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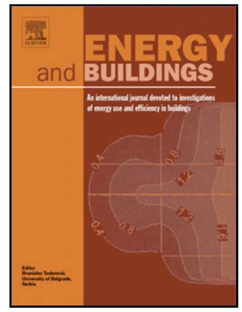

Title: Principles of climate sensitive urban design analysis in identification of suitable urban design proposals. Case study: Central zone of Leskovac competition

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Principles of climate sensitive urban design analysis in identification of suitable urban design proposals. Case study: Central zone of Leskovac competition

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Highlights

- Thermal comfort is one of the most important for the cities with hot summers
- Retrofitting has become more significant than creating new spaces
- Urban design competitions became the most significant mechanism for retrofitting
- Aspects of climate sensitivity need to be clearly defined in the competition tasks
- ENVI-met is the most convenient tool for simulating and quantifying UHI effects

Principles of climate sensitive urban design analysis in identification of suitable urban design proposals. Case study: Central zone of Leskovac competition

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Abstract

Paper represents the analysis of the change in the outdoor comfort during the summer days of open public space of the main square in Leskovac. The analysis covers the present state, two rewarded design proposals at urban design competition and proposal resulting from the evaluation of these solutions. The article focuses on the thermal comfort in outdoor space as a one of indicators in competitions of urban design, considering the fact that the re-design of public spaces often has a has negative consequences of decisions made during the competitions. Following the thesis that successful public spaces should be responsive to the needs of their users, the paper considers the thermal comfort as the main quality of open public space. Analysis of microclimate could help designers to create comfortable urban place, which could attract vast number of users throughout the year, especially during hot summer periods. The aim of this paper is to highlight the complexity of the relationship between microclimate comfort in public open spaces and urban design, especially interventions such as implementation of the greenery and new surface materialization in order to emphasize the importance that this relationship has to be taken into account in urban design competitions.

Keywords: Climate sensitive urban design, urban design proposals, urban competition, main square, Leskovac, Serbia

Introduction

Climate change has a variety of effects throughout the world. In southern central Europe, there has been recorded increase in temperature, leading to Urban Heat Island (UHI) effects with some

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extreme temperatures [**1** , **2**].

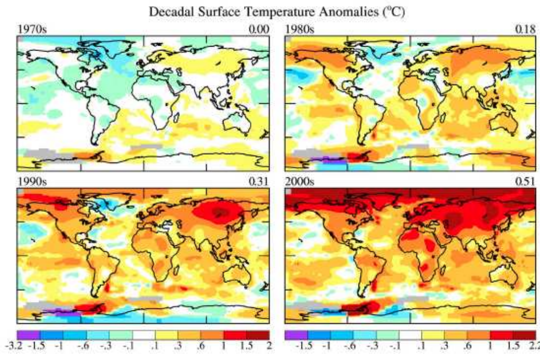


Fig. 1: Decadal surface temperature anomalies relative to 1951– 1980 base period **3**]

Warming in these recent decades is larger over land than over ocean [**3**]. Hansen at al. [**3**] has shown that the warming during the past decade is enhanced, relative to the global mean warming, by about 50% in the United States, a factor of 2– 3 in Eurasia, and a factor of 3– 4 in the Arctic and the Antarctic Peninsula (see Fig. 1).

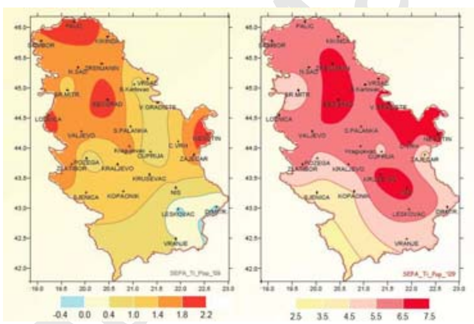


Fig. 2: Geographic distribution of the sign and intensity of the trend of annual air temperature in Serbia, according to data from the period 1951 – 2007 [**4**]

Explicit air temperature growth trend is present on the whole territory of Serbia [**4**]. Geographic distribution of the sign and intensity of the trend of annual air temperature in Serbia, according to data from the period 1951 - 2007 is given in Fig. 2 (left). Based on the reseach results presented by Popovic et al. [**4**] an increasing trend is dominated on the most of the terriotory of Serbia, while a slight decreasing trend is characterised only on southeast. According to the data after 1991 the whole of Serbia is experiencing a rapid increase in temperature, Fig. 2 (right).

Following these phenomena, public outdoor activity continues to stay a very important part in urban design, and its elements need to generate comfortable outdoor spaces where different types of use and different activities can play a major part in the quality of urban life [**5**]. The concentration of both users and activities in outdoor spaces produces liveability and vitality in cities [**6**, **7**, **8**, **9**, **10**, **11**]. Recent research has shown that microclimate is a very important factor for the success of public space. Comfortable and pleasurable outdoor spaces have the higher intensity of use [**12**, **13**], so there needs to be alleviation from high temperatures. Microclimatic comfort in urban spaces depends on appropriate urban design and morphological characteristics in the built environment [**14**]. Previous research has identified that thermal radiation is determined by surrounding surfaces and their materials [**15**], ground surface evaporation and evapotranspiration of plants [**16**], shading effect, and artefacts placed in the spaces [**17**]. Understanding the relationship between environmental conditions, human behaviour and the patterns of usage, open public spaces should contribute to the design of the outdoor environment and increase positive social and environmental outcomes. The aim of this paper is in determining the climatically sensitive aspects of urban design. In cities, public spaces already exist and retrofitting has become more significant than creating new spaces. Urban design competitions have become the most significant mechanism for retrofitting process. Thus, the primary objective of this research is to test highly rated competition proposals for the main square in Leskovac[B] and compare them to the existing situation.

The paper presents a case study about the open public space in the centre of Leskovac, in which the correlation between the character of urban intervention at ground level (greenery and pavement) and microclimatic comfort has been assessed through comparative analyses of urban design competition proposals.

The focus of the research is the main square in the city centre of Leskovac. Originally built in late 1960`s, after transformation of traditional planning into the principles of modernist urbanism. Over the next 50 years of its urban existence, the square has been subjected to numerous adjustments and changes of function and materialization. However, during the last decade, the local government decided to do redesign the square. The changes to the surroundings during the last decade of 20th century had an impact on the character and quality of public spaces, their environment, accessibility and aesthetic values. The site was devastated by unplanned interventions, lack of maintenance and large parking place.

This paper has been developed under the hypothesis that the competition proposals will improve the thermal comfort [local microclimate] by following the principles of climate sensitive urban design resulting regarding the temperatures increase caused by climate change and global warming.

Methodology and material

The competition titled: “The open, public, preliminary competition for urban design of the Central zone of Leskovac”, was announced by the City of Leskovac and the Directorate for the Urbanism and Construction in Leskovac on 8th July 2013. All persons and companies skilled for this type of work had the right to participate in the competition.

[B] Leskovac is the city where the rapid increase in temperature was recorded.

Urban design competition for the central zone of Leskovac

The competition boundaries were Liberation Boulevard (Bulevar oslobodjenja) to the north, Koste Stankovica Street to the east, Stojana Ljubica Street to the south and the left riverbank of Veternica River to the south (see Fig. 3).

Fig. 3: The subject of the competition for urban design of the Central zone of Leskovac.

The aim of the competition was to provide comfort for the users. The scope of the intervention was determined by proposing changes at ground level to planting, new pavement, new urban equipment and a variety of outdoor experiences that would enrich use and intensity of use. It was envisaged that the principles of the selected design would form the basis of planning documents for the area.

The objectives of the competition were to:

1. Update the public square between the "Beograd" department store and the "Modna kuca" business and commercial building;
2. Interconnect routes in the space giving the priority to pedestrians rather than vehicles
3. Detail hard surfaces
4. Develop the landscape design
5. Propose street furniture including benches, bins, bus shelters, etc.; and lighting design
6. Re-arrange parking in the area [**18**].

Microclimate comfort was not included in the objectives of the competition, although the thermal conditions tend to be more extreme especially during the summer period.

The competition received eight urban design proposals. Examining the submissions, the jury has decided not to award a first prize, but to distribute the awards as follows: two first special mentions (proposals no. 15498 and no. 10194), two second special mentions (proposals no. 22112, no. 97456 and no. 95861) and three compensations (proposals no. 35317, no. 20104 and no. BU235). According the jury's` opinion none of the proposals satisfied all objectives of the competition.

For the purposes of this research, the two first special mentions could be considered as the most appropriate urban design solutions. The research was conducted in two phases. In the first phase, the two proposals[C] and the existing layout were analysed by the ENVI-met 3.1 Beta 5 model. The second phase produced a scenario solution that was also tested using the same methodology and tool.

ENVI-met 3.1 Beta 5 model

The ENVI-met 3.1 Beta 5 model is a tool specifically developed for studying and prediction of urban microclimate. It is a grid-based three-dimensional model for the simulation of airflow, heat and vapour exchange, exchange at vegetation and vegetation parameters, turbulence and particle dispersion in urban areas. The software performs micro-scale simulations with a typical spatial resolution of 0.5 - 10 m with 10 seconds time frames. It takes into account the key modelling inputs, including site locations, initial climatic parameters, soil and plant types, building structures, and thermal properties**19**]. It can generate three-dimensional distributions of radiation, temperature, heat flux, humidity, wind flow and other relevant data such as PMV (predicted mean vote). Recently, the ENVI-met has been adapted mainly to simulate surface-plant-air interactions in urban canyons, and to predict climatic consequences of different urban design options [**20**].

The three-dimension ENVI-met CFD model can calculate meteorological parameters in each point of the grid – [**21**]. Validation of the software has been done in different environments, especially for research concerning the urban morphologies [**22**]. The main prognostic variables in the atmospheric mode are the wind flow, temperature, humidity and turbulence. The temperature and humidity are given by the combined advection-diffusion equation developed by Burse [**23**]**.**

However the model simulation results can deviate from the measure values. This is mostly due to setting the software. Up to date, ENVI-met does not have anthropogenic-generated heat included in calculations. Also buildings set in the model are considered as high-density cases and share the same building mass. So the anthropogenic heat can be added in simulation as a background contributed heat. Validation of the ENVI-met software has been done in different environments, especially for research concerning the urban morphologies. Extensive validation work was done by University of Sheffield [**21**].

Taking all the comparative results into account, the ENVI-met model is regarded as a effective tool to evaluate the modification of the site layout and greening. Nevertheless, the underestimation of the maximum temperature may occur in the simulation, which may need to be considered. The validation of data presented below is from the research of Gill et al. See **22**] for more details of the model validation.

[C] Proposals no. 15498 and no. 10194. We would continue to use these competition labels, because they are taken from the official competition proposals presentation delivered by the Jury.

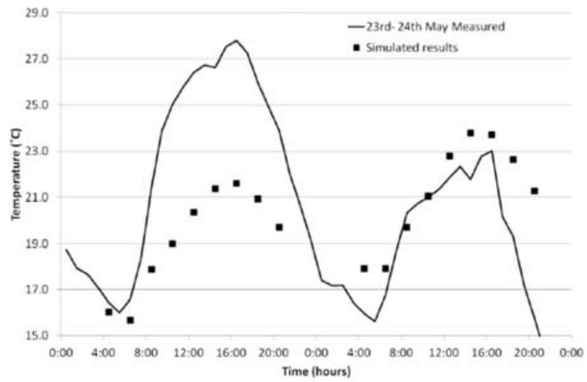


Fig. 4: Measured averaged temperatures from the 6 central temperature loggers read over 2 days alongside the results from a 2 day simulation from ENVI-met [**22**]

The setup of ENVI-met model is divided into two groups: a) meteorological information, dates and durations of simulation, materials and vegetation properties, sun radiation factors, shades, turbulence factors etc., and b) information about the morphology of environment, such as positions and heights of the buildings, position and type of the plants, distribution of the surface materials and soil types, position of sources and receptors, geographical positions of the location on earth and so on.

In this paper, the Central zone of Leskovac is analysed in four study cases: existing conditions, two highly ranked proposals (proposals no. 15498 and no. 10194) and scenario solution. Tables 1 and 2 contain all settings of the main model. The specific meteorological values for the city of Leskovac have been taken from the Republic Hydro-meteorological Service of Serbia[D].

Table 1: Model configuration input data for the ENVI-met simulation.

Model parameter	**Model Value**
Simulation date	**24.07.2014**
Starting time	**12am, on 24 July 2013**
Time for initialization (h)	**From 6AM on 24 July till 6AM 25 July**
Simulation Duration (h)	**24h**
Initial air temperature (K)(°C)	**295 K; 24.85°C**
Wind speed 10m above ground (m/s)	**4**
Wind direction (North 0, East90)	**337 (North West)**
Relative humidity at 2 m (%)	**70**
Specific humidity in 2500 m (g water.kg air−1)	**16**
Cloud cover (low/mid/high)	**0/0/0**
Adjustment factor for solar input	**1**

The simulation was performed for the July 24th 2013, day with typical summer values of temperature in Leskovac. Initial air temperature was 24.85° C; wind speed at 10m height above the ground was 4m/s from North-West direction; relative humidity till 2 m height above the ground was 70%; specific humidity in 2500 m was 16g water.kg air−1 and adjustment factor for solar input was 1. Duration of simulation was 24 hours from 6.00am until 06.00am next day. Air temperature and humidity at 0.3 m

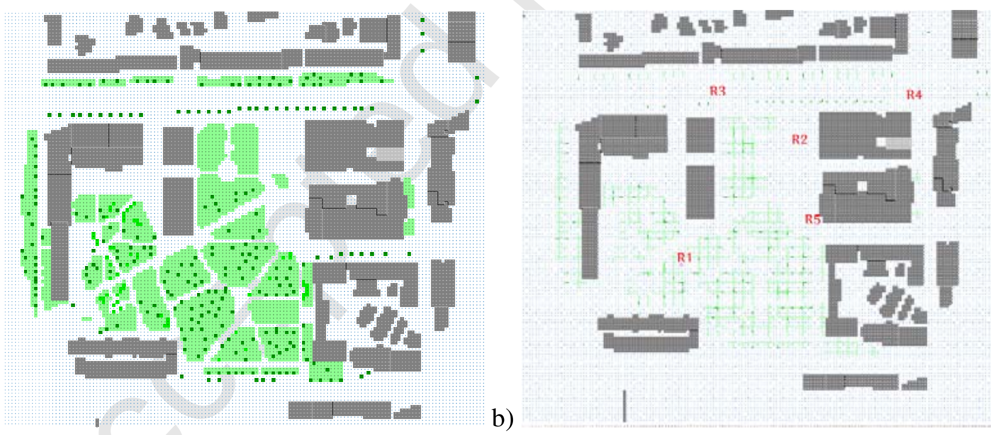
[D] See more http://www.hidmet.gov.rs/index_eng.php above the ground have been extracted from the results.

Table 2: Model area input data for the ENVI-met simulation.

Model parameter	**Model Value**
Dimensions	**150x130x30 grids**
Size of grid cell in meters	**dx=2.5; dy=2.5; dz=3**
Location	**Leskovac 43°0'0''N, 21°57'00'' E**

The ENVI-met has a raster-based area matrix. The model is organizes as a rectangular area with cells, which extends in x-, y- and z- direction. In the model z- direction cannot be seen but it is important part of the model as it influences wind and turbulence directions. The maximal number of cells in the model is 250x250x30 for x-, y- and z- direction respectively. Where the cell dimensions are smaller the simulation results are more precise, although this has significant impact at the computing power and time needed to run simulation. Thus, the cell dimension has to be calculated in such a way so the research area can fit within the model borders.

The dimensions of the research area in Leskovac are 375m x 325m x 50m and are represented in ENVI-met model by the 150 x 130 x 30 cell grid with cell dimensions dx=2.5; dy=2.5; dz=3, respectively. In order to be able to compare results from different models, grid and cell sizes have remained the same for all analysed models. Only square organization and special distribution of objects and the vegetation is changed.



a) b)

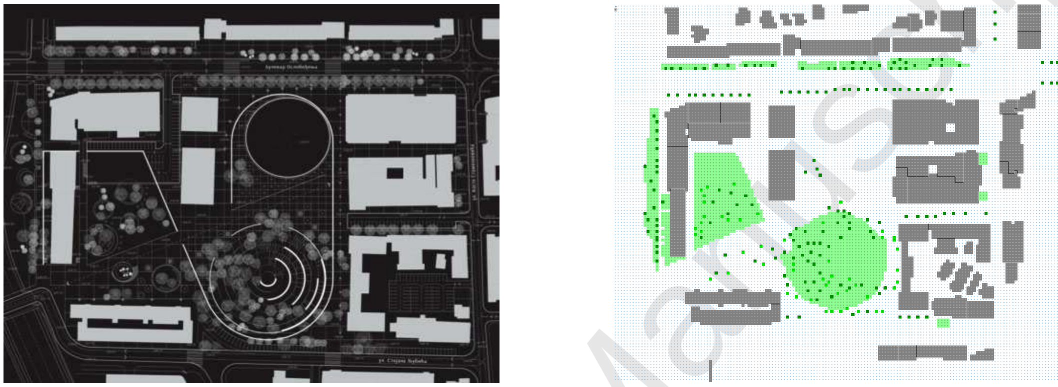
Fig. 5: a) Area model - existing state and b) Area model with spatial allocation of receptors

A starting model of the existing state of the Central zone of Leskovac is presented in figure 5. This model was used as a reference point to detect if the thermal performance and human experience in the space have been improved or deteriorated with the new proposed urban designs. Figure 6 illustrates competition[E] design solutions of the Central zone and its corresponding ENVI-met models.

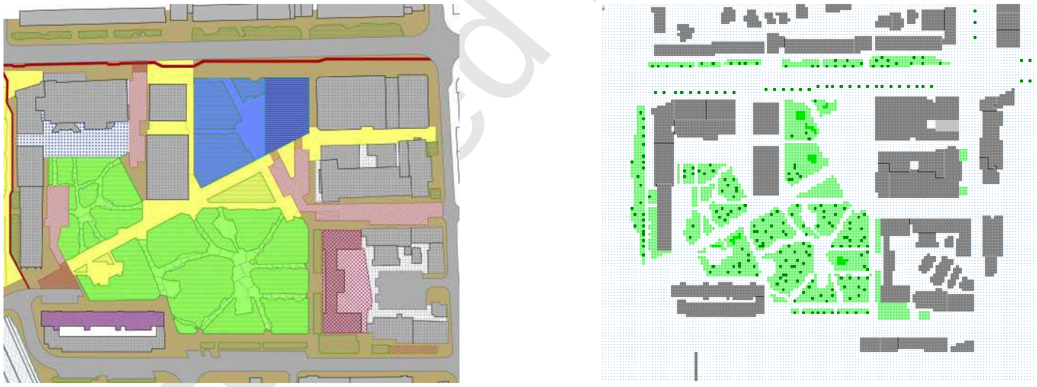
The software is calculated the atmospheric parameters in every single grid point, and produce a

[E] National competition for concept urban – architectural design of central zone in Leskovac significant amount of data that will be presented on thermal maps later in this paper. If there is interest in a specific point in space, it is possible to set up "receptors" (data-extraction points) for easier understanding and reading of the microclimate performances. For this research, five receptors were placed to track the thermal performance of different existing and suggested urban designs. Figure 5b is a graphical representation of the special distribution of these five receptors. They are positioned in such way to capture thermal performance of the new designed areas.

Competition proposal no.15498



Competition proposal no. 10194



a) b)

Fig. 6: Awarded competition proposals. a) Urban design and b) Area Model

The urban solutions obtaned from competition are presented here for the reference purposes; however, they will not be the subjects of further detailed architectural or urban analysis.

The same methodology is used in testing the scenario solution defined on the basis on the results of the evaluation present state and the best proposals obtained from the competition.

Results

Present state of the competition territory – central zone of Leskovac

The subject of the competition forms the centre of Leskovac in all repects. It is the focus of all events and encounters. Immediately following damage from the Second World War, this part of Leskovac was transformed into a modern city, with morphology and content largely self-referential and not related with historical part of the city centre (see Fig. 7). In 1983, a diagonal street, which had been cutting across the area, was changed into a pedestrian route. Liberation Boulevard, which runs along the site is a busy highway. Its pavements are in a very poor condition. Part of the northern pavement is at a lower level than the carriageway. Parking and green areas are realised along the Stojana Ljubica Street. The quay, alongside the Veternica River, is mostly resolved and appears in relatively good condition.

Fig. 7: Present state of the competition territory. Source: City of Leskovac

The competition area is mainly surrounded by buildings that were built in the modernist style six decades ago. These are principally Economic Court and the Beograd Hotel to the northwest, restaurants and accommodation facilities on the south, the Beograd department store, business centre and Sindikat building to the northeast and the centre for social work, and the Instance Court to the south-east. In the south-western part is located a multi-family residential building, called the southern block and its annex, which has the character of an office building. An eight storey building is situated in the western part of the site, predominantly occupied by city administration. A monument dedicated to the Liberators of the First World War is situated on Revolution Square, and Toma Zdarvkovic's and Kosta Stamenkovic's monuments, sculptures and memorials are placed in the Park (see Fig. 8).

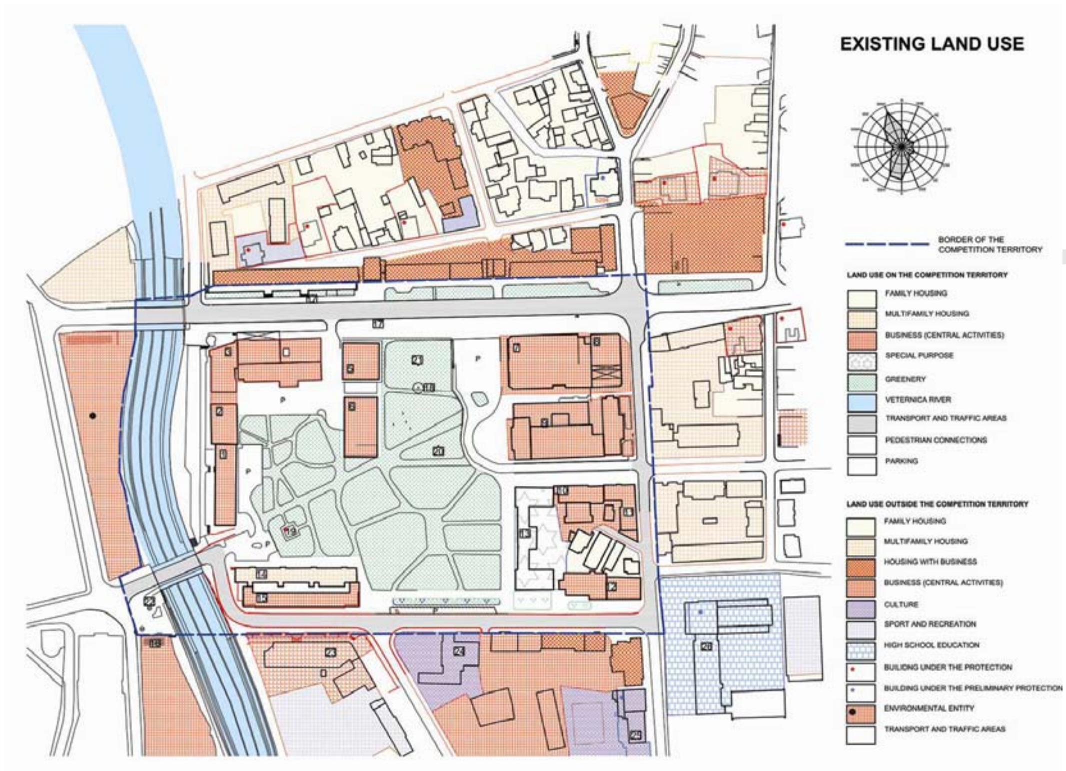


Fig. 8: Present state of the competition territory – Existing land use. Source: City of Leskovac

In accordance with the current characteristics of this area, the concept solution should contribute to the establishment of an urban environment that will, by its functional and formal organisation, contribute to raising the value and attractiveness of the area, improve the visual effect and provide a safe and pleasant gathering of citizens.

Competition proposal No. 15498

According the competition submission, the main characteristic of this proposal is that the site is divided into 6 segments that permeate each other (see Fig. 9). These segments could be built separately, but together make a harmonious solution. The project is founded on functional and physical connections of old and new urban forms and structures, and most of the interventions are at ground level, which are used to emphasize the square. The main geometry of the public square are circles and diagonal coming out from the centre of the circles to symbolise one life, i.e. to introduce a place of gathering, meeting and socializing.

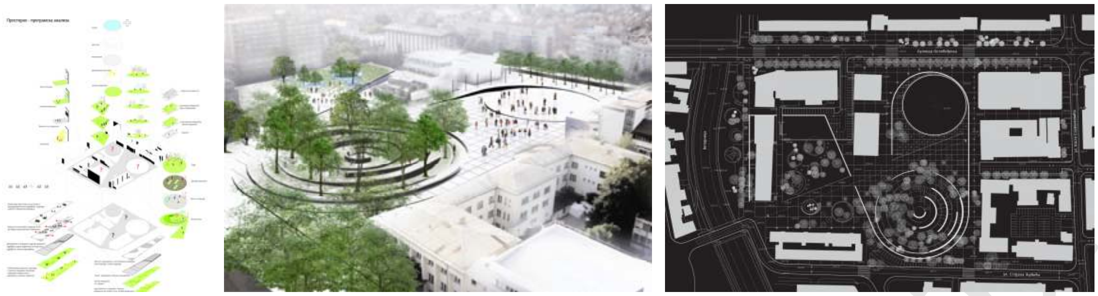


Fig. 9: Competition proposal no. 15498

The solution is characterized by the flexibility and adaptation for the users. It gives the possibility of combining and composing simplified geometric forms so that the solution is not limited to predetermined uses. It is intended that there should be interaction between people and place. In this proposal, the Central Zone of Leskovac is treated as a system of interconnected and overlapping hard spaces, green places and small plateaux that offer the possibility to go from one spatial form to another, without boundaries creating barriers. The central area of the square is designed as a unique, open stage that could provide the focus of public life in the city.

Competition proposal no. 10194

The proposers of this design state that the multi-use public space character of the main square is fundamental in determining the conditions that will allow the vibrancy of events, as well achieve greater functionality. The public square is connected with the future pedestrian Svetozara Markovica Street along the main pedestrian route that ends at the square. The riverbank between the two bridges[F] is complemented by an amphitheatre that could be used as a meeting place, as well as for cultural and leisure events. The proposed urban design originated from the need to create a functional urban area, which gathers citizens and allows them to meet their own needs for deeper social integration, as well as sense of belonging in the city.

Fig. 10: Competition proposal no. 10194

The diagonal pedestrian connection that was once the city's main street, is emphasised in dimensional terms by the type of surface finish, and the significant water feature suggests the

[F] Bridge near the post office and bridge along the Liberation Boulevard presence of the river (see Fig. 10). The perimeter of the park is designed in geometrical, rectilinear hard surfaces, while the interior is planned as a peaceful place where children can play in soft landscape. On the other side, plateaux with the memorial statue and the newly designed amphitheatre allow for various types of cultural and entertainment events to have a central place in the compositional definition of the park.

The presented projects, highly ranked by the final decision of the jury were analysed using the ENVI-met 3.1 Beta 5 model tool, which simulation results are presented in next subsection.

ENVI-met simulation results

July 24th 2014, demonstrated that overall, the existing square does not offer a specific microclimate.

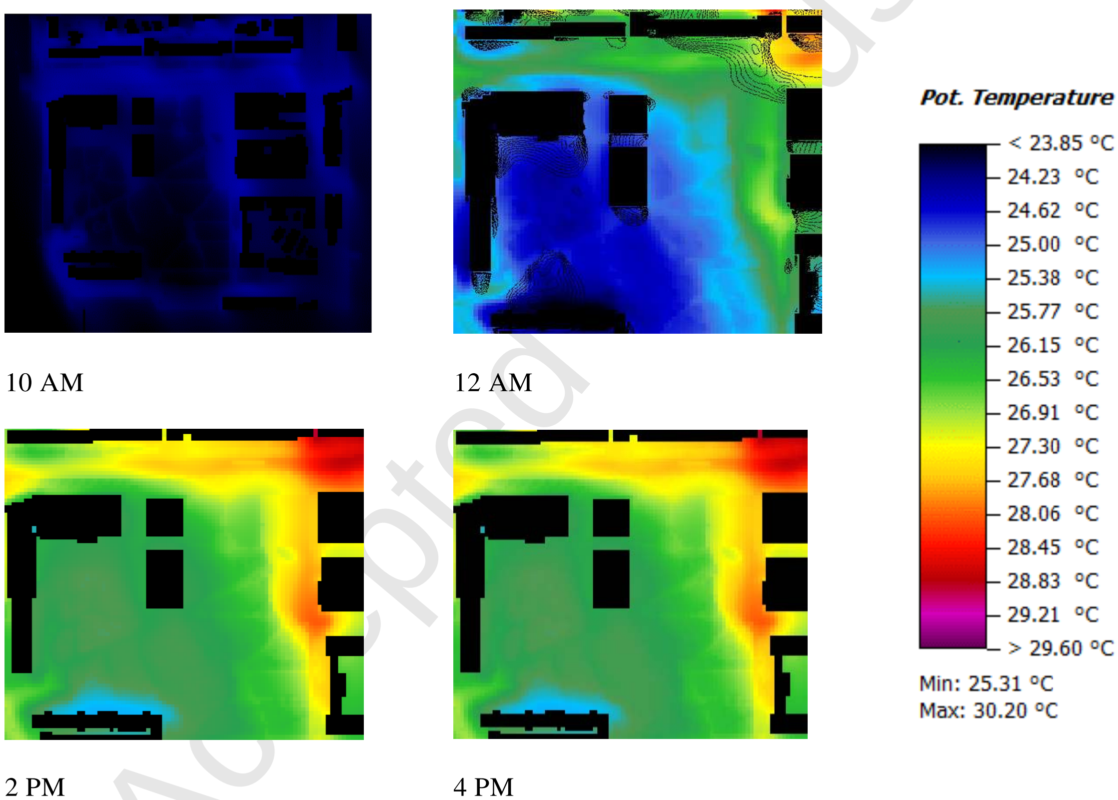


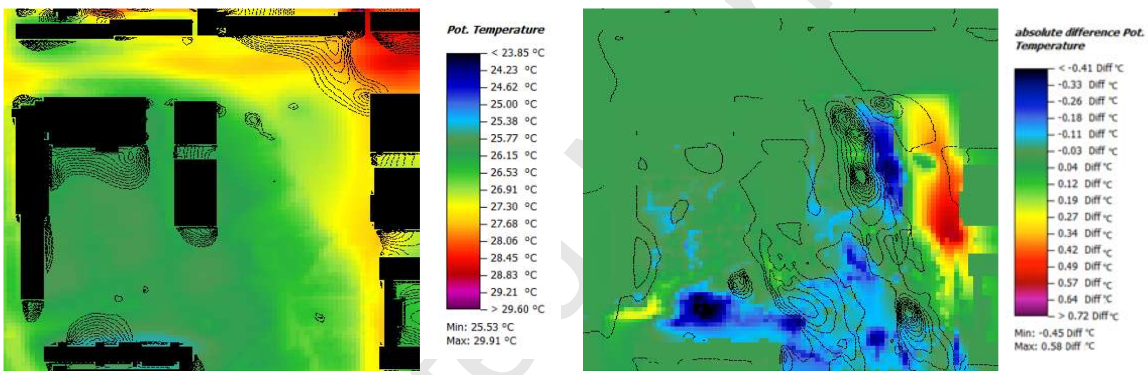
Fig. 11: ENVI-met thermal maps of Main Square in Leskovac – existing state, 24.07.2014

Figure 11 shows the outcomes of the stimulation for the existing conditions in the central zone of Leskovac at four different day times (10 AM, 12 AM 2 PM and 4 PM). It can be clearly seen there is a significant difference in microclimate conditions of the parts of the site with rich vegetation and the surrounding areas covered with concrete or asphalt and areas [without vegetation]. The highest difference in air temperature between vegetated and non-vegetated areas reaches nearly 3°C. In the similar manner, the air temperature in the parts covered by trees is about 0.5-0.6 °C lower than the parts covered by the grass. The highest temperatures are at the cross road between Liberation Boulevard and Koste Stamenkovic Street. The parking area in front of the Beograd department store and Sindikat building have influenced air temperature so it is slightly higher around these buildings than the rest of the square.

The temperature peak is recorded at 2 PM, thus this time point will be used to analyse and compare the selected competition designs.

Thermal maps

Figure 12a shows the results for competition proposal no. 10194. As it can be seen on the thermal map, decrease in the vegetation has led to slight increase in air temperature. However, the displacement of the parking area in front of Beograd department store and Sindikat building has reduced air temperature. To better understand the significance of the change, the comparison of these results with the existing conditions is presented in fig. 12b.

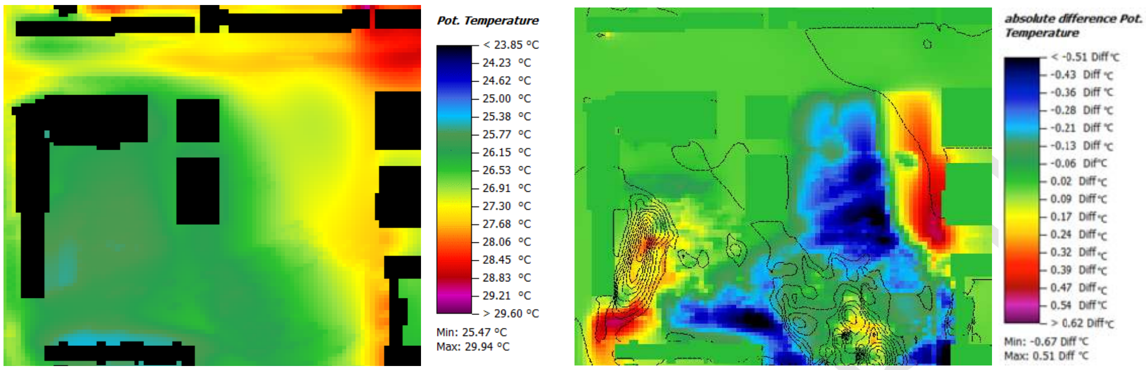


a) b)

Fig. 12: ENVI-met thermal map: a) The Central zone of Leskovac proposal no. 10194 and b) Comparison of thermal maps of the Central zone of Leskovac – existing state vs. competition no. 10194; at 2 PM, 24.07.2014

Project no. 10194 in average has 0.33 °C higher temperatures than existing situation. The only significant difference in in the area of cross road between Stojan Ljubic Street and Svetozar Markovic Street, where new parking space is introduced, and the temperature is 0.41 °C higher. It is seen that the improvement has been made in the northeast parts of the area, where temperature has dropped by 0.34 °C. The rest of the site, as expected, was not influenced by the change of new organization.

Competition proposal no. 15498 shows progress in following places: a) in front of the Beograd department store and Sindikat building, where new hard surface materials would be introduced, temperature drop by 0.32 °C as recoded; b) in front of the building on the west edge of the parking area is intended to be transformed a green space. The decrease of air temperature in this area would be from 0.24-0.47 °C. However, the north side of the square, as well as south recorded an increase in the temperature by 0.51 °C as a direct result of lack of vegetation (see Fig. 13b).



a) b)

Fig. 13: ENVI-met thermal map: a) The Central zone of Leskovac proposal no. 15498 and b) Comparison of thermal maps of the Central zone of Leskovac – existing state vs. competition no. 15498; at 2 PM, 24.07.2014

The solution scenario for the central zone of Leskovac

Thus the differences in temperature in both proposals, compared with the exhisting, in less than 0,5C and therefore insignidicant. In order to demonstrate how temperatures might be reduced, a separate scenario was run on the software.

The proposed solution has retained a diagonal pedestrian street as well as the greenery within the city park. Along this main communication a "water mirror" is suggested and more vegetation on the northwest side.

Fig. 14: Solution scenario for the central zone of Leskovac

The main part of the square, which was paved with asphalt and concrete, is covered by grass and the rest of the square is paved with cool materials that are characterized by high solar reflectance and infrared emittance values: granite cubes with mortar joints, coloured concrete blocks, non-vegetated permeable pavements, vegetated permeable pavements combined with splash fountains and large marquee on the south side of the square (see Fig. 14). Parking remained almost the same, with minor changes in pavement and urban furniture.

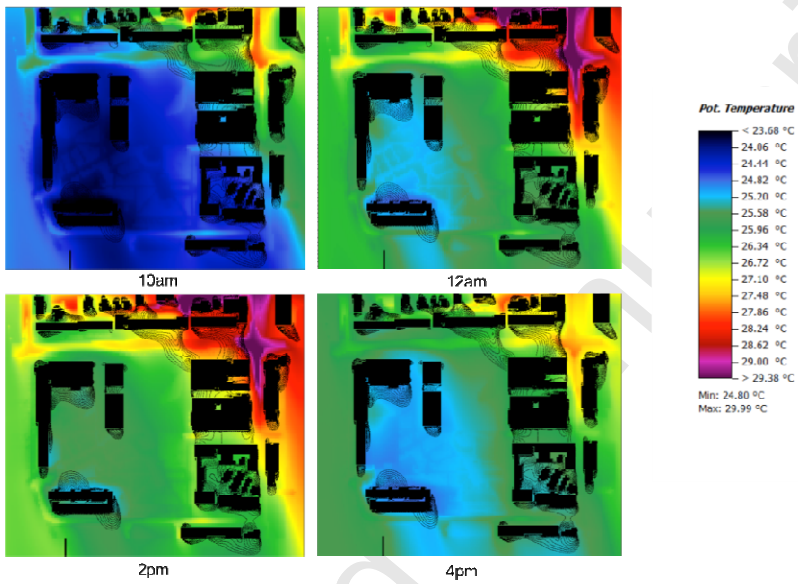


Fig. 15: ENVI-met thermal maps of Main Squaare in Leskovac – final solutions, 24.07.2014

Following analyses of the competition, the scenario design solution was developed and tested in ENVI-met. In general overall location the lower temperature has been noticed. This is due to better organization of the public urban space and usage of the ground materialization with higher reflective surfaces.

Table 3: Comparison between Existing and final solution at 4pm

	10h		12h		14h		16h	
	Present	**Scenario**	**Present**	**Scenario**	**Present**	**Scenario**	**Present**	**Scenario**
R1	24.364	**26.161**	25.696	**25.259**	26.05	**25.654**	25.39	**25.123**
R2	25.647	**25.88**	27.251	**26.305**	27.538	**26.621**	26.513	**25.802**
R3	25.711	**26.956**	27.296	**26.936**	27.542	**27.204**	26.461	**26.205**
R4	27.965	**27.882**	29.824	**29.782**	29.65	**29.593**	27.628	**27.620**
R5	25.468	**25.888**	27.466	**26.182**	27.88	**26.677**	26.822	**25.958**

From the table 3 it can be seen that the temperatures are in average smaller from 0.3-almost 1.5°C (R5 at 12h). It is important to mention that temperatures in R3 have been recorded to be slightly smaller (between 0.1-0.3 °C). Although this receptor was placed outside the researched area, the aim was to show that design of one place has influence on surrounding areas and that surrounding area (border area) has to be analysed for consequences. As mentioned before, the ENVI-met has slight difference between different simulations which can be observed in R5 measurement, however, this are imperceptible deviation from 0.01-0.05 °C. From obtained results, it is clearly seen that, regarding air temperature and Urban Heat Effect, final solution has better thermal performance indicators than the existing situation.

Even the scenario produced results produced results that were not significantly better than the exhisting. They are significant if we consider that the proposals were reduced solely on interventions in the domain of landscaping, planting and greenery and new pavement materials. Presented results indicate the situation in which we should anticipate as well the interventions on surrounding buildings in the form of an increase in the number of storeys, but following the measures provided for the protection of architectural and urban heritage in the study area.

Temperature plot at control points (receptors)

By analysing the results, certain interest points have been identified and the comparison analysis has been conducted to have overall look at the solutions. Due to change of design, receptors R1 (at dominant pedestrian diagonal through park), R2 (in front of "Beograd" department store) and R5 (in front of "Oslobodjenje" building) are important for cooperation of thermal performance of tested area, while receptor R3 (in the Liberation Boulevard) and receptor R4 (placed on cross road between Liberation Boulevard and Koste Stamenkovic Street) will serve as a reference, as they should not be influenced by change of square's urban design. The identified receptors were analysed throughout the day performance.

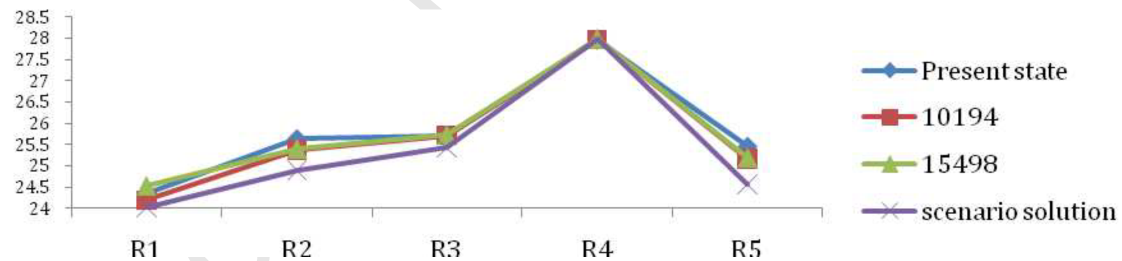


Fig. 16: Leskovac - temperature plot at control points (receptors) at 10am, 24.07.2014

Even at 10 AM difference between vegetated areas (R1) and non-vegetated ones (R2, R3, R4 and R5) is obvious. Instead of that the existing state shows the higher temperature in R2 and R5, which is due the change of surface materialization and dislocation of parking. As expected R3 and R4 have the almost identical values (Fig. 17). The final proposal has the best results in all receptors for this period.

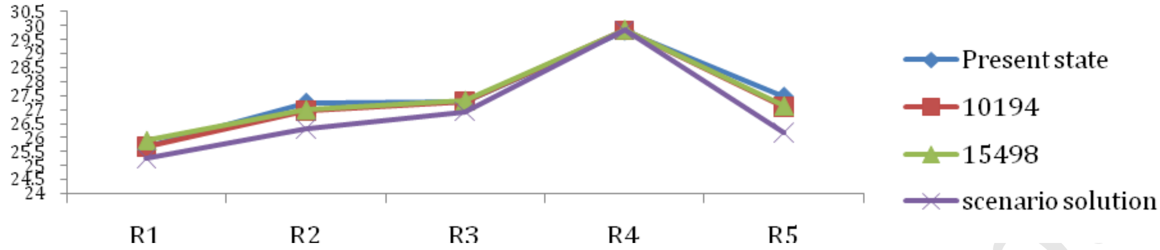


Fig. 17: Leskovac - temperature plot at control points (receptors) at 12 AM, 24.07.2014

At 12 AM and 2 PM the situation is similar as the previous time point (Fig. 18 and Fig. 19), however trend of higher temperature above asphalt areas (compared with pavement, wood, grass) is present as well (R2 and R5). So the materialization has to play a considerable roll in future process of shaping the cities.

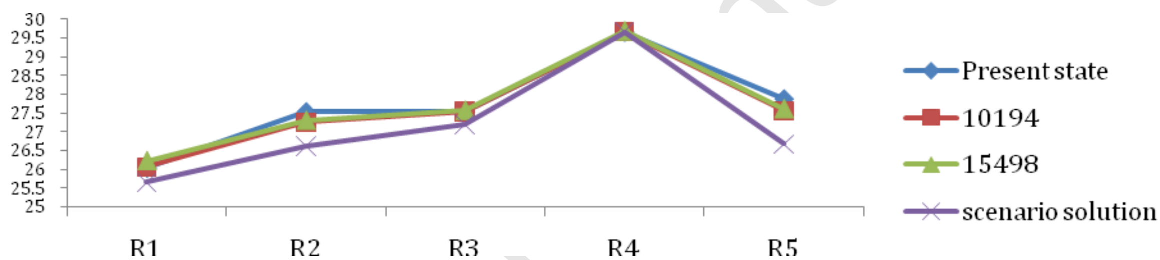


Fig. 18: Leskovac - temperature plot at control points (receptors) at 2 PM, 24.07.2014

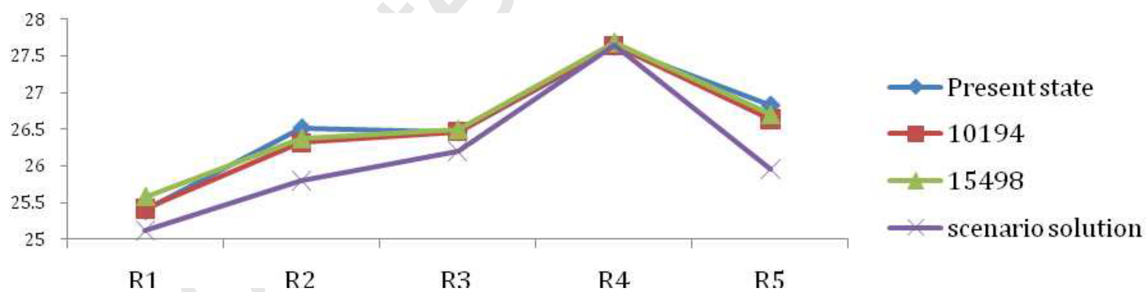


Fig. 19: Leskovac - temperature plot at control points (receptors) at 6 AM 24.07.2014

One interesting thing that was obtained from results is that all selected competition proposals at the end of the day (6 PM) have the slightly lower temperature then existing state (except R2, but that can be influence of materialization). However with change of materialisation in public spaces and introducing well-placed greenery the final proposed solutions has had lower temperature at the end of the day. This can especially be seen at R5, where the ground materialization (high reflective) has played a big role in reduction of heat accumulation. Importance of this phenomenon is in fact that this is first sign of the

Urban Heat Island effect – accumulation of heat over night. In other words the finale proposed solutions have a faster rate of cooling, which helps with accumulating heat and leading to UHI effect.. Unfortunately, this paper covers 24 hours simulation and accumulation of heat did not have direct impact on results. However, this is something that is proposed for future research.

Like the temperature difference on horizontal plane (at the one meter elevation from the ground), the difference across the vertical plane shows us correlation between change in the surface temperature [due to different materials or difference of shading factors] and air temperature. In the following illustrations results of temperature over the z axis will be presented.

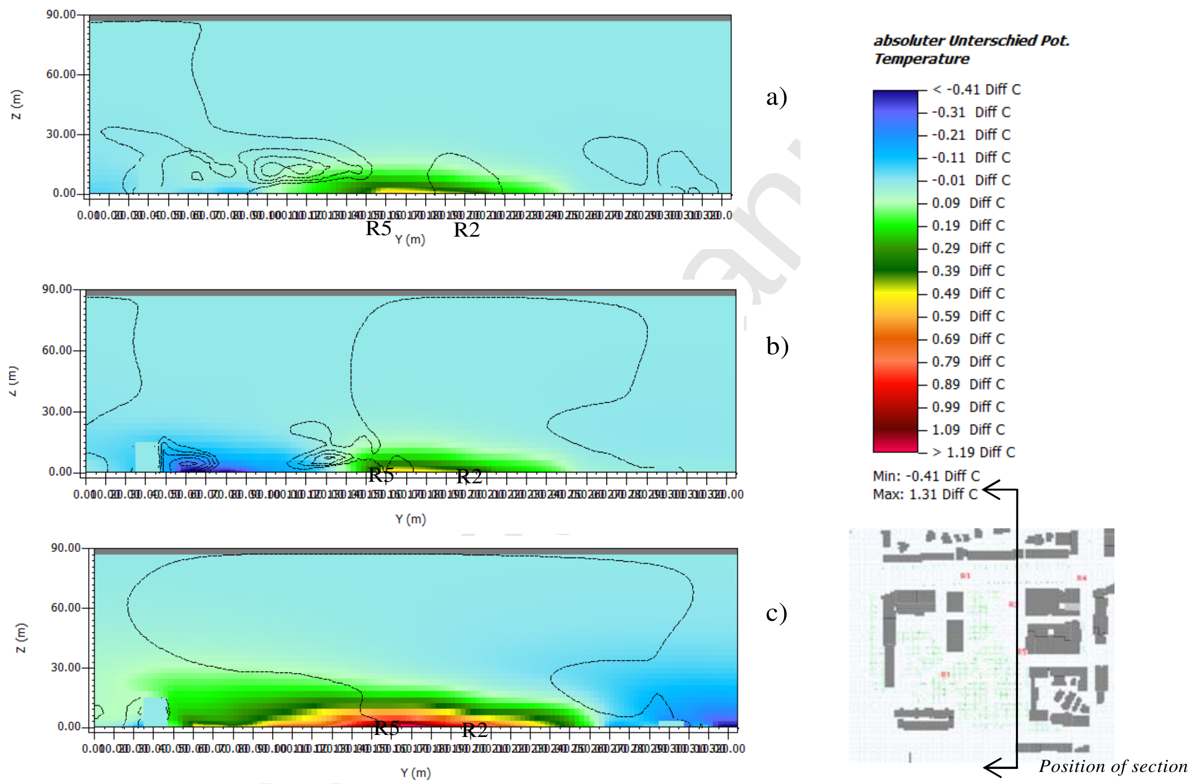


Fig. 18 Temperature difference in vertical plane through R2 and R5: a) between existing state and proposal 10194; b) between existing state and proposal 15498; c) between existing state and final proposed solution;

The simulation of proposed solutions no.10194 and no.15498 has recorded a minor improvement in the cooling effect [from 0.09 to 0.5^{o}C]. The proposed solution no.15498 has even the increase of surface and air temperature in certain parts due to the significant reduction of the green areas. On the other hand it can be clearly see [Fig.18] that vertical profile of the final proposed solutions is much cooler than the one of existing situation. The temperature difference goes up to 1.3 ^{o}C [between 0.2 - 1.3^{o}C]. This is mainly result of the change in the surface materialization and shading. The surface and air temperature in fist urban layer [up to 10m from the ground] are in 1.3 ^{0}C and 0.59^{0}C degrees lower than in existing situation, respectively. It has to be noticed that due to limits of software, the water fountain in the final proposal was not included in simulations. However, the literature review has showed that through the detailed CFD models, which are calculating heat, mass and momentum transfer between surface, water droplets and air **[24]**, that water fountains has cooling effect between 1°C and 4 °C [with absolute temperature deviation of 0.7°C]. By taking this into the consideration, the positive step forward in design of urban space [temperature comfort] with proposed final solution is made.

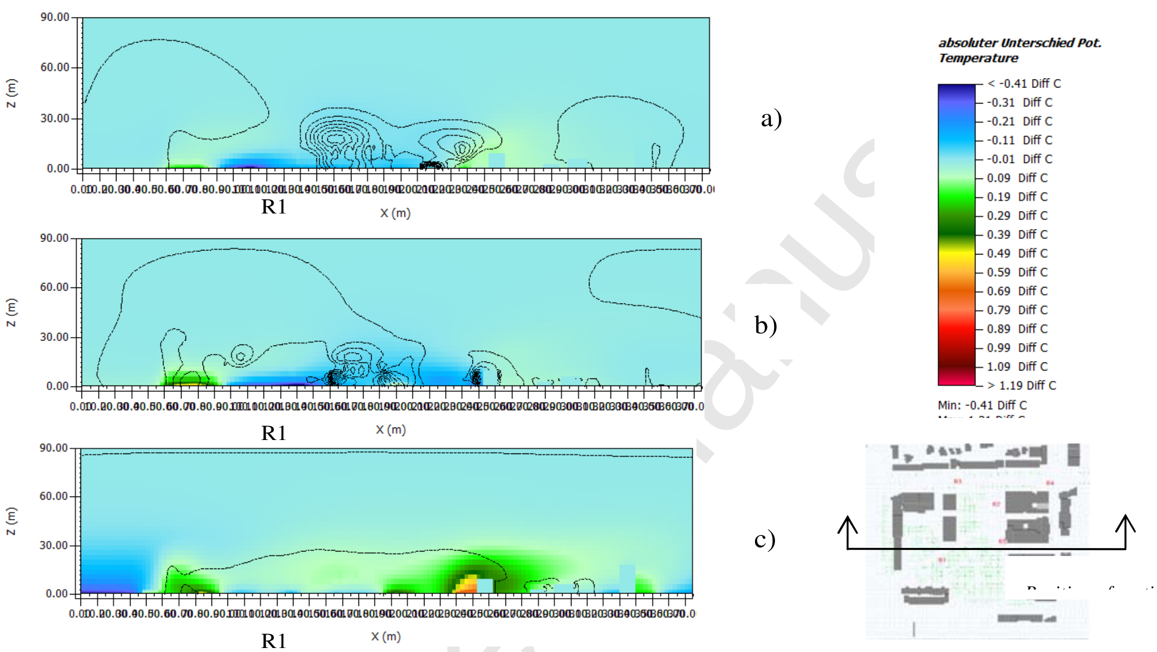


Fig. 19 Temperature difference in vertical plane through R1: a) between existing state and proposal 10194; b) between existing state and proposal 15498; c) between existing state and final proposed solution;

In the vertical plane around R1 receptor [Fig. 19], no significant changes were recorded. The pavement and vegetation disposition in this section is relatively the same, so steady conditions were expected. However, small cooling effect in final proposed solution has been recorded [0.5°C] as a direct result of a implementation of additional high vegetation. On the other hand, the proposed solution no. 15498 has slightly higher temperature, which is direct impact of increase of the pavement areas.

Discussion and conclusion

This paper presents the results of outdoor climate comfort analyses of two competition design proposals for the retrofitting of the main square in Leskovac as well as the scenario proposal. According to the reviewed literature, public space has a main role in promotion of the qualities of urban life. However, thermal comfort is one of the most important for the cities with hot summers. The findings confirm that a climate comfort was actually neglected in the judging criteria in the urban competition for the main square in Leskovac. It is necessary that climatic consideration becomes a focus for future retrofitting of open public spaces. Following the analysis of the results, several problem areas were identified, and needs to be addressed in order to receive appropriate urban design competition proposals in future.

In the preparation and announcement stage of an urban design competition, aspects of climate sensitivity in the proposals need to be clearly defined in the competition documentation. Temperature data for the existing site should be included in the competition details[G]. In addition, entries should include comparative simulation of temperature levels in the proposals, with agreed software**.** This kind of information could be very effective in presentation of the actual problems in relation to reducing overheating in the competition site. These recommendations could contribute to increased awareness and in proposing solutions that meet this important aspect.

The most softwares that are used in urban planning and design are usually focused on a single aspect: wind (MISKAM, MUKLIMO_3), radiation flux (SOLWR16 RayMan). ENVI-met is the only one three-dimensional software. The literature shows that ENVI-met is one of the few micro-scale models that fulfill all criteria and which are commonly used for simulating and quantifying urban heat island effects. According to research [**24**, **25**, **26**, **27**, **28**, **29**, **30**]. ENVI-met software's result is more precise and reliable in comparison with other software. As evidenced in practice in 2010 ENVI-met has more than 1700 registered users all over the world and shows successful results in research in countries and cities all around the world. This software is the one most frequently used by architects and urban planners - as an environmental assessment tool in city design processes. The greatest advantage of ENVI-met is that it takes into account the influence of vegetation on outdoors air temperature.

As the rise in air temperature is becoming a significant problem in cities [especially within 40^0 to 50^0 North latitude], reduction in temperature needs to become routine in city design processes. ENVI-met is a freeware [not open source] numerical simulating tool, thus it does not represent additional cost for the government, local authorities or designers.

The ENVI-met is easy-to-use. It has a user-friendly interface, and no highly advanced knowledge is needed to create and edit the 3D models. However, data are necessary to run the simulations and to obtain accurate results. These data can be accessed from literature or manufacturers information. The model can generate outputs at any time of the day in any location. This means that a vast number of data could be produced, although for decision making it is necessary to draw out a specific part of this data. For this purpose, ENVI-met comes with a visualization tool, Leonardo, which allows users

[G] Competition announcement, competition task, illustration of the competition site with the acquired obligations, geodetic drawing, ortophoto, situational plan and photo documentation of the competition site.

to view simulation results in 2D and 3D.

This paper has identified the importance of including outdoor climate comfort as one of the main criteria in urban design. Accordingly the urban design competitions should consider this aspect during all phases of the process in order to avoid situations in which prize-winning solutions do not satisfy outdoor comfort criteria. Furthermore, the results indicate the necessity of regular use of contemporary tools and applications developed for simulation and prediction of thermal effects that could be generated after the implementation of the proposed solutions in order to obtain the most suitable design for a particular open public space.

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