OUTDOOR THERMAL COMFORT AS AN INDICATOR OF THE "BELGRADE GREEN CITY" CONCEPT - ADVANTAGES AND APPLICATIONS

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ABSTRACT

The main goal of this research is to present outdoor thermal comfort (OTC) as one of the criteria and instruments for creating a more efficient urban planning policy, with the aim of mitigating the effects of climate change. Also, the idea is that the application of various indices that determine OTC can contribute to the improvement of the urban planning methodology. Belgrade's vision is to become a "green city", and one of the dominant features of green cities is that the bioclimatic conditions of the urban environment are favorable for people's life and work. This aspiration was formally confirmed in 2018 when Belgrade became part of the large international project "EBRD Green Cities", but also with the adoption of the "Green City Action Plan of Belgrade" in 2021. However, while there is a clear aspiration, achieving this goal will be very challenging. First, due to climate change, Serbia's climate is characterized by a warming trend since 1980, which is confirmed by many scientists. In recent years, summer anomalies, extreme weather conditions, and intense heat-waves are becoming more frequent, which results in increasingly unfavorable OTC. On the other hand, construction in Belgrade has significantly intensified (in the period 2016-2020 the number of annually built apartments increased by 70%), while the central city area is markedly deficient in greenery, and public green areas cover only 2.83% of the total territory. OTC, that can help us in understanding these problems, but also in solving them, is not yet recognized in domestic urban planning practice.

Keywords: outdoor thermal comfort, indicator, Belgrade Green City, urban planning

1. INTRODUCTION

Due to rapid, uncontrolled and unplanned urbanization that has affected many parts of the world, there has been a dramatic transformation of the morphological structure of cities (Brilhante and Klaas, 2018; Cetin, 2019). Unbridled urbanization has eradicated green cover in many cities and intensified the vulnerability to climate change (Sharmin and Steemers, 2018). Growing urbanization poses a threat to people, but also to biodiversity and vulnerable terrestrial ecosystems (Marselle et al., 2020).

During the last 30 years, as a result of the numerous economic, political, and social turmoils that shook the Republic of Serbia, similar transformations in the biggest urban areas took place in our country as well. The landscape of Belgrade has completely changed in recent decades, and in the same period, the impact of climate change on the city microclimate becomes increasingly pronounced. Extreme weather conditions such as extreme temperatures, longer and more intense heat-waves (Lukić and Milovanović, 2020; Lukić et al., 2021; Pecelj et al., 2021), and more pronounced urban heat islands enhanced by urbanization, call into question the quality of life in the Serbian capital. A higher heat load results in more health risks in the general population but also results in higher consumption of energy resources (Cetin, 2019). All of this puts an additional burden on the economic and social stability of underdeveloped countries such as Serbia.

After the 2000s, climate change issues were placed at the center of the discussion on sustainable development and urban sustainability (Brilhante and Klaas, 2018). It is clear that we cannot talk about sustainable urban development if we do not deal with the issue of how climate change affects the daily life of citizens. If citizens do not feel comfortable or their health is threatened when they are in the outdoor environment, then we can say that there is a direct impact on the human population. The purpose of each modern, democratic and conscientious community should be to create a space that will be tailored to all residents, a high-performance city that will be able to meet the needs of citizens. A city with a preserved environment rich in biodiversity and greenery, a city that provides support for the improvement of public health, wellbeing and safety (Lukić et al., 2021). All of this ultimately leads to high standards of life quality, which is impossible to expect if sufficient attention is not paid to outdoor thermal comfort which influences permeate a number of sectors of social life.

In order to better understand what thermal comfort represents, we will provide a definition by the ASHRAE Standard 55 (2020), where thermal comfort is the "*condition of mind that expresses satisfaction with the thermal environment and is assessed by subjective evaluation*". Thermal comfort (whether outdoor or indoor) can have a more or less pronounced impact on the work performance of employees, the health of the general population, quality of life, living conditions, etc. (Lukić et al., 2021; Pecelj et al., 2021).

During the stay in the outdoor environment, the human body is exposed to various influences, and some of the most significant are microclimatic conditions. Outdoor thermal comfort (OTC) is not only affected by climatic parameters, but also is directly and indirectly affected by anthropogenic factors such as intensive urbanization, high population density, industry, large infrastructure corridors and commercial zones, lack of public and other green areas, air pollution (aerosols, GHG), etc. According to Tsoka et al. (2017) the progressive modification of the morphological characteristics of urban areas, i.e. the expansion of zones dominated by artificial materials such as glass, steel and concrete at the expense of natural materials and surfaces, leads to the accumulation of a large amount of heat energy. All these factors together contribute to the formation of what we call the "urban heat island" (UHI), and the air temperature of the urban area is almost always higher than that recorded in the surrounding semi-urban and rural areas (Gunawardena et al., 2017).

The main goal of this research is to present outdoor thermal comfort as one of the instruments for creating sustainable urban planning policy, as well as a tool for achieving the Belgrade green city concept. Microclimatic characteristics and OTC should be taken into account more in urban planning, which is currently not the case in the urban practice of Belgrade. The perception of city development must change from planning to meet the needs of investors and the construction sector to meeting the needs of the general population.

2. URBAN DEVELOPMENT OF BELGRADE IN THE PAST DECADE - GENERAL CHARACTERISTICS

The urban development of the Serbian capital in past years can be simply described as an example of intensive urbanization. Conversion of green areas into residential, commercial and mixed city center zones and increasingly dense construction both in new and existing parts of the city. As the number of active construction sites has never been higher, Belgrade rightly bears the epithet of the largest construction site in Europe (Mitić-Radulović et al., 2022). Construction in Belgrade has significantly intensified in recent years: 30% of all construction works performed in Serbia in 2020 were performed in Belgrade, from 2016 to 2020, the number of apartments built per year increased by 70%, the annual value of construction work performed increased by 105%, and the number of square meters of high-rise buildings built per year increased by as much as 350% (Mitić-Radulović et al., 2022a, 2022b). On the other hand, green areas cover 12.38% of Belgrade and are characterized by unfavorable territorial redistribution. The largest green areas are city forests, which are located outside the city and cover 9.55% of the total territory. The central city area is markedly deficient in greenery, and public green areas cover only 2.83% (Mitić-Radulović et al., 2022a, 2022b).

3. THE INTERRELATIONSHIP BETWEEN URBAN GREENERY AND THERMAL COMFORT AND THEIR IMPORTANCE IN URBAN PLANNING

3.1. Why is greenery so important for the urban development and where is the link with OTC?

Urban greenery includes a wide range of shapes and formations from urban forests, parks, street trees, verges, public gardens, fringes of transport corridors, green roofs and facades (Gunawardena et al., 2017).

Urban greenery and various types of green infrastructure can improve the urban microclimate: lower summer temperatures up to 3-4°C, mitigate climatic extremes, mitigate excessive insolation and strong winds, regulate

air humidity, etc (Filipović and Đurđić, 2008). Abdollahzadeh and Bilori in their research (2021) came to the result that greenery and trees especially can increase specific humidity up to 0.56g/kg and improve the thermal comfort of the surrounding area. In addition, the average mean radiant temperature will decrease between 1.32°C and 1.49°C by using dense and sparse tree-planting options. Furthermore, greenery provides diverse ecosystem services to the urban environment including reduced surface runoff, flood relief, and sustainable drainage (Gunawardena et al., 2017). Trees, green roofs, and lawns reduce the amount of particulate pollution and retain dust particles (Stošić-Mihajlović et al., 2017). It also reduces CO_2 and other GHGs emissions (Lalošević et al., 2018), which means that it not only helps fight climate change, but also improves air quality.

Apart from this, urban green areas also have a pronounced health function. There are more and more studies that show that greenery in the city reduces depression and anxiety, which became very evident in the context of the Covid 19 pandemic, and being in the park began to be officially used for health purposes: for the treatment of diabetes, high blood pressure, ADHD- a, depression, etc. (Angel et al., 2021). Marselle et al. (2020) have found a lower rate of antidepressant prescriptions for people living within 100 m of higher density of street trees.

3.2. Is the OTC really that important for urban planning and how can it be explained in the easiest way?

In domestic urban planning practice, OTC is not considered to a sufficient extent, which is confirmed by the situation on the ground. All the pressure is concentrated on the maximum number of square meters that will be built, and how people feel in that environment is left aside. Urban planning is becoming more and more challenging. The accumulated problems of polluted environment, climate change, degraded urban biodiversit, etc., are becoming bigger and more difficult to control and solve. Every year we witness extreme weather conditions, temperature records, and severe heat waves that especially affect urban areas. However, completely unjustifiably, in Serbian urban planning practice, the issue of microclimate is discussed only declaratively, and more serious research into thermal comfort is absent. Given that the city is a “living organism” and that its physiognomy is constantly changing due to urbanization, it is highly likely that the microclimate and OTC of Belgrade will change over time and become even more unfavorable.

How important thermal comfort can be in urban planning is perhaps the easiest to explain with an example of "health care facilities zones", i.e. parts of the city where hospitals, maternity wards, clinical centers, etc., are located. Obradović-Arsić (2014) in her book entitled "*Medical-geographical factors in planning and protection of space*" dealt with this very topic. She states that the planning of such urban zones requires the functional integration of both climatic and urban aspects in order to regulate extreme values of meteorological parameters. If it is not approached in an adequate way, unfavorable OTC can significantly burden the recovery of users of health institutions (Obradović-Arsić, 2014). It is not rare that in Belgrade, patients of the largest health facilities complain about inadequate living conditions, especially in the summer period, during heat waves. All this is additionally influeced by the lack of green areas in the immediate surroundings. The same author further states that OTC is an equally important indicator in the planning of school zones, kindergartens, sports centers and playgrounds, residential, industrial and work zones, etc.

4. OTC, URBAN MICROCLIMATE AND BELGRADE GREEN CITY

4.1. Green City Action Plan of Belgrade (GCAP)

In light of climate change and other global threats, it is necessary to find an adequate response that will minimize the negative impacts, establish the sustainability of urban environments, preserve nature and improve the living conditions in cities (Lukić, Burazerović, 2020). One of the urban planning models that offer mechanisms for solving the mentioned problems is the concept of “*Green cities*”. The green city concept is one of the latest potential solutions to the problems caused by dispersed urban development, as well as an instrument for creating more sustainable, greener, and more livable urban areas (Brilhante and Klaas, 2018).

Encouraged by this, the European Bank for Reconstruction and Development (EBRD) launched a new international project “*EBRD Green Cities*”, and in 2016 it presented the “*Green Cities Program Methodology”*. The “*EBRD Green Cities*” project provides cities with the tools necessary to make substantial, positive improvements in their environmental performance and to establish important, globally adaptable solutions to increasingly prevalent environmental challenges. The program presents the definition of green cities, and part of the definition coincides with the topic of this paper, which we can conclude based on the following: ...*green city is a city that shows high environmental performance in relation to established criteria in terms of mitigating*

and adapting to risks arising from climate change... (Green Cities Programme Methodology, 2016). Today, this project covers more than 40 cities of the world, among which is Belgrade.

Belgrade has recognized the advantages and opportunities offered by the concept of "green cities", and thanks to this, it became part of this project in August 2018. Three years later, in June 2021, the "*Green City Action Plan for the City of Belgrade (GCAP)"* was adopted by the Assembly of the City of Belgrade. It is this document that confirms all the problems of inadequate urban development that Belgrade has been experiencing in recent decades. The key problems that have been singled out connected to this topic are:

- Uncontrolled urban growth in many cases happens at the expense of green areas.
- The park and recreation zone network requires improvements. The few large recreation zones that exist are not enough for many residents for daily use.
- A range of climate hazards was identified including, heat-waves, extreme weather, and flooding present the highest risks to Belgrade.
- The population has a low adaptive capacity and high sensitivity to climate (in particular the elderly, infants and children, people with mobility impairments, chronic illnesses, etc.).

The adoption of this plan, as well as the clear identification of existing problems and the definition of activities that could lead to a solution, represents an important step forward. What the next period will show is how much the City of Belgrade is really ready to tackle the above-mentioned problems and whether we have the necessary knowledge and capacities.

In the next chapter, we will present examples of how OTC can help and support the implementation of this project.

4.2. How OTC can support establishing Belgrade Green City and sustainable urban planning?

It is unjustified and irrational to expect that the expansion of cities will stop so easily, and the current trend is that the population of the largest metropolises is increasing year after year. UN estimates are that by 2050, 66% of the world's population will live in cities. While we await the results of the new Population Census of the Republic of Serbia, which will be held in October 2022, according to existing estimates, around 25% of the total population lives just in Belgrade (Statistical Office of the RS, 2022). At the same time, the increase in mean, minimum, and maximum temperature values, which leads to further changes in environmental conditions, is a new reality to which we must adapt. Practically every year, we have more and more citizens who live in a relatively small space, who consume more and more energy and create more and more pressure on the environment. Also local authorities in Belgrade just declaratively promote urban greening and sustainable development, and a significant discrepancy between policies and practice is obvious, as stated by Mitić-Radulović and Lalović (2021).

When we talk about the discrepancy between the policies and practices of Belgrade's urban development, it is interesting to point out that Belgrade has been unsuccessfully applying for the European Green Capital Award (EGCA) for several years now (Pantić and Milijić, 2021), while at the same time many call it the largest construction site in Europe (Mitić-Radulović et al., 2022a,b). Part of the process of adapting and responding to this new conditions in which we live is a change in the paradigm of urban planning.

What do the results of previous research on OTC and the urban microclimate in Belgrade show? Pecelj et al. (2021) presented general temporal bioclimatic conditions in Belgrade for the period 1976 to 2018. During the period of 43 years covered by this research, it registered a positive trend and the increase in the value of each index bioclimatic, increase in subjective thermal stress and thermal discomfort in Belgrade. This confirms the findings of other authors who found that average temperatures have recorded a constant increase since the 1980s. According to Unkašević et al. (2005) the average summer temperature at Belgrade increases at the rate of 0.1316◦C/year. Except during the summer period, the rise in temperatures is also recorded in other parts of the year. For instance, in Belgrade, the average spring temperature has a positive trend of 1.32◦C/100years, while the minimum spring temperature has a positive trend of 1.92◦C/100years. The average autumn temperature has a positive trend of 0.74◦C/100years. Further, the minimum winter temperature in Belgrade has a positive trend of 2.97◦C/100years (Đorđević, 2008). Lukić and others (2021) dealt with the evaluation of OTC in Belgrade during different seasons in the period 1999-2018. They have used UTCI (Universal Thermal Climate Index) to assess outdoor thermal comfort. Findings show the presence of a growing trend in seasonal UTCI anomalies, especially during summer and spring. In addition, there is a notable increase

in the number of days above the defined UTCI thresholds for each season. Average annual UTCIs values also show a positive, rising trend, ranging from 0.50◦C to 1.33◦C. A significant occurrence of thermal heat stress was registered especially during summer which makes this part of the year bioclimatically the most unfavorable.

What tools can we use to get applicable OTC data and how to apply them? Part of urban planners, spatial planners, and policymakers who act and think in a progressive manner is engaged in the development of new urban development strategies that combine urban planning, land use, and urban climate. In our country, as we have already stated, the approach to urban climate and outdoor thermal comfort air is very superficial, and it is mostly dealt with by a small number of people who come from narrow scientific and academic circles. The profession remains rather rigid and insufficiently motivated to engage in rethinking the existing way of city planning. Nevertheless, under the influence of global and local pressures, as well as the awareness of the group of experts and decision-makers, the GCAP of Belgrade was recently adopted, as well as a set of other plans and strategies dealing with the sustainable development of Serbian capital. As we could already conclude, the green city concept does not only mean the introduction of green infrastructure but the formation of a city resistant to climate change, a city that successfully fights existing environmental and social problems, and a city that supports public health. However, the link between land use and OTC is still missing (generally).

Prevention is the best solution, which means that with adequate planning and bioclimatic design of urban districts, the occurrence of UHI and unfavorable OTC can be prevented in advance. Tapias and Schmitt (2014) emphasize that the integration of microclimate data into the creation of new urban forms using outdoor thermal comfort as an indicator is a way to establish resilient and sustainable neighborhoods. So what to do with already built urban zones? Is it possible to influence the improvement of thermal comfort in such areas as well? Nikolopoulou et al. (2001) state that it is possible to regulate thermal comfort even in cases of already built urban fabrics. As an example, they highlight the shading of entire streets using trees, with the advantage of cooling through evapotranspiration through leaves, but also other types of vegetation that can be applied. Emmanuel and Loconsole (2015) conducted a survey in the Glasgow area which showed that an increase in greenspace of 20% above the current level could eliminate between a third and a half of the city's expected UHI effect in 2050.

Of course, it is not enough to raise greenery by itself but to first perform analyzes and assessments of locations that have the most unfavorable OTC and the most pronounced UHI. For that, we need continuous micrometeorological measurements at different locations, as well as the use of modern technologies and software. This is where GIS and various software intended for bioclimatic research such as ENVI-Met stand out. ENVI-Met is one of the most widely recognized software for urban climate modelling. This software allows the investigation of the effects of urban planning and architecture on outdoor microclimate through various simulations (Madeco Alves et al., 2022). This methodology has been applied in different cities worldwide and has produced quality and applicable results: Valladolid (Spain) study by Madeco Alves et al. in 2022; Nanjing (China) study by Rui et al. in 2019; Cairo (Egypt) study by Fahmy and Sharples in 2009; Netherlands study by Taleghani et al. in 2015; Sao Paolo (Brazil) study by Carfan et al. in 2012; Hanover (Germany) study by Forouzandeh in 2021, Sydney (Australia) study by Abdollahzadeh and Bilori in 2021, Xi'an (Northwest China) study by Huang et al. in 2016, etc. In the case of the city of Belgrade, this model was applied by Lalošević et al. in 2015 when they investigated the role of green roofs in urban heat island mitigation (4 locations - parts of the territories of the municipalities of New Belgrade, Vračar, Stari grad, and Zemun). Another example is the use of GIS tools - Cetin in 2019 have created thermal perception maps of Bursa city (Turkey) by using ArcView GIS^{TM} 10 and meteorological data (average wind speed, temperature and relative humidity values). In addition to these, there are other different software designed for bioclimatic research, the application of which is very common in scientific research, such as RayMan and Bioklima software. All this includes the use of various thermophysiological and bioclimatic indices, among which PET (Physiological Equivalent Temperature) and UTCI are the most commonly used (Universal Thermal Climate Index) (Abdollahzadeh and Bilori, 2021; Lukić, 2019; Lukić and Milovanović, 2020; Lukić et al., 2021; Pecelj et al., 2021; Tapias and Schmitt, 2014; Huang et al., 2016; Zhang et al., 2020).

5. CONCLUSION

The main aim of this article is to present OTC as one of the instruments for improving urban planning policy in Serbia, with a focus on mitigating the effects of climate change. Belgrade was chosen for the case study, as the largest urban area in Serbia, with the largest number of inhabitants and the highest population density, far above the national average. Also, the most pronounced urban heat island has been identified in

Belgrade so far, as well as a significant difference in the temperature of the central and semi-urban parts of the city. In addition to climate change, UHI has additionally intensified by high concentrations of polluting particles and aerosols, which often puts Belgrade at the very top of the world's most polluted cities. On top of all that, in recent decades, Belgrade has been facing rapid, often uncontrolled and unplanned urbanization. As we mentioned, the pressure from investors, capitalism and the construction business is tremendous: 30% of all construction works performed in Serbia in 2020 were performed in Belgrade, from 2016 to 2020, the number of apartments built per year increased by 70%, the annual value of construction work performed increased by 105%, and the number of square meters of high-rise buildings built per year increased by as much as 350%.

At the same time, citizens' dissatisfaction is growing. Polluted environment, lack of public green areas, and harmful projects that violate the public interest are becoming the new realities. City authorities only declaratively deal with sustainable development, while in practice hardly anything is achieved.

New hope was brought by the adoption of the Green City Action Plan of Belgradeas well as other documents covered by the "green regulation". Considering the accumulated problems, it is clear that the existing urban planning practice must be revised and improved with new methods that will allow a better understanding of the circumstances in which we are now. In order to achieve the set goals - the realization of the Belgrade green city concept and and eventually winning European Green Capital Award, the perception of the role and interaction of greenery, thermal comfort and urban microclimate on the quality of life must change.

OTC can help us in many ways to understand more easily and better how climate change affects the urban microclimate, and how it influences the general population. Indicators used to assess thermal comfort, such as various bioclimatic and thermophysiological indices, can help us to more efficiently locate UHIs, and to understand their impact on the mental and physical health of citizens. Various software tools used in bioclimatic research can be used in initial research when creating urban planning documentation. Thermal perception maps can be part of the regular graphic attachments that we meet in urban plans. All of this together can help us plan more adequately and sustainably the spatial layout of green areas, work and business zones, zones where health care and education facilities are located, sports and recreational zones, etc. In this way, one day we will really be able to say that Belgrade has become a green city.

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