing the investment in the control of the management of usable resources, the level of overall success increases. To manage

resources means to set a precise procedure that will guide all employees. It is necessary that every employee is exactly familiar with the procedure that is applied. It is necessary to direct human resources and develop their skills towards achieving business excellence.

Modern society is based on modern technology, knowledge and new management theories. The application of new technologies has greatly helped to improve the quality of human activity in many areas. Companies increasingly attach importance to quality. In order to fully realize the quality system, it is necessary to clearly and precisely define the goals and strategies by which the company is run. The acquisition of new knowledge and skills as well as the use of new ideas are a pillar of modern economic flows. new technology belts, digitization and digital transformation modify existing or create new business processes. For many companies, this is a business challenge, but also a chance to improve their competitive position on the market. The integration of digital technology into business processes results in changes in the very way of doing business and creation value for consumers. Thanks to technology, companies are innovating business processes to be more responsive to consumers. New technology and digitalization enable existing business activities to be better and the transition from traditional to digital business. A digital transformation strategy has four main areas: 1) capture the attention of consumers, 2) transform products from traditional to digital, 3) optimize operations to reduce costs and achieve higher revenues and profits, and 4) empower employees with new knowledge and skills (Singh , 2020).

The countries of Southeast Europe (SEE) lag behind in creating the prerequisites for successful digitization and the application of the Industry 4.0 concept. Although e-government projects have brought significant changes in the functioning of countries and their economies, further efforts are needed at the regional and national level in terms of taxation, social systems, labor regulations, education modernization and innovation support. The potential for job creation, skills acquisition and growth in SEE countries is huge, but it remains to be seen whether these new economic areas will be fair in the social context (Mondekar, 2017).

DIGITALIZATION OF BUSINESS PROCESSES

According to McKinsey, nearly 3,000 employees said the strongest motivations for adopting a sustainable mindset are: alignment with company goals, missions or values; building, maintaining or improving reputation; meeting cus-

tomer expectations; and developing new growth opportunities (Spilakos, 2018). Apart from the financial and business result, the impact on the environment is important regardless of the size of the company. SMEs contribute 64% of the environmental impact in the EU (Blundell et al., 2013). Therefore, SMEs could similarly improve their own environmental performance and demonstrate their significant power as drivers of industry change (Seidel et al., 2008). Digitization can be a driver of cooperation between countries. The observed increase in digital transformation and convergence of the countries of the Western Balkans has a positive impact on economic cooperation. This implies that increased digital convergence through increasing overall technological progress could strengthen regional economic cooperation and contribute to the economic stability of the region (Broz et al., 2020). The importance of cooperation is especially important

reflected in various initiatives, in order for the countries of the region to move to the circular economy as a new paradigm of business and economic development with the help of the digital economy (Kragulj et al., 2020).

Serbia's industry after 2000, in conditions of late and unsuccessful transition, is characterized by resource-intensive exports, high imports, unfavorable production structure, technological and economic lagging of most capacities, insufficient inflow of foreign capital. Although certain positive developments were made after 2015, the growth of industry is still insufficient. Although in the entire post-war period our country was characterized by extremely dynamic industrialization, that process was not accompanied by an appropriate industrial policy. Digital technologies are changing the way we connect and create value for our clients. The key to digital transformation lies not in technology, but in strategy and new ways of thinking.

INNOVATIVE MODELS OF EMPLOYEE EDUCATION

Industry 4.0 was heralded by the emergence of innovative solutions in the field of information technology, and its strengthening is heralded by the widest application of those solutions in practice. "Artificial intelligence can be defined in different ways - it is a field that deals with the possibilities and forms of intelligent behavior of machines (computers, robots), which is recognized through key characteristics: learning from experience, acquisition and application of knowledge, logical reasoning, possibility of abstraction, flexibility, responsiveness, ability to understand natural languages and explanation" (Stošić, 2013). The analysis of the literature led to research conducted in European countries. Their state systems are heavily in favor of introducing a dual system of edu-

cation in their school system. Research conducted in Germany highlights the importance of professional education and training. In Germany, vocational education is available to all young people regardless of qualifications. Graduates in this country choose secondary vocational schools after completing the basic cycle of education. On average, 52% of the respondents gave an affirmative answer. Industry 4.0 represents a logical continuation of the redefining of the way of doing business that was brought about by the previous three industrial revolutions. From the first industrial revolution to today, 250 years have passed in which conditions have changed first at the local level, and in recent decades more and more at the global level. All these changes were simultaneously the cause and effect of the development of companies and new market conditions, so the industrial revolution is actually called technological leaps that significantly influenced changes in the previous way of production, but also led to changes in people's everyday lifestyle (Nikolić & Rogale , 2017). Today's business world requires each individual employee to take a leadership role in their area of expertise. Regardless of the current position in the company where he is employed, he should highlight his abilities and continuously improve his skills. The wrong way is to set a competitive attitude, but on the contrary, it is necessary to give every employee confidence that success is achievable for each of them. It is necessary to constantly introduce new changes in the company's operations in order to reach a leading position. It is necessary for companies to act with an attitude on the market that will impose on consumers the introduction and application of innovative products. Key changes in competencies that employees need to have in order for companies to successfully transform their operations in line with Industry 4.0 (Fabian, Galeitzke, Flachs, & Kohl, 2016)

CONCLUSION

Modern ways of doing business increasingly require the economical use of resources. The newer economy bases its resources on human potential. The application of the concept of human resources is gaining more and more importance in all business processes. Without an adequate distribution of human resources, business loses both efficiency and effectiveness. Therefore, profitability decreases in this way. By increasing the investment in the control of the management of usable resources, the level of overall success increases. It is almost impossible to imagine the functioning of a company's business without the provision of services and the exchange of information at a distance using the Internet. The means of communication have been transferred to the application of social networks and virtual communication. Meetings have increasingly moved out of

offices and physical presence. The deals take place through virtual platforms. The development and organization of management systems as well as information is gaining more and more importance in various organizations of service and production activities. Nowadays, the application of knowledge management is gaining in breadth and increasing importance. Human potential is becoming a strategic resource in companies around the world. Constant improvement of the knowledge management application model is necessary in order to raise the entire business to a higher level.

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COMPARATIVE ANALYSIS OF STUDENTS' ACHIEVEMENTS IN HYBRID AND TRADITIONAL LEARNING

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Abstract

In this paper we analyze students' achievements in online and hybrid learning versus their achievements in traditional learning. Due to the sameness of the curriculum and due to the precision of information, this analysis includes students of the first grade of Arhitectural technology school, generation 2020/2021 and generation 2021/2022. The period which is analysed is the second term of the 2021 school year (online and hybrid learning) and 2022 school year (traditional learning). The source of information are electronic grade book and the survey of 67.41 % of the first-grade students in generation 2020/2021, and 72.29 % of the first-grade students in generation 2021/2022.

Key words: achievements, hybrid learning, traditional learning

INTRODUCTION

The pandemic of the Covid-19 virus, which affected the whole world and therefore the Republic of Serbia, brought changes in various spheres of life and affected education as well. At the beginning, there were difficulties in carrying out a different kind of teaching because neither the students nor the teachers were ready. But, the organization became better and better, standardized platforms and digital material began to be used, so online and hybrid teaching became significantly easier.

EXPLANATION OF BASIC TERMS

Traditional learning refers to the use of learning methods that usually take place in the classroom and are taught didactically by the teacher. The teacher conducts communication with the students, which can be one-way or two-way. The advantage of this type of teaching is that the presence of the teacher can direct the students, the socialization and emotional engagement of the students

is enhanced and the teacher can better control the knowledge check. The disadvantages of traditional learning are particularly reflected in the domain of individualization of teaching and learning, raising internal and external motivation, more realistic and objective evaluation of students' knowledge. In traditional learning, learning from books and mechanical memorization is favored, instead of insisting on independently finding information and analyzing it in order to arrive at applicable knowledge.

Newly created conditions in the situation of the threatening virus Covid-19 created the possibility to move lectures from the classroom to online platforms.

Online learning uses the possibilities provided by the Internet and digital technologies. The advantages of online classes are in terms of the place and time of knowledge transfer, the removal of barriers related to shame and fear of talking with other participants in the class, the possibility of participating in classes from any digital device that has access to the Internet, and the curiosity and motivation of students if the material is interesting.

In certain periods, the so-called hybrid learning model was used.

Hybrid learning consists of at least two components: traditional learning and application of information technologies (online learning). Traditional and online lectures are combined and thus complement each other. Hybrid learning in secondary schools in the Republic of Serbia is organized by dividing students into two groups. Each group attended traditional classes every other day, and online classes on other days.

An important source of information in this paper was based on summative and formative grades taken from the electronic diary.

Summative grades refer to the numerical evaluation of student achievements at the end of a program unit or qualification period. These are the grades: excellent (5), very good (4), good (3), sufficient (2) and insufficient (1).

Formative assessment is focused on student results and the evaluation of the learning process itself. This type of assessment represents continuous monitoring of the student's attitude towards work, student's independence, way of learning and mastering the material. The formative assessment is descriptive and contains a description of the student's achievements, a description of the student's engagement in class and recommendations for further advancement. Summative and formative grades complement each other and enable monitoring of the degree of achievement of goals and standards of achievement, the degree

of development of competencies for mastering the course program, as well as the degree of engagement and progress of students compared to the previous period.

WORK METHODOLOGY

Two sources of information were used in the paper: a survey and data from the electronic diary related to summative and formative grades of students.

The survey was conducted on two samples. The first sample consists of students of the generation 2020/2021 who attended the first grade of high school (hybrid and online classes). The second sample consists of students of the generation 2021/2022, who attended the first grade (mainly in traditional classes). The survey was conducted in June 2022 through a Google questionnaire. The anonymous survey was identical for both generations, it did not contain questions related to a specific type of teaching, but only to the satisfaction and achievements of students in the teaching of the Computer Science and Informatics course, regardless of which type of teaching it refers to. The sample on which the survey was conducted included 120 students of the first-grade generation 2020/2021 (67.41 %), and 135 students of the first-grade generation 2021/2022 (72.97 %). Statistical data from the electronic diary were used on a sample of 100% of students from both generations.

The period which is analysed is the second semester of 2021 and 2022 due to the validity of the data and the identity of the teaching units.

The paper deals with *the achievements of students in traditional learning versus the achievements of students in hybrid and online learning*.

Based on the problem and the aim of the work, a general assumption is made which reads: *Secondary school students show better achievements in traditional than in hybrid classes*.

RESULTS

Displaying the results of the questionnaire for students

The first question from the survey was about whether students have a computer at home. The results show that students who worked in hybrid classes owned a computer in 96.67% of cases, while students who had traditional classes owned a computer at home in 98.52%.

With regard to the teaching areas covered in the second semester of secondary schools in the subject of Computer Science and Informatics, the students were asked whether they have the MS Office package installed. Students who worked mainly hybrid had this package in 60% of cases, while students in traditional learning had the MS Office package in 89.63% of cases. This can be explained by the fact that students of the generation 2020/2021 were not prepared for online classes, while the students of the generation 2021/2022 already encountered this type of teaching in elementary school (Chart 1.)

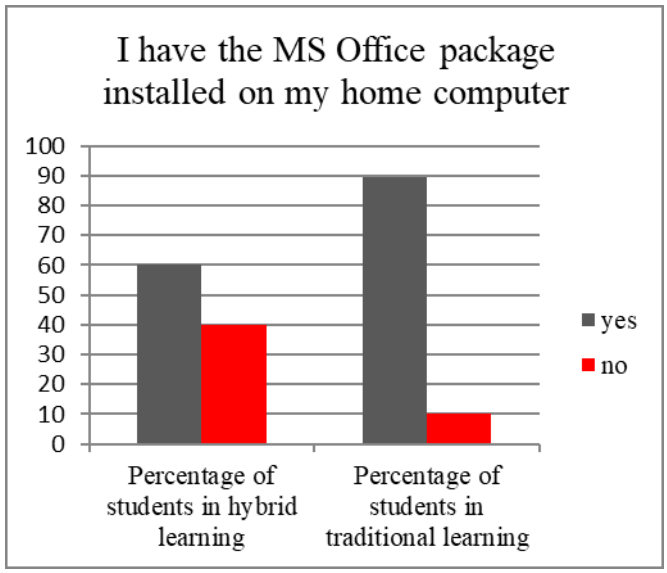

Chart 1. Comparative view of the structure of students in hybrid and traditional learning who have/do not have the MS Office package installed

Analysis of the survey found that 60% of students in hybrid learning fully understood the teaching material and lectures, while this percentage was slightly higher in traditional learning (68.89%). There is a negligible number of students who were completely dissatisfied with lectures in traditional and online learning.

A higher percentage of students (62.96 %) declared that they found the lessons in traditional learning more interesting than the lessons in hybrid learning (53.33 %). The number of students who were not interested in either type of teaching is negligible.

The analysis of the survey found that the teacher used digital material to a greater extent in hybrid learning (95%) than in traditional learning (79.26%).

During traditional learning, students were more regular in doing their homework. 70.73% did assignments regularly, while in hybrid learning that percentage is slightly lower and amounts to 60%.

A higher percentage of students declared that the teacher was more available for consultation during traditional learning. In hybrid learning, 80% of students fully agreed that the teacher was available for consultation in traditional

learning, the percentage is higher and amounts to 94.07%. 16.67% of students in hybrid classes do not have an expressed opinion on the issue of consultation with the teacher, so it can be concluded that they did not need it. The number of students who believe that they could not consult with the teacher during any type of learning is negligible.

The students think that they have better mastered the chapters provided by the Program of the Computer Science and Informatics course during traditional learning. 74.81% of students fully agree that they have mastered all chapters.

That percentage is slightly lower in hybrid learning and amounts to 56.67%. (Chart 2.)

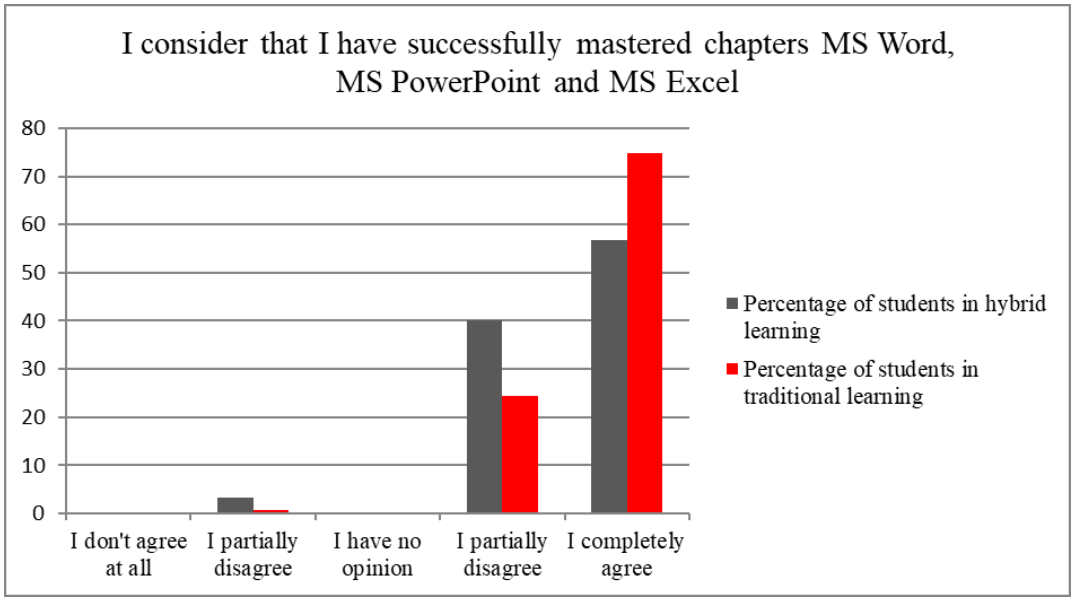

Chart 2. Comparative presentation of the percentage of students in hybrid and traditional classes showing the mastered material

Presentation of results obtained by statistical analysis of summative grades

By looking at the numerical summative grades that exist in the electronic diary, it can be concluded that the average grade of students in the teaching chapters of MS Word, MS Excel and MS PowerPoint is higher in traditional than in hybrid learning. The average grade in the teaching chapters covered in the second semester is 4.11 in hybrid learning, while in traditional learning it is 4.48. (Chart 3.)

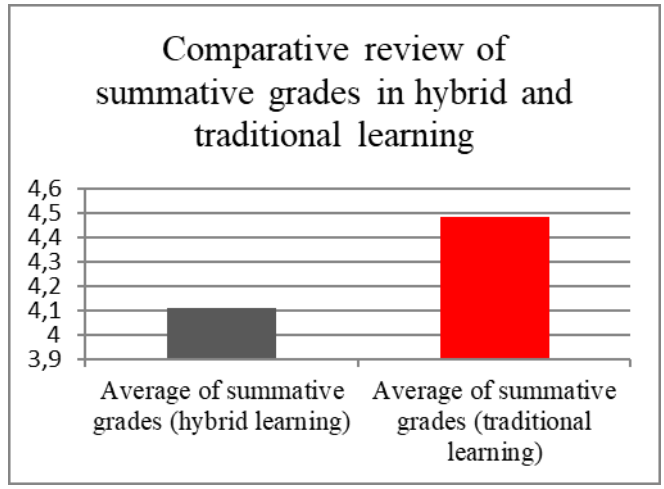

Chart 3. Overview of summative grades - MS Word, MS Excel and MS PowerPoint

Presentation of the results obtained from the analysis of formative grades

Formative grades are often a better indicator of student progress than summative grades. Table 1 shows a selection of formative grades divided into three chapters that are covered in the second semester. By analyzing the table, it can be concluded that the students mastered the material better in traditional learning. 63.45% of students (hybrid learning) got the highest grade in the teaching area of MS Word, and even 78.09% in traditional learning. As for the teaching chapter MS Excel, the situation is similar. 58.75% of students got the highest grade in hybrid learning, while 68.35% were slightly higher in traditional classes. In the chapter of MS PowerPoint, the highest level of grades was obtained by students in traditional learning (92.05%). The percentage of students with intermediate and lower formative grades increases in hybrid learning.

Table 1. Comparative presentation of formative grades in hybrid and traditional teaching in the areas of MS Word, MS Excel and MS PowerPoint

Selection of formative grades in MS Word, MS Excel and MS PowerPoint	**Hybrid learning**	**Traditional learning**
The student independently creates and formats a digital document and more complicated tables. Effectively applies complex options when working with text. He/she shows a strong interest in the teaching area and submits homework within the stipulated time. It is recommended that the student continue to work successfully as before and to show interest in additional work.	**63.45%**	**78.03%**
The student independently creates and formats a digital document and simpler tables. It applies simpler options when working with text. He/she mostly fulfills the teacher's requests and submits homework on time. It is recommended that the student, with the help of the teacher, applies more complex options when working with the text.	**32.36%**	**19.27%**
The student creates a digital document with the help of the teacher. He needs additional support in his work. He does not submit homework on time or it is incomplete. Often absent from class. It is recommended that the student join the supplementary classes.	**4.19%**	**2.70%**
The student effectively plans and creates a table in MS Excel, enters data into the table, uses and combines formulas and functions. Finds the best solution for creating charts depending on the type of data. He actively participates in class discussions, solves homework on time and behaves well. It is recommended that he continue to work in the same way and deepen his knowledge by joining additional classes.	**58.75%**	**68.35%**

The student plans and creates a table in MS Excel, enters data into the table, uses simpler functions for addition, mean value, minimum and maximum. Creates simpler charts. Participates in discussions and submits homework on time. It is recommended that, with the help of the teacher, he/she practices creating graphs with different types of data, to encourage his creativity and show more interest in the subject.	**39.25%**	**30.55%**
The student creates a table with the help of the teacher. He can write simpler formulas with basic arithmetic operations. Can't use functions. Creates simpler graphs with teacher help. It is recommended to join supplementary classes.	**2.00%**	**1.10%**
The student knows and effectively uses the rules for making a presentation. It can format text, add tracks, animations and transitions, insert hyperlinks and adjust the presentation for public display. Very successfully finds digital material for multimedia presentation. Respects copyright. He/she has a good performance in presenting. It is recommended that the student continue to study successfully and join additional classes.	**73.06%**	**92.05%**
The student knows the rules for creating a presentation. It can format text, add tracks, animations and transitions, insert hyperlinks and adjust the presentation for public display. He needs the teacher's help in finding adequate material for creating a multimedia presentation. Respects copyright. A student needs support during public speaking. Cooperates with other students in group work. It is recommended that the student show more creativity and relax during the presentation.	**23.56%**	**5.02%**
The student creates a presentation on a given topic. He/she cannot independently choose adequate material for a multimedia presentation. Formats the text but shows difficulties in using animations, transitions and inserting hyperlinks. It is necessary to join supplementary classes.	**3.38%**	**2.93%**

CONCLUSION

Based on the results obtained in this paper, the following can be concluded:

- The results of the analysis of the survey showed that the students mastered the intended material better in traditional learning. There is a higher percentage of students who declared that the teaching material and the teacher were more accessible to them in traditional classes. Also, the students think that the material was more interesting to them and they turned in their homework more regularly. A comparative analysis found that students who worked in traditional learning achieved better results in individual chapters that are covered in the second semester.
- The results of the analysis of summative grades showed that the mean numerical grade that shows student achievements is higher in traditional compared to hybrid learning.
- The results of the analysis of formative grades showed that the level of student progress was higher in traditional than in hybrid learning.

It can be concluded that: *Secondary school students show better achievements in traditional than in hybrid teaching*.

Traditional and hybrid learning have their advantages and disadvantages. The fact is that the students are used to attending the classical type of teaching in the classroom, so the results of this work are in accordance with that. The chapters in the second semester required intensive work with the teacher, the "living word", demonstration and greater student motivation through the teacher's presence. It is necessary to prepare interactive learning materials, mandatory supplementary and additional tasks, homework deadlines, video materials with detailed instructions for students and provide a platform through which students will feel as if they are in a class at school. In that case, we can talk about equalizing the achievement and level of progress of students in traditional and hybrid learning.

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METHODOLOGICAL BASICS FOR CREATING A RESEARCH PROJECT ON THE EXAMPLE OF CREATING A MASTER'S THESIS ON THE TOPIC - SAFETY AND PROTECTION OF PEOPLE AND WORK PROCESSES IN THE PIROT FREE ZONE

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Abstract

The paper will deal with a research project development model on the topic "Safety and protection of people and work processes in the Pirot free zone." Through that topic, the research problem, research subject, research goals, hypotheses, research method, scientific and social justification and research plans.

Key words: model, project, problem, subject, goals, hypotheses, security and protection, Free Zone Pirot.

INTRODUCTION

Free zones in the Republic of Serbia are a physically fenced and marked part of the territory, equipped with infrastructure, where production and service activities can be carried out with certain stimulating benefits. They were developed in the Republic of Serbia at the end of the nineties of the 20th century with the aim of creating a more favorable environment for the development of the Serbian economy and improving the competitiveness of Serbian products.

There are a total of nine free zones in the Republic of Serbia. One of the Free Zones is the Pirot Free Zone (SZP). The problem investigated in this paper was related to "Safety and protection of people and work processes in the Pirot Free Zone."

The safety and protection of people and work processes in SZP is in the effective implementation of measures, actions and procedures in conditions of increased contamination of people, space, machines, assets, storage space, means of transport in the conditions and time of the COVID-19 pandemic. All these

parameters affect the overall safety and protection of people and work processes in SZP. Certainly, the overall safety and protection of people and work processes in SZP is greater and at a higher level, if all prescribed and preventive and necessary measures are fully known and adequately implemented by all employees in the production process.

It is known from theory that if all employees in SZP adhere to all prescribed and ordered measures, actions and procedures that are prescribed for the safety and protection of people and work processes in the specific zone, that the negative impact will be minimal. Also, it is known that the negative impact on the safety and protection of people and the work process in SZP will be maximum if all employees in the production process do not fully comply with all prescribed measures, actions and procedures.

It is also known from practice that it is necessary to constantly act on the awareness of every employee in the SZP so that everyone, without exception, fully respects and implements the prescribed and ordered measures, actions and procedures in the right way. If there were any failures in the implementation itself, the danger should be eliminated as soon as possible and the cause that produces unwanted consequences should be eliminated. Personnel affected by the COVID-19 virus should be referred to a health facility for adequate medical treatment as soon as possible.

Based on the location of the problem, the essence of the problem and hypothetical positions, it was possible to ask the following basic question: "How to implement (realize) the safety and protection of people and work processes in the Pirot Free Zone during the COVID-19 pandemic?"

There are well-known cases of how the safety and protection of people and work processes was implemented in different countries of the world, starting with China, the United States of America, the Russian Federation, the United Kingdom, France, Germany, Italy and all other countries of the European Union and other countries of the world. And there were different interpretations, starting from the cause itself, the way of transmission, to a reliable and appropriate vaccine and adequate therapy. Even today, there are numerous ambiguities and disagreements about certain details of the measures taken. We certainly know that here in the Republic of Serbia, despite the measures taken, a large number of people lost their lives during the period of the COVID-19 pandemic.

The importance of researching this problem for the theory itself is great. Despite the passage of time, some theoretical positions remained undefined. How the virus itself originated is still shrouded in mystery. Was it created naturally

or in artificial (laboratory) conditions? Also, the effectiveness of individual vaccines has not been fully clarified. In the coming period, the theoretical provisions on the very occurrence, causes and method of adequate therapy in combating the COVID-19 pandemic should be unified and harmonized.

Also, the importance of researching this problem for practice itself is great. Generally, a large number of modern successful countries of the world have suffered great human losses. A large number of countries in the world are now trying to make up for the economic backlog during the period of the COVID-19 pandemic. Solidarity and non-solidarity between individual countries of the world were also shown. Some have gained experience in relying on their own forces and a small number of friendly-oriented countries.

The research of this problem has a special importance for the development of the scientific research methodology itself. Those countries of the world that paid the necessary attention to the development of their own science and methodology very quickly managed to produce appropriate vaccines, to create adequate tests for the rapid detection of the presence of the virus. Thus, the success of the fight against the virus was at a higher level. However, the number of people who lost their lives in the fight against the COVID-19 pandemic was too great. Those countries of the world that will invest more money in science, research and the methodology itself, will certainly have more results for success in the fight against these or similar diseases. Certainly, the consequences for their population will be much less. Therefore, the conclusion follows that certainly in the period of absence of illness, the necessary amount of material means and resources should be allocated for research and development of the methodology itself and scientific methods in research.

METHODOLOGY

Theoretical determination has a fundamental function, because it provides a comprehensive insight into the scope and content of the subject of research. Through this determination, it is necessary to: differentiate the scientifically known from various marginal knowledge and from the scientifically unknown; separate the concepts that are included in the subject of the research and, through the definition of the concepts, specify the meaning and content of the subject of the research. The theoretical determination of the research subject contains two parts: knowledge analysis and definition of terms.

Analysis of knowledge:

a) Proven scientific knowledge is related to the very concept and definition of Free Zone in the country, business in free zones, existence and total number of free zones in the Republic of Serbia. The Pirot Free Zone is known and defined. The space it covers. It is known exactly who does business within the SZP. The safety and protection of people and work processes in SZP is defined. The theoretically defined COVID-19 pandemic. Duration and prevalence. Some earlier pandemics that affected the population of the globe are known.

b) Knowledge that has not been verified is that knowledge related to the safety and protection of people and work processes in free zones, and especially SZP during the COVID-19 pandemic.

v) Experiential knowledge is that which has been experienced in practice in the fight against previous pandemics that have affected the world in the previous period and refer to the way of organizing the safety and protection of people and work processes in the conditions of previous pandemics. Such experiences should be looked at with possible use in new conditions and in the fight against the COVID-19 pandemic.

g) Knowledge that does not exist, is what should be obtained through research. In this particular case, it refers to the safety and protection of people and work processes in the Pirot Free Zone during the COVID-19 pandemic.

The safety and protection of people and the work process in SZP includes all positions of employees in the production process and staying in the area of SZP. This includes external physical technical security and all entrance gates for loading and unloading goods, finished products and other necessary items for the normal functioning of the SZP in all conditions.

The safety of people in SZP during the COVID-19 pandemic includes the safe functioning of individuals in all positions in the production process in SZP.

The protection of people and work processes in SZP during the Covid-19 pandemic includes the necessary and necessary measures that are taken in order to smoothly perform the prescribed duties in the production process caused by the COVID-19 pandemic.

Free Zone Pirot is one of the SZ in the Republic of Serbia.

SZ "Pirot" includes:

- Michelin – Tigar Tires, production of car tires,
- Tigar footwear, production of rubber footwear,

- Tigar technical rubber, production of rubber products,
- D Company, production of molds for the rubber industry and
- STR Stojanovic.

The time of the COVID-19 pandemic is the period in which the employees of SZP were under special (special) treatment, from 2019 to May 2022 in the production process.

Safety and protection of people and work processes in SZP at the time of COVID-19 can be: large, medium or small, measured by the number of persons (%) who are absent due to illness and are removed from the production (work) process.

It is large if it is more than 95 to 100% in the workplace. It is medium if it is from 80 to 95% at the workplace. Small if less than 80% are in the workplace.

It includes all positions of employees in the production process and staying in the SZP area. This includes external physical technical security and all entrance gates for loading and unloading goods, finished products and other necessary items for the normal functioning of the SZP in the time of COVID-19.

Safety is measured and monitored through indicators for each workplace. The protection of people and work processes in SZP is reflected and measured through indicators for each workplace.

DISCUSSION

The main goal of this research is to arrive at certain findings that have scientific and social value. The general goal is to use certain methods to find out how to implement (realize) the safety and protection of people and work processes in the PIROT Free Zone during the COVID-19 pandemic.

The following will be scientifically described, classified and explained by the scientific procedure and the application of scientific methods:

- It will be scientifically described "how to implement (realize) the safety and protection of people and work processes in SZP during the COVID-19 pandemic;"
- Scientific classification (classification and typology) of measures taken for the safety and protection of people and work processes in the SZP during the COVID-19 pandemic;

- The connection between the application of the prescribed and required measures (wearing a mask, protective gloves, hand disinfection, spray, alcohol, keeping the necessary distance and other measures) and absence from work and the number of infected and sick people will be scientifically explained.

The practical objectives of the research allow to find out how to implement (realize) the safety and protection of people and work processes in SZP during the COVID-19 pandemic. Also, the aforementioned knowledge can be used to realize the safety and protection of people and work processes in other Free Zones in the Republic of Serbia during the COVID-19 pandemic and in other similar situations in our country and in the world. The life and health of employees and the production process as a whole largely depend on the application and implementation of measures.

CONCLUSION

The way of research, as well as the methods used in that process, are conditioned by a clearly defined research problem, theoretical and operational determination of the research subject, established hypotheses and the complexity of the topic being discussed and studied. The necessary literature, master's theses, surveys that were done in previous years, as well as all the necessary material in written, electronic, video or audio form, which talk about the given topic, will be studied.

Data collection methods: Bearing in mind the multidisciplinarity of the researched topic, philosophical, general, special (logical) and individual (empirical) scientific methods were used in this paper. Of the philosophical methods, the positivist method was useful, because it helped to approach some phenomena and some attitudes that are quantifiable. In addition to them, rationalist and dialectical methods were used, which enabled the description of facts, the relationship between phenomena and indicators. Of the logical, that is, special scientific methods, the methods of analysis and synthesis, induction and deduction, abstraction and concretization, methods of generalization and specialization, as well as proof and refutation were used. Of the individual (empirical) methods, the methods of observation, examination and content analysis were used. The technique of the examination method was surveying and interviewing.

Data sources: The very nature of this scientific work required the collection of data from different (types of) sources. All specific data sources are listed from the existing bibliography. The most important ones will be highlighted here:

- statistical reports,
- analyzed written surveys,
- master theses of various universities,
- publicly available books in electronic form,
- media contents (internet editions, newspaper articles).

It is also extremely important that a survey of employees in SZP was conducted. These are certainly primary data, i.e. data obtained from the persons themselves who are employed in the Pirot Free Zone. Analysis of various texts, textbooks, master's theses, newspapers and other written forms were secondary sources of data, and they related to this topic. These secondary data sources were for the most part open source. The survey was anonymous.

The scientific justification of this research is reflected in the contribution to methodologists, analysts, managers and scientists in general when it comes to this specific topic. This paper can be an incentive to researchers for further, deeper and broader research on this specific topic, and it can also be a document for comparing the situation in the past and possibly similar conditions in the future.

Given that the scientific goals were correctly set in this research, starting with scientific description, scientific classification and scientific explanation of connections, this research is also socially justified. If safety and protection measures for people and work processes in the Pirot Free Zone are better known and applied during the COVID-19 pandemic, all employees will be better prepared to eliminate threats in the future in case of similar situations. All employees should be open to cooperation and giving recommendations and proposals for solving any crisis situations, which may not have been foreseen in the plans and instructions for dealing with various cases. This would make this research even more socially justifiable.

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APPLICATION OF INFORMATION TECHNOLOGIES IN PUBLIC UTILITY COMPANY "NAISSUS", NIS

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Abstract

Information technology is present in many segments of life and work. Within this paper, the application of information technology is presented in order to ensure efficient business operations, efficient disposal of resources, quality work organization and work planning, and all in the ultimate goal - quality water supply of the city of Nis. By building a reliable server system in 2009, as well as a link connecting 2 locations where JKP "Naissus" is located (location Management and location Mediana), JKP" Naissus" has united the IT network, which provides the necessary preconditions for building advanced IT services, among them is **Microsoft Office SharePoint Server 2007.** The technologies on which Share Point is built offer great opportunities to connect users, teams and knowledge, offering all employees insight and further use of numerous information. The Corporate Portal of JKP "Naissus" is an example of how properly selected server technology and quality implementation can solve problems in the functioning and mutual cooperation within and between organizational units of JKP Naissus.

Key words: information technology, server system, Microsoft Office SharePoint Server 2007

INTRODUCTION

In addition to technology specific to the activities of the company, it is necessary to properly select and apply technology that is equally important for the survival and success of all companies and that is information technology.

Information technologies is a significant factor of modern management and a key resource for making strategic business decisions, their operationalization and control of the performance of decisions made in this way, and it is as valuable as the user is able to use it.

Considering that the Naissus water supply system supplies over 300 000 users, that there are over 60 000 water meters, keeping in mind the obsolescence of the system because most of the network is 30-40 years old, the distance to the sources on which the water supply of Nis is based, Management of Naissus, recognized this situation for the introduction of information technology in order to efficient and quality management of the water supply system.

The application of information technologies in JKP "Naissus" is in order to rationally use the capacity, resources and energy to improve the efficiency and effectiveness of processes and activities related to water supply, all with the aim of quality water supply of the city of Nis.

USE MICROSOFT OFFICE SHARE POINT PORTAL SERVER

Due to the rapid and accelerating development of applied technologies that change the way of business communication, as well as the growing amount of data required in the daily business of the company often face a challenge - all the necessary information exists somewhere in the organization, but it is difficult to find and use when needed. In order information to be useful, it needs to be organized, accessible, consistent. This is made possible by Microsoft Share Point. Using Microsoft Office Share Point enables: easier monitoring between teams, greater efficiency due to transparency and faster retrieval of information, efficient management of documentation due to possible easier browsing, as well as gathering a central database, because there is no loss of information.

CORPORATE PORTAL OF PUC "NAISSUS", NIS IN THE WATER SUPPLY SERVICE OF THE CITY OF NIS

Public utility company Naissus from Nis, deals with water supply and sewerage in the city of Nis. Water supply is provided from a number of sources

which, in certain periods of the year, are supplemented with processed surface water from the Nisava River.

Water supply system Studena - ″karst″ natural spring and pipeline with facilities, capacity up to 340 liters per second, Water supply system Ljuberađa - Nis, through karst natural springs (Ljuberađa, Divljana, Mokra, Krupac) and supply pipeline with facilities up to 1450 liters per second , Mediana system, groundwater source fed with previously purified water from the Nisava watercourse, capacity up to 600 liters per second.

Situations at karst springs are closely related to the meteorological situation. Information about:

- water quality at the springs (turbidity, conductivity)
- quantities of water produced at springs at a given time,
- weather conditions at springs, including the abundance of springs due activities undertaken in order to ensure a sufficient amount of hygienically correct water and its distribution to consumers,

if they are up-to-date and accessible to teams of employees, they are crucial for a normal water supply.

Troubleshooting is a priority work in order to maintain the functionality of the system. Quality records of failures, including the address where one goes to the field, description of failures as well as information on their completion, their recording in certain systems are prerequisites for any future quality analysis.

Figure 1: Title site-corporate portal
Source: Corporate portal JKP „NAISSUS"

Figure 2: In-site navigation
Source: Corporate portal JKP „NAISSUS"

As in fig. 1 The title site-corporate portal can be seen from the sites, the following are open on the Portal: 1. Finance (activities of the Sector for Finance and Billing) 2. Maintenance of VIK (activities of the Sector for Maintenance of water supply and sewerage network) 3. Production (activities of the Sector for Production and Distribution of Water) 4. SANIN for systematic analysis of NIVOS and NIKAS) 5. IT Sector (activities of the Sector for Information Technologies).

The zone is marked with a green rectangle and the number 1, in Figure 1, in which the names of all sites on the Corporate Portal are arranged from left to right. Each time a site is selected, its title page with Navigation within the site on the left appears below (Figure 1, No. 2 in green in the picture). Navigation within the site is shown in Figure no. 2- Navigation within the site and is always in the form of a vertical panel on the far left side of the page -it is the first level of access to the functionalities of each site.

An important feature of the corporate Portal is that the work on it is authenticated. All users (employees of JKP Naissus) who access computers in JKP Naissus network, have already formed a username and password that serves them to access the computer at work, e-mail, messenger, and other services within the JKP ,,Naissus,, network.

Figure 3: User identity. Source: Corporate portal JKP ,, NAISSUS,,

The authentication system that Microsoft has built into SharePoint Server works in conjunction with Windows Server, which already identifies the user when you turn on your computer or log on to Windows. A welcome message that is printed in a line at the top of the screen (Figure 3-User identity is the first thing to check every user who enters the portal. Corporate Portal is closely based on MS Windows Domain system for user authentication.

WEBSITE OF THE SECTOR FOR WATER PRODUCTION AND DISTRIBUTION

Fig. 4 shows the title page of the portal, and Fig. 5 overview of the current situation at the springs.

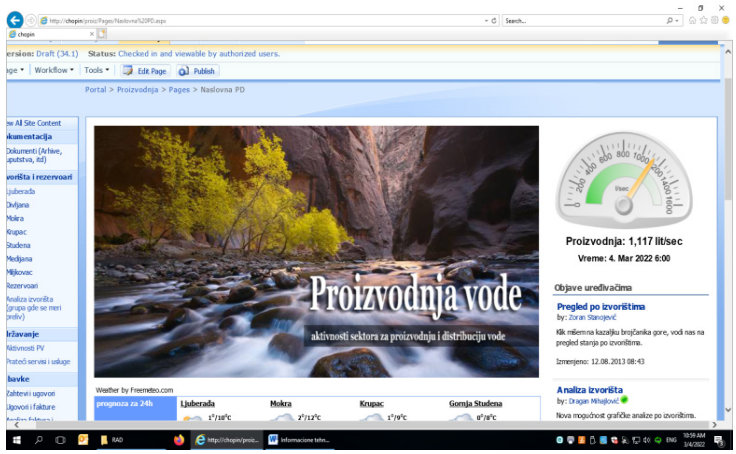

Figure 4: Portal cover page - Source: Corporate portal JKP ,, NAISSUS,,

Mouse click on the arrow, leads to a large overview board consisting of clocks that show the current state of the sources, namely: engaged flow and turbidity for each source individually. The website of the Water Production and Distribution Sector is intended to support the functioning of the Water Production and Distribution Sector as well as a source of information from this Sector for the entire JKP ,,Naissus,,.

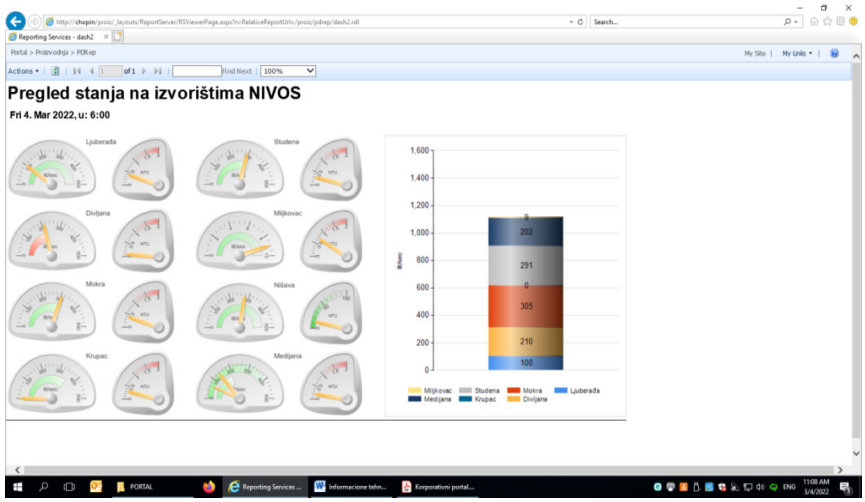

Figure 5: Overview of the current situation at the spring
Source: Corporate portal JKP ,, NAISSUS,,

Every 6 hours, the head of the shift in the Sector for Water Production and Distribution "calls out" all parameters of importance by springs and important water supply facilities in the city. For data entry needs and for a specific source be chosen concretely source (or reservoirs) for which values will be entered, and then from the "New" drop-down menu (Fig. 7-Data overview, No. 1 in the above figure) and option ,, Add item,,

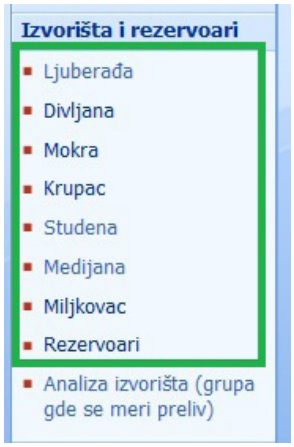

Figure 6: Sources and reservoirs
Source: Corporate portal JKP ,,NAISSUS"

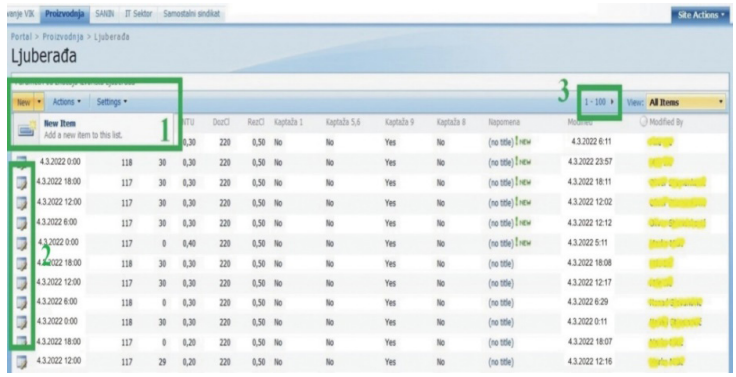

Figure 7: Data overview
Source: Corporate portal JKP ,,NAISSUS"

On the mask for changing the existing data (Fig. 8- Mask for entering / changing data), we arrive from the table view by selecting the symbol at the beginning of the row (Fig. 8 No. 2 in the figure) that we intend to change. On the front page the data carrying the current day is filtered.If the user so wishes, he can change the date for which the source data is displayed by entering the date via the date selector.

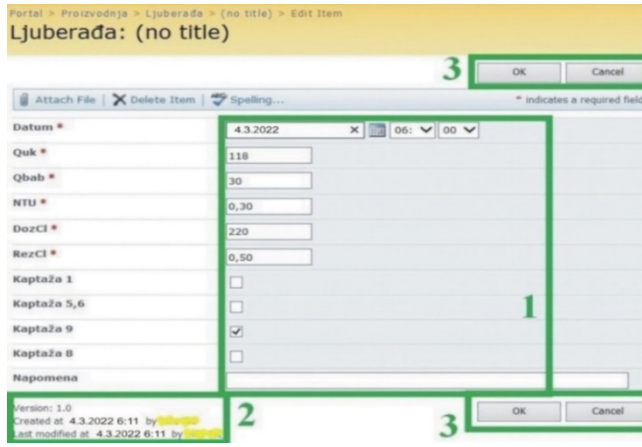

Figure 8: Mask for entering or changing data - Source: Corporate portal JKP „ NAISSUS"

ANALYSIS OF SOURCES ON WHICH FLOW IS MEASURED

A panel has been developed to analyze the sources where the overflow is measured. The same source is placed symmetrically with itself with a distance of one or two years in relation to the selected period (Fig. 9 Analysis of springs where the overflow is measured, No. 4). The yield of the sources is assessed mainly taking into account the period of the year.Graphs are always observed in pairs: The upper graph is always in the selected period, while the lower one is one or two years back in relation to the period of the upper graph (Fig. 9 No. 3).

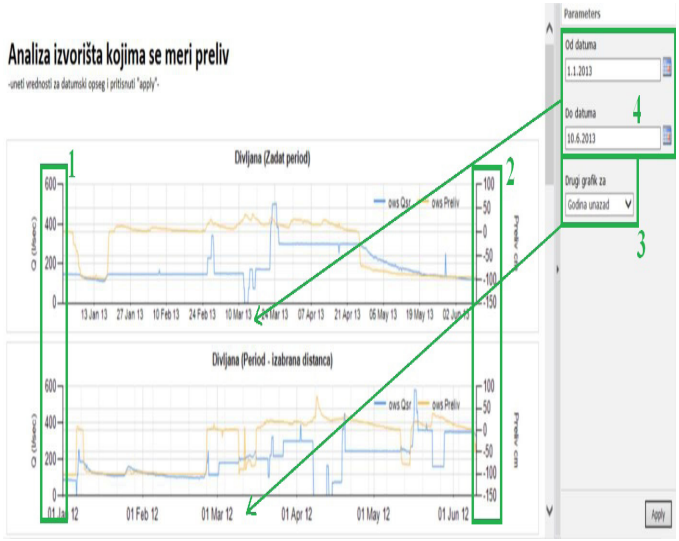

Figure 9: Analysis of springs where the overflow is measured- Source: Corporate portal JKP ,, NAISSUS,,

METEOROLOGY

Assessment of the situation regarding further water supply from the aspect of quantity and quality of water at karst springs is closely related to the meteorological situation,because weather conditions affect the water supply. More detailed precipitation administration in catchment areas is important for NIVOS, in order to predict the abundance of springs, as well as water quality. Any changes that are made will be immediately visible to users at this location. Source names are links at the same time. By clicking on the source, we can see the current weather situation at each source separately and the forecast weather situation in the future.

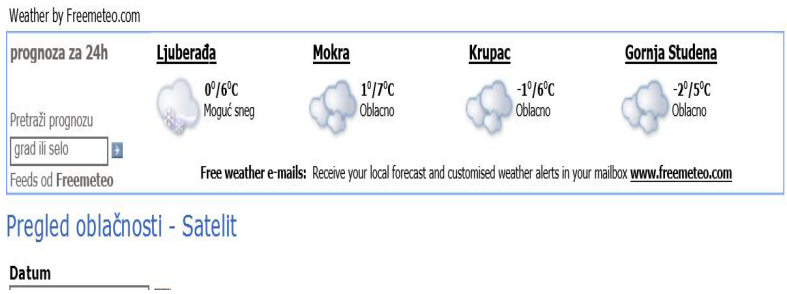

Figure 10: Element of metrology on the PIDV website - Source:Corporate portal JKP ,, NAISSUS,,

MAINTENANCE OF WATER SUPPLY FACILITIES

The work orders of the PIDV Sector are divided into Activities in the core business (PV activities) and works that resulted from the subject PV Activity (Supporting services). If the PV Activity is of such a nature that it is necessary to involve an external service provider, then its activities will be found in "Support Services and Services". The table of water production activities looks standard and the table has a link "Add new" (Fig. 11, No. 2) which leads us to the form for adding a new work order PV activities.

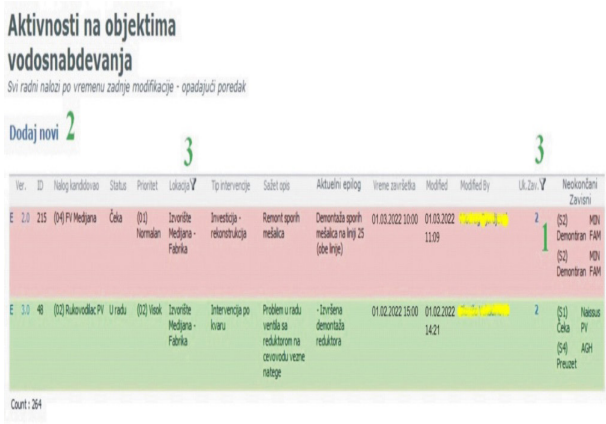

Figure 11: Table of water production activities -Source:Corporate portal JKP ,, NAISSUS,,

CONCLUSION

The technologies on which SharePoint is built offer great opportunities to connect users, teams and knowledge, offering all employees the insight and continued use of a lot of information. The Corporate Portal in JKP "NAISSUS" is in the function of providing quality and reliable water supply.

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Mihajlović, D., 2013 CORPORATE PORTAL OF PUC ,, Naissus ,, Niš.

PREDICTION OF ROBOTIC PLATFORM MOVEMENT IN UNDEFINED STRUCTURED TERRAIN

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Abstract

Robotic platforms in teaching processes have existed for years. Technological progress and the development of new technologies and systems allow us to make ideas that were science fiction yesterday a reality today. In this work, we use a modular differential robot platform designed in our computer laboratory under the working name UNI 1 (UNI ONe). In the realization of the platform, new technologies and materials were used. The modularity of all elements of the platform was emphasized. By replacing or adding modules (drive group or sensor assemblies), the type of platform as well as the functionality changes very quickly. This allows us, depending on the type of surface, to equip the platform with elements that are suitable for the given terrain structure and the given movement prediction. The designed platform allowed us to conduct experiments predicting robot movement in an undefined unstructured space.

Key words: differential robot platform, modular robot platform, motion prediction

INTRODUCTION

In order to perform experiments in our laboratory in accordance with modern teaching processes and technological requirements, it was decided to design and build a new robot platform (Panah & Panh, 2010) (Fox, Burgard, & Thrun, 1999). Thus, our many years of experience in working with different types of platforms would give us the right model needed for modern robotics teaching. Generic robo-platforms intended for educational processes are generally not de-

signed for changing the motor unit or drive wheels. The equipment of the sensor groups is fixed or has a limited range of replacement elements. All of the above is a limiting factor in the experimental possibilities of a robo platform. Dealing with these problems for many years at the robotics department, we gathered a fund of solutions that were applied in the design and realization of the UNI1 (UNI ONE) modular robot platform. The paper does not deal with the platform itself, but some elements should be apostrophized because of their importance.

PLATFORM ELEMENTS

The base of the UNI1 platform is designed so that the drive motors can be easily replaced, Figure 1. The ultrasonic sensor and motor unit 2 are shown in Figure 2. With the motor unit, we also replace the wheels depending on the needs dictated by the terrain structure, Figure 3

Figure 1 Drive motors type 1

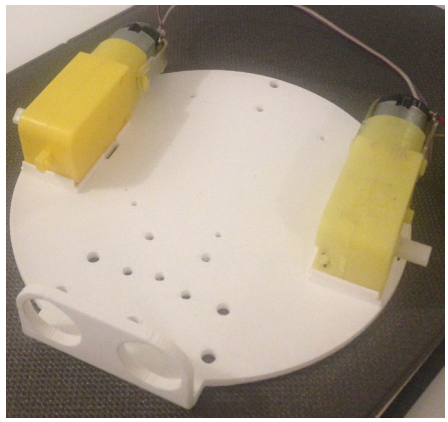

Figure 2 Platform UNI1 with drive motors type 2

Figure 3 Wheels that have been used

Figure 4 shows the electronic components of the platform itself.

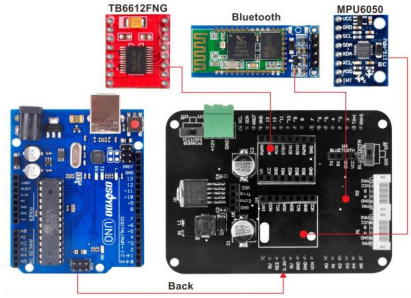

Figure 4 Platform electronic components

Figure 5 shows the realized platform.

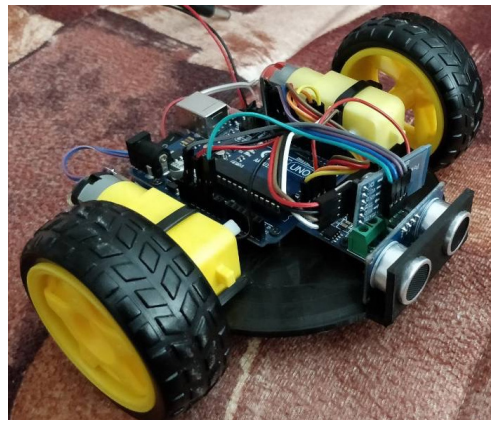

Figure 5 Platform equipped with type 3 wheels and ultrasonic sensor

SOFTWARE PLATFORMS

The software is relatively complex because they have to be synchronized (paired) all the time, Figure 6.

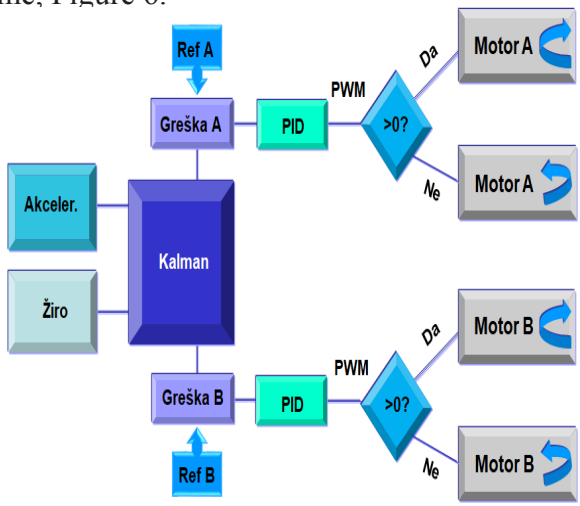

Figure 6 Block diagram of the software system

Those systems (motor groups) can be precisely controlled by a PWM signal. The motors are equipped with Hall encoders, which allows us even greater control. Of course, everything works under PID, (proportional-integral-derivative controller) figure 7.

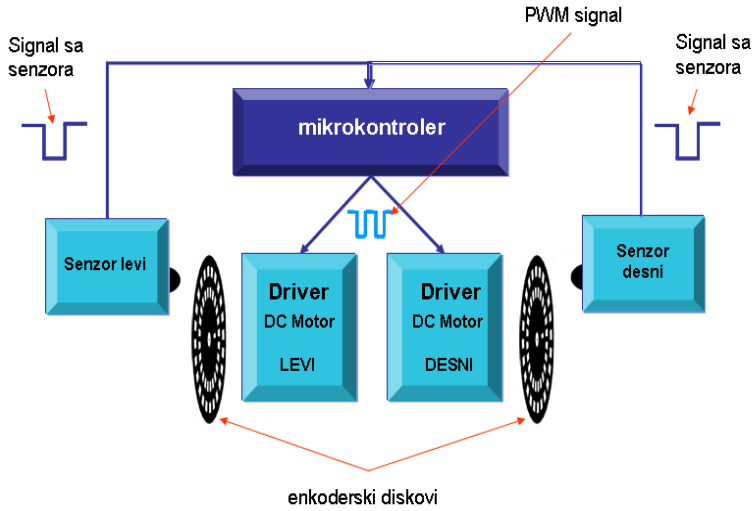

Figure 7 Engine control scheme

That's why we also use the Kalman filter to filter the data generated by the sensors to a useful input into the system. All sensor measurements and physical laws of motion are used to generate the estimated value (Faragher, 2012).

The Kalman filter uses different states where the value of the previous state is included in the estimation of the next one. The estimation often becomes more accurate and the filter works recursively with three states in the calculations, past, present and future (Kleeman, 1996).

SCANNING OF ENVIRONMENT

In order for the platform to be able to move independently in an undefined environment, we use an ultrasonic sensor group (Rodin & Štajduhar, 2017).

Rotating around its axis, the sensor scans the environment. We achieve this by rotating the wheels in the opposite direction, at a constant (uniform) engine speed. This creates a torque that rotates the platform around the vertical axis, Figure 8. The force Fml (left engine) and the force Fmd (right engine) are of the opposite direction and the same intensity and as such create a coupling of forces that conditions the rotation of the platform along a path whose diameter is the distance between the wheels of the differential drive.

We calculate the moment of force using the classic formula:

$$M = F * r$$

since we have two forces acting on the platform the total moment of the forces is:

$$M = M_{ml} + M_{md}$$

from which follows:

$$M = F_{ml} * r + F_{md} * r \quad \Rightarrow \quad M = r(F_{ml} + F_{md})$$

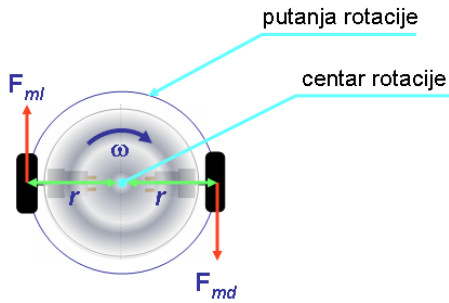

Figure 8 Coupling of forces that conditions the rotation of the platform around the vertical axis

Figure 9 shows the robot platform environment.

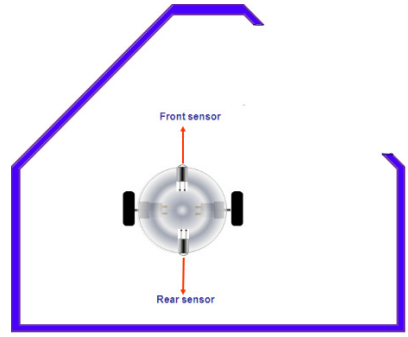

Figure 9 A differential robo platform in the environment

To scan a given environment, the platform rotates around the central axis, Figure 10. If v1 = -v2, then the radius R is zero and the robot rotates around CA (rotates in place). The rotation of the platform is exactly 4s. By scanning the environment (a full 360º circle), signals are obtained from ultrasonic sensors (located in the front and rear).

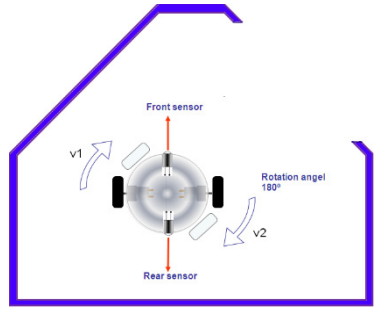

Figure 10 Rotating a differential robo platform in an undefined environment

During this time each sensor has 25 readings (scans). This means that every 8ms it performs a new scan as shown in the calculation formula (1).

$$t_s = \frac{t_r}{n_r} = \frac{400}{50} = 8ms \quad (1)$$

where are:

ts time of scaning

tr time of rotation

nr number of rotation

It has been experimentally proven that this is a satisfactory level of accuracy. From the sensor, the signals are transferred to the PLC, to the memory module. The algorithm that was written analyzes the memory content, the footprint. A memory array dump (Olajide, Trafford, Akmayeva, & Shoniregun, 2012) shows a numerical number that gives (after conversion) the position of a point and a complete scan image of the robo platform's scanning environment, Figure 11 and Figure 12.

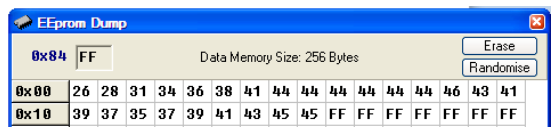

Figure 11 Memory dump (half scan, rear sensor)

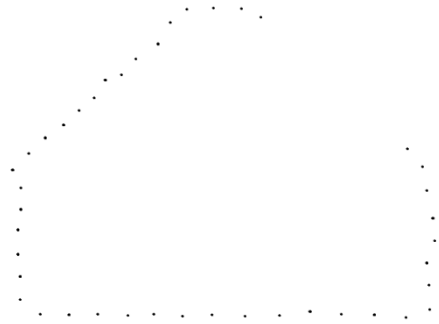

Figure 12 The resulting image of the scanned environment

The memory layout area consists of two segments and an empty area, Figure 13.

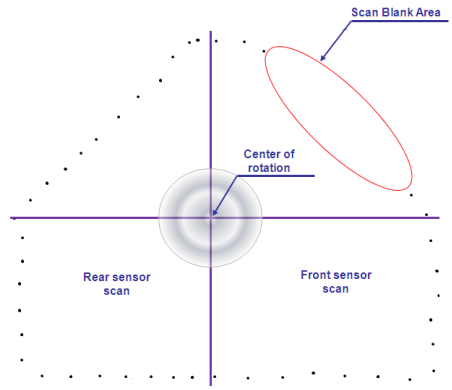

Figure 13 Scan environment with empty area

RESULT OF THE SCAN

The empty space (new point) is the point where the robotic platform should be positioned to scan the new environment. In other words, the platform is placed in its original position (rotation by 180 degrees). The prediction of the robot's movement is calculated based on the scan of the front sensor (Chivarov, et al., 2021). There are 25 points of scan data in memory for 180 degree scanning. A simple formula that gives a scan (each item) made at an interval of 7.2 degrees, respectively, fig. 14.

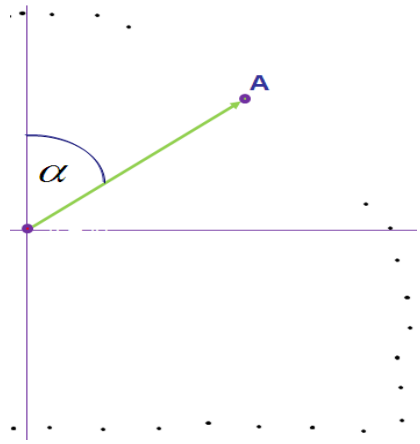

Figure 14 Memory dump (half scan, rear sensor)

$$\alpha = \frac{\varphi_r}{n_r} = \frac{180}{25} = 7.2° \quad (2)$$

where are:

α - ugao pojedinačnog skeniranja

φ_r - ugao rotacije

nr - broj rotacije

Based on the previous postulates, the formula that calculates the angle the robot platform should take in relation to the current stationary position (Sun, Guan, Chang, Li, & Gao, 2019). The angle of rotation is expressed in degrees.

$$\alpha = (Nscan) + \left(\frac{Nempty}{2}\right) * 7.2^{*} \quad (3)$$

Nscan - number of scan items

Nempty - number of empty scan items

* single scan angle (formula 2)

The microcontroller program is defined to rotate the robot platform in a period of 2.22ms by one degree. In the example presented in this article, the required angle is 46.8 degrees. In order to achieve the required angle, the platform

must rotate in a period of 104 ms. Central rotation, it is necessary that both DC electric motors work simultaneously, but with opposite rotations of the wheels. It is known that the electric motor is of great importance in the differential operation of robotic platforms, it is necessary to match the speed of the wheels. The part of the code used is shown below:

```
//encoder routine
if (input(PIN_B1) && (!flagd))
{
flagd=1;
distd++;// distance
ratecountd++;// reset all interrupts}
if (!input(PIN_B1)) flagd=0;
if (input(PIN_B2) && (!flagl))
{
flagl=1;
distl++;
ratecountl++;
}
if (!input(PIN_B2)) flagl=0;
//end encode counter
```

PLC uses PVM (Pulse Width Modulation) so the microcontroller generates PVM to achieve precise control over electric motors (Kilani, Degardin, Laly, Lienard, & Degauque, 2013). Figure 15 shows the new position of the robot platform and the movement from the initial position to point A.

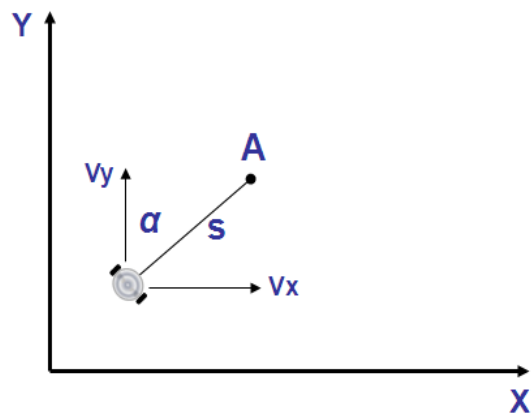

Figure 15 Image of the robot's new position

Prediction of the movement of the scanned object to the next point can be shown in Figure 16. Using formula (4,5,6) it is possible to predict the movement, Figure 16, without scanning the environment.

$$X = s_1 \cos \theta_1 + s_2 \cos(\theta_1 + \theta_2), \quad (4)$$

$$Y = s_1 \sin \theta_1 + s_2 \sin(\theta_1 + \theta_2), \quad (5)$$

$$\theta = \theta_1 + \theta_2 \quad (6)$$

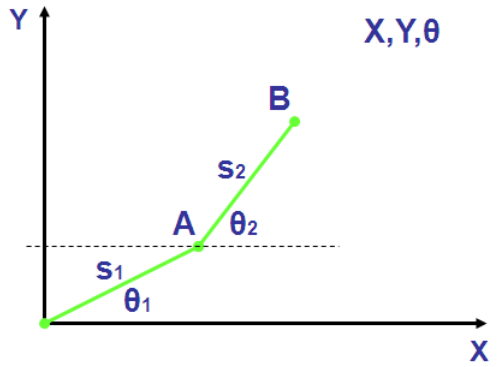

Figure 16 Point-to-point prediction of robo platform movement

From the starting point to point A, Figure 17 uses the average distance of the points in the boundary zone of the empty areas. The value is obtained by scanning.

Using the speed of the robot platform of 0.25 m/s, the engine operating time to reach the path can be easily obtained according to formula (7).

$$s = V * t \quad (7)$$

S – distance to point A,

V – speed of the robot platform,

t – engine operating time

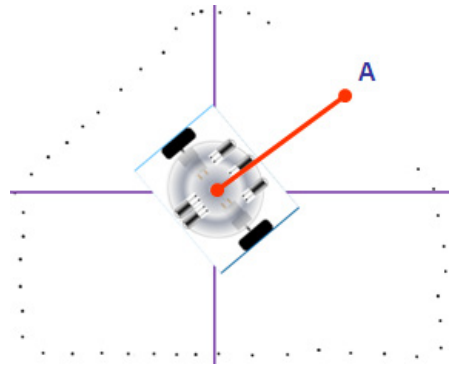

Figure 17 The penultimate phase of motion prediction

By placing the robot platform at point A, the process is completely completed, Figure 18. It is possible to repeat the cycle by the program itself or define the number of repetitions.

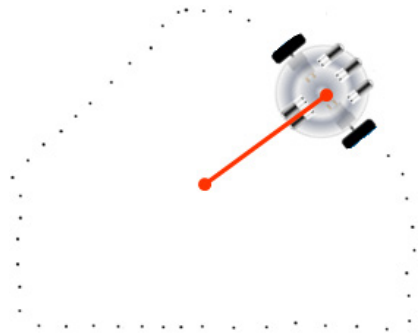

Figure 18 The last stage of movement prediction

CONCLUSION

With the robotic platform, we can scan the undefined environment in a simple way and set pointers for the movement of the robot platform. Equipped with two sets of ultrasonic sensors, the UNI1 platform can be used for a wide range of teaching modules in the fields of information technology, technical education, mechanics and electronics. Whether you want to introduce new solutions to mechanical shells, discuss sensors and actuators with your students using practical examples, or want to create a new robot program, a robot platform of this type (equipped with a motion prediction program) is an ideal starting point. The very construction of the robot platform UNI1 increases the motivation and interest of

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INTUITIONISTIC FUZZY AHP IN DECISION MAKING FOR EVALUATION OF THE FACTORS IN SUCCESSFUL INTERNET OF THINGS

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Abstract

With the rapid development of technology, the need for users to be online has increased. In recent years, the term Internet of Things (IoT) has been introduced, defining objects that can connect and transmit data via the Internet. The main indicators and the corresponding sub-indicators identified through the study are set aside for promoting a successful IoT transition in the business operations of the enterprises. As a result of the study, the multi-criteria decision-making method determines the degree of the importance of factors that affect performance and reduce some strains. The paper develops a decision support platform using the Intuitionistic Fuzzy Analytic Hierarchy Process (IF-AHP) to assess Difficulties factors in IoT. The study establishes which indicators enterprises that want to switch to the Internet of Things should be taken into account to speed up this transition by minimizing time and money losses. The results show that enterprises in the IoT process pay attention to technology, communication, privacy, and security criteria. We suggested important indicators and their order of significance to enterprises. This research shows that they are principal indicators of success: addressing, data management, network security, architecture, and design.

Keywords: Internet of Things; IoT; Multi-Criteria Decision-Making; Intuitionistic Fuzzy AHP

INTRODUCTION

The Internet of Things (IoT) is a network between things that can be addressed uniquely because the things in that network communicate using a common protocol (Mohammadzadeh, 2018). IoT transmits information to another object with data it receives from the environment, and this continuous connection is possible by increasing interoperability between physical devices (Andročec et al., 2018; Lelli, 2019). Interest in the Internet of Things is growing daily with the rapid development of technology. Internet of Things in the business sector is related to Industry 4.0 (Selim, 2021). The IoT connectivity concept can measure and optimize various business processes using sensors, wireless networks, large amounts of data, and analytical data processing. Enterprises that want to make the transition to the IoT face many difficulties. The ultimate goal of IoT is to enable commercial activities within the enterprise and outside the market, although there are challenges for companies to implement innovative concepts immediately. IoT gives the ability to control things (computers, networks, laptops, etc.) to develop products or services and ensure the delivery of a smart enterprise (Abdel-Basset et al., 2018). The decision-making process for IoT enterprises faces data inconsistencies and uncertainties. Although IoT has positive effects on businesses, it also has many obstacles. Many negative impacts need to be reduced or eliminated to ensure the successful delivery of IoT to businesses. The study evaluates the IoT framework. The proposed method improves decisions and services in the use of IoT by small and medium enterprises. Many authors have researched IoT recently (Uslu et al., 2019; Milošević et al., 2021). The paper consists of 4 sections. After the introduction, the methodology is given in the second section, and the results in the third. The last section provides a conclusion.

MATERIALS AND METHODS

Based on the literature review, this paper identifies six main influencing factors: technology, communication, privacy and security, job, legal regulations, and culture as in Table 1.

Table 1. Influencing factors

Main criteria	Sub-Criteria and designation
Technology	• Addressing – T_1 • Data Management – T_2 • Infrastructure – T_3 • Software – T_4
Privacy and Security	• Data Privacy – P_1 • Network Security – P_2 • Internet of Things Device Security – P_3 • Software Security – P_4 • Conflict of Interest – P_5
Communication	• Architecture and Design – C_1 • Heterogeneity of Devices – C_2 • Hardware Structure – C_3 • Fault Tolerance – C_4
Job	• Business Model – J_1 • Investing in Internet Development of Objects – J_2 • Economic Development Opportunities and Problems – J_3 • Customer Expectations and Service Quality – J_4
Legal Regulations	• Data Usage Rate – L_1 • Ownership – L_2 • Standardization – L_3 • Global Cooperation of the Company – L_4 • Obligation – L_5
Culture	• Ethics of Education and Teaching – Cl_1 • Ethics – Cl_2 • Confidence – Cl_3 • Vandalism – Cl_4

The Analytic Hierarchy Process (AHP), developed by Satty (1980), is one of the most well-known MCDM methods. Classical AHP has shortcomings regarding consistency and uncertainty. The combination of the Analytic Hierarchy Process and the fuzzy set theory is called Fuzzy Analytical Hierarchy Process (FAHP). The Intuitionistic fuzzy sets have been introduced by Atanassov (1986).

Intuitionistic Fuzzy Sets

Intuitionistic fuzzy sets (IFSs) have extended to many multi-criteria decision-making methods. Some definitions of IFSs, their mathematical operations, aggregation operators, and comparison functions will be reviewed in this section (Duleba, 2021).

Definition 1. Let X is a nonempty set. An intuitionistic fuzzy set I drawn from X is defined as: $I = \{\langle x, \mu_I(x), \nu_I(x) : x \in X \rangle\}$, where the functions $\mu_I(x), \nu_I(x)\ X :\rightarrow [0,1]$ indicate to degree of membership and non-membership of the element x from X to set I, respectively, and for every $x \in X$, the condition $0 \leq \mu_I(x) + \nu_I(x) \leq 1$ has to be satisfied. Furthermore, $\pi_I(x) = 1 - \mu_I(x) - \nu_I(x)$ called the hesitancy degree of x in I. For each IFS, the π_I is also belong to [0, 1].

Definition 2. Suppose $\widetilde{X} = (\mu_{\widetilde{X}}, \nu_{\widetilde{X}})$ and $\widetilde{Y} = (\mu_{\widetilde{Y}}, \nu_{\widetilde{Y}})$ be two IFSs. Therefore, the basic mathematical operations could be defined as follows:

$\widetilde{X} = \widetilde{Y}\ if\ \mu_{\widetilde{X}} = \mu_{\widetilde{Y}}\ and\ \nu_{\widetilde{X}} = \nu_{\widetilde{Y}}, \quad \widetilde{X} \geq \widetilde{Y}\ if\ \mu_{\widetilde{X}} \geq \mu_{\widetilde{Y}}\ and\ \nu_{\widetilde{X}} \leq \nu_{\widetilde{Y}},$

$\widetilde{X} \leq \widetilde{Y}\ if\ \mu_{\widetilde{X}} \leq \mu_{\widetilde{Y}}\ and\ \nu_{\widetilde{X}} \geq \nu_{\widetilde{Y}}, \quad \widetilde{X} \oplus \widetilde{Y} = \{\mu_{\widetilde{X}} + \mu_{\widetilde{Y}} - \mu_{\widetilde{X}}\mu_{\widetilde{Y}}, \nu_{\widetilde{X}}\nu_{\widetilde{Y}}\},$

$\widetilde{X} \otimes \widetilde{Y} = \{\mu_{\widetilde{X}}\mu_{\widetilde{Y}}, \nu_{\widetilde{X}} + \nu_{\widetilde{Y}} - \nu_{\widetilde{X}}\nu_{\widetilde{Y}}\}, \ \lambda \cdot \widetilde{X} = \left\{1 - \left(1 - \mu_{\widetilde{X}}\right)^{\lambda}, \nu_{\widetilde{X}}^{\lambda}\right\}, \lambda > 0,$

$\widetilde{X}^{\lambda} = \left\{\mu_{\widetilde{X}}^{\lambda}, 1 - \left(1 - \nu_{\widetilde{X}}\right)^{\lambda}\right\}, \lambda > 0.$

Definition 3. Suppose $\widetilde{X} = (\mu_{\widetilde{X}}, \nu_{\widetilde{X}})$ is an intuitionistic fuzzy number (IFN). Intuitionistic Fuzzy Weighted Geometric Operator (IFWG) and Intuitionistic Fuzzy Weighted Arithmetic Operator (IFWA) with respect to, $w = (w_1, w_2, \dots, w_n)$, $w_i \in [0,1] \quad w_1 + w_2 + \cdots + w_n = 1$. Is defined as follows:

$IFWG_w(\widetilde{X}_1, \widetilde{X}_2, \dots, \widetilde{X}_n) = \left\{\prod_{i=1}^{n} \mu_{\widetilde{X}_i}^{w_i}, 1 - \prod_{i=1}^{n}(1 - \nu_{\widetilde{X}_i})^{w_i}\right\},$

$$IFWA_w(\widetilde{X}_1, \widetilde{X}_2, \dots, \widetilde{X}_n) = \left\{1 - \prod_{i=1}^{n}\left(1 - \mu_{\widetilde{X}_i}\right)^{w_i}, \prod_{i=1}^{n} \nu_{\widetilde{X}_i}^{w_i}\right\}.$$

Definition 4. To defuzzify IFNs the following score function can be used (Xu and Liao, 2013)

$$Sc(\tilde{X}) = \frac{1}{2}(2\mu_{\tilde{X}} - \nu_{\tilde{X}}).$$

$$\rho(\alpha) = 0.5(1 + \pi_\alpha)(1 - \mu_\alpha) \qquad (1)$$

Intuitionistic fuzzy analytic hierarchy process (IF-AHP)

The following step may formulate IF-AHP.

Step 1: Identify the decision-making problem's objective, criteria, sub-criteria, and alternatives. Construct the net of the hierarchy of the defined problem.

Step 2: Develop intuitionistic fuzzy judgment comparisons matrix based on DMs. The scale is defined as shown in Table 2 by linguistic terms and their

corresponding IFNs as nine levels. An intuitionistic fuzzy judgment matrix is generated using pairwise comparisons during evaluation The decision-maker's vagueness has represented by the triangular intuitionistic fuzzy number.

Table 2. Intuitionistic fuzzy linguistic terms

Linguistic terms	(μ, ν)
Absolutely High Importance (AH)	$(0.9, 0.1)$
Very High Importance (VH)	$(0.75, 0.15)$
High Importance (H)	$(0.6, 0.15)$
Slightly High Importance (SH)	$(0.6, 0.25)$
Equally Importance (E)	$(0.5, 0.4)$
Slightly Low Importance (SL)	$(0.4, 0.5)$
Low Importance (L)	$(0.25, 0.6)$
Very Low Importance (VL)	$(0.15, 0.75)$
Absolutely Low Importance (AL)	$(0.1, 0.9)$

Step 3: Check the consistency index (CR) of the aggregated intuitionistic fuzzy judgment matrix. If all of the intuitionistic preference relations are of acceptable consistency, go to Step 5: otherwise, go to Step 4.

Step 4: Repair the inconsistent intuitionistic preference relations. Return the inconsistent ones to the decision-makers for reevaluation until they become acceptable. The CR threshold is less than 10% for satisfactory results.

Step 5: Calculate the intuitionistic fuzzy set priority weights for the hierarchy of sub-criteria and alternatives concerning all criteria.

Step 6. Fuse all the weights from the lowest to the highest level, rank the overall weights using the formula (2), and then choose the best alternative.

RESULTS

In accordance with the selected criteria, the hierarchical structure in Figure 1 was adopted.

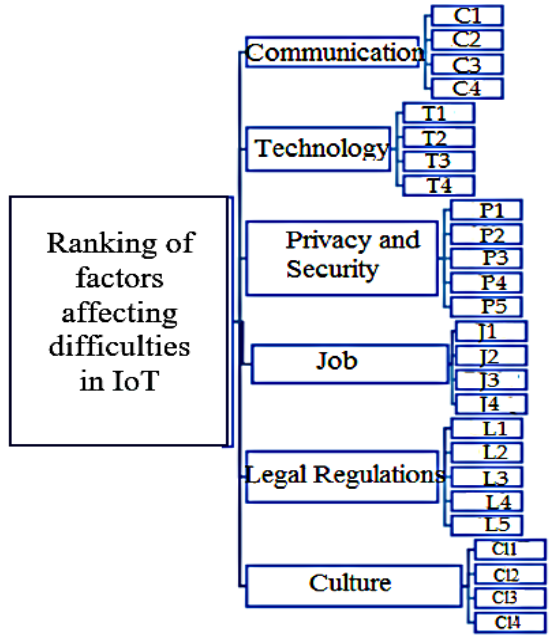

Figure 1. Hierarchical structure

The comparison matrix for main criteria and sub-criteria suggested by the experts is given in Tables 3. Consistency conditions are met.

Table 3. Criteria and sub-criteria comparison matrices

	T	P	C	J	L	Cl
T	E	SH	H	VH	VH	AH
P	SL	E	SH	H	H	VH
C	L	SL	E	SH	SH	H
J	VL	L	SL	E	1	SH
L	VL	L	SL	1	E	SH
Cl	AL	VL	L	SL	SL	E

	P_2, L_1	P_1, L_3	P_3, L_2	P_4, L_5	P_5, L_4
P_2, L_1	E	SH	H	VH	AH
P_1, L_3	SL	1	SH	H	VH
P_3, L_2	L	SL	E	SH	H
P_4, L_5	VL	L	SL	E	SH
P_5, L_4	AL	VL	L	SL	E

	$T_1(C_1, J_1, Cl_3)$	$T_2(C_2, J_4, Cl_2)$	$T_4(C_4, J_2, Cl_4)$	$T_3(C_3, J_3, Cl_1)$
$T_1(C_1, J_1, Cl_3)$	E	SH	H	VH
$T_2(C_2, J_4, Cl_2)$	SL	E	SH	H
$T_4(C_4, J_2, Cl_4)$	L	SL	E	SH
$T_3(C_3, J_3, Cl_1)$	VL	L	SL	E

Figure 2 shows the weights of the main criteria and Figure 3 gives the final ranking of the sub-criteria

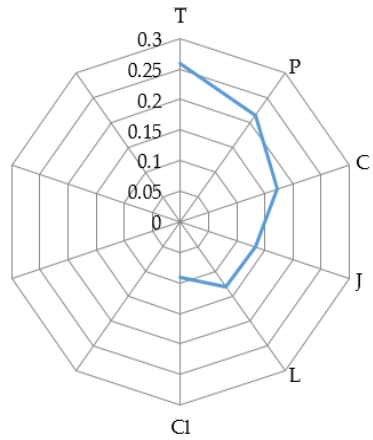

Figure 2. Weights of the main criteria

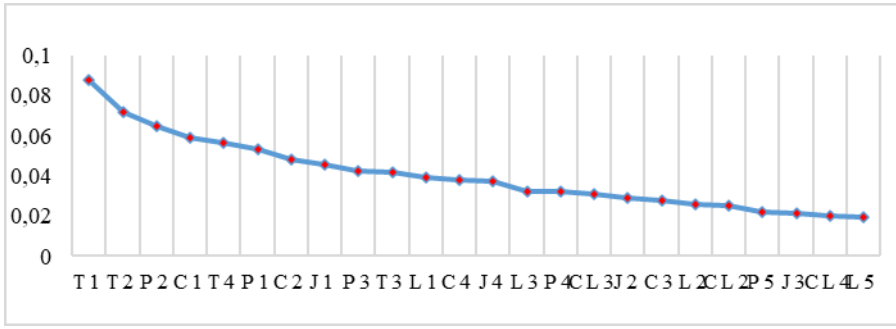

Figure 3. Final ranking of indicators

CONCLUSION

Enterprises that aim to utilize the Internet of Things correctly should order the importance of the difficulties encountered, which can help detect the causes of the difficulties beforehand. In this study, medium-sized enterprises were considered, focusing on problems related to the IoT. Difficulties associated with IoT are identified as criteria and assessed by experts. Six groups of criteria were distinguished - communication, technology, work, privacy, security, legal regulations, and culture and 26 sub-criteria. Through the consistent application of the

Intuitionistic Fuzzy AHP method, indicators such as suggestions for companies on which factors should be taken into account and their order of importance have been extracted. The most significant factors are data management, network security, architecture, and design.

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