THEORY AND SMART PRACTICE IN THE REDUCTION OF NEGATIVE EFFECTS OF URBAN HEAT ISLAND

by

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Review paper
https://doi.org/10.2298/TSCI170530128S

Urban environment could be considered as a complex biotechnical system. Multidisciplinary, interdisciplinary, and intradisciplinary analyses are required in order to achieve sustainable urban communities and healthier cities, especially in the era of climate changes. The main goal of this paper is to investigate, select, and review the theories and smart practices in negative effects of urban areas heat problems reduction and to define the objective function of the issue. The objective function could be treated as the force, with magnitude and direction of influence that operates in a certain space, which is considered to control certain factors and parameters, including time as a dimension. Spatial and temporal gradient of canyon effect are defined with nodes canyon effects interaction. The thermal islands are analyzed by its volume, sources of heat, thermal gradient, with the goal to select strategies to reduce the negative effects of heat islands. Positive smart practice in the world is discussed. The purpose of this study is to find, by literature review and by holistic methodological approach application, better practice and adequate solutions for building, energy, water, and carbon balance in urban environment. The results are expected in the movement towards the blue and green cities.

Key words: *urban environment, biotechnical system, thermal island, canyon effect, blue green cities*

Introduction

Urban areas originate and exist as a consequence of fulfilling different human needs. As such, they are unavoidable phenomena in civilization development. At the same time, construction and maintenance of urban area as well as products of human activities continuously violate the existing biological and environmental conditions. Also, assuming that conditions for human existence (quality of air and water and temperature, to mention only a few of them) are sensitive and shall vary only in certain span of values, it immediately follows that there are a lot of efforts to be done in order to provide them. Bearing in mind that providing all conditions for human existence on the certain quality level in urban area could lead to conflict between them (for example: increasing density of people per kilometer square could lead to canyon effect or heat islands) it is obvious that solving one, another problem could appear.

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Synergy of technical and biological systems is necessary for solving balancing conflicts problems in this complex system, aiming to reach sustainability of it. Combining technology and biological systems in order to provide conditions for human existence on the adequate quality level, while the humans themselves influence both technological and biological environment has a consequence that urban area becomes a complex biotechnical system. Efficiency in providing conditions for human existence in urban areas is also one of the main goals because it is tight connected with sustainability and it additionally increases their complexity [1].

This paper aims to point out some ideas about complexity of urban areas and possible solutions. The living surroundings of contemporary men is in the same time very demanding and stressed by different influences that are often less than optimal for human health. On the determined living space, it is necessary to build a system of objects where basic human needs will develop and there by supply them with the existential elements as air, water, food, and all that on adequate quality level. Besides these existential elements, it is also necessary to build the technical systems, which enable adequate functioning and supplying to places where it is needed, in the sense of quality and quantity and suitable dynamics. The outcome of supplying is energy consumption needed for all systems functioning. The energy consumption has as its own consequence the contamination of physical and social environment.

Hence follows the paradox: the tendency for growth of quality of life brings it to its own destruction. Intensive urbanization and traffic increasement causes pollution of air, water, and environment [2]. Violent behavior, the one without holistic approach of monitoring the growth of life quality and the consequence that growth has on the environment, has high chances of leading towards the degradation of physical and social environment and reducing the quality of life on a determined living space. In conclusion: violent behavior is not sustainable, and from an aspect of modern civilization development, it is not even acceptable.

Different opinions, researches and discussions are in progress, including papers and studies, about influences of cities on global warming. In [3] it is more than 90%. In [4] is stated that cites are less than 75-80% of GHG emissions responsible, which prevails in literature. Even though the authors in [4] were right, it is still irrefutable that cities have significant impact on global environment. In this paper, the focus shall be on the local impact of cities especially because their influences, by default, are maximal inside the city. *In average, urban temperatures are about 1 to 3 ºC higher, but in specific weather conditions (calm, winter nights without clouds) the air temperature can be higher for 10 ºC than in surrounding rural areas* [5].

Effects of urban heat islands are especially clear in the cases of heat waves. The most known heat wave occurred in Europe in year 2003. It *began in June and continued through July until mid-August, raising summer temperatures 20 to 30% higher than seasonal average in Celsius degrees over a large portion of the continent, extending from the northern Spain to the Czech Republic and from the Germany to Italy ... with a death toll estimated to exceed 30 000, the heat wave of 2003 is one of deadliest natural disasters in Europe for last 100 years and the worst in last 50 years* [6, 7]. Heat wave combined with urban conditions and other negative parameters were researched in literature and related with mortality [8].

In [9] is proposed a systematic methodology for urban heat islands mitigation strategies with the most sustainable building form and site layout. Mitigation strategies vary from the practical measures in green roofing [10] to the maximization of the use of greenery design to improve daytime thermal comfort [11]. The newest phase change materials (PCM) are also investigate with their contribution with cool roofs within urban heat islands mitigation measures [12], as well as solar energy implementation within the façades or roofs [13].

The current state of the art of the researches concerning urban heat islands and urban canyon effect is relied to different strategies design methodology of the buildings and cities [11, 14, 15], new analytical models [16] new materials technics [17], and greenery of the buildings [18], and streets [19]. The problem is complex and requires holistic research of numerous subelements in correlation, starting from the wind velocity and dimensions in the canyon to mitigation of diverse adverse effects [20].

This paper contains the main elements of a built environment, presented and analyzed theoretically by objective functions, as a physical appears and phenomenon, with its correlation and impact on the humans and environment.

Blue green cities philosophy, as a designed strategy is presented through its private and public benefits. According to the proofed world mitigation measures, the goal of green areas increase and water resources optimization, mathematical model of blue green cities is created.

Because of conciseness, some of explanations were given in mathematical form.

Materials and methods for heat urban areas problem research

Every built, urban area can and should be looked as a complex, biotechnical system. There are at least two reasons that best explain the statement:
– the objects artificially build fit into the already existing natural ambient and
– the natural courses of existential elements are changing.

The anthropogenic activities in urban areas additionally increase the complexity because they influence both existing biological and technical system introducing new elements, which have not existed in urban area before (such as products of vehicles, heating systems, *etc.*).

Objective function of urban environment as a complex biotechnical system

The objects built in an existing natural ambient change the regimes of natural processes, existing up to then, establish new processes and the new state of interaction of the changed regime of natural processes and those newly arisen appear, which can be presented:

$$S = (PP - \mathit{\Delta}) + NP + I\left[(PP - \mathit{\Delta}), NP)\right] \tag{1}$$

where S is the set of processes after construction of the given natural area, PP – the natural process before construction of the given area, $\mathit{\Delta}$ – the processes disappeared due to construction of the given area, NP – the new processes arisen after the construction of the given area, and I – the interaction.

Holistic approach implies the identification of all relevant parameters for realization of defined goals, as well as in space and time. The realization of goals in space is connected to a space horizon of constructed area. The space horizon of constructed area can be defined as a distance from a constructed area where all its influences on a physical and social environment and other parts of environment stop. Space horizon of constructed area is best described by:

$$\lim_{d \to \max} i_{\mathrm{UA}} = 0 \tag{2}$$

which could be explicated in followed way: *space horizon of urban area influence*, i_{UA}, *is the maximum distance on which the influence of urban area on environment equals zero* [21]. In the previous equation i_{UA} means the influence of urban area on surrounding environment disappears on the certain distance, *d*, from its source.

Time horizon of urban area is the time interval in which the consequences of it last. Simple description of time horizon could be given by:

$$\lim_{t \to \max} i_{\mathrm{UA}} = 0 \tag{3}$$

which could be explicated in followed way: *time horizon of urban area influence,* i_{UA}, *is the maximum time interval in which the influence of urban area on environment equals zero* [22]. It actually means that urban areas will not last infinitely. If the complexity of the system is indicated by number of its elements and by set of connections between them, it is possible to state that urban area is very complex system, especially because some parameters which define the quality of life must be kept above predefined values, *i. e.* above values which provide desired level of life quality in urban area.

The sensitivity of the model of urban heat problems is indicated by the problem of assumption about the consequences caused by changes of its elements. Basic objective function of urban areas is to present the correlation between main elements of urban areas and to support efficiency in human's needs satisfaction. Of course, level of efficiency is dependent on different factors and parameters. The subject of this paper represents an attempt to exploratory cover, in one place, all elements of the system, with the analysis of the correlations between the connections, where the goal would define the further research with the aim of more detailed investigation of each influence.

Urban units of the canyon type and its effect

The definition of the notion, criteria and mathematical models of urban heat problem

The streets in which, because of the significant heights of the constructed objects in the long parts or along the complete streets, there is a weak circulation of air, the effect of holding down the air appears, increased contamination of air and noise, are called the streets of the canyon type. All the negative consequences of the construction of these types of the streets and buildings are analyzed by the function of the appearance of the wind, depending on their direction and intensity.

The design of the street and the objects along her length did not significantly effect on the ability – inability of the air circulation in the streets of canyon type. The correlation of the highness of the objects and width of the street can be of different values but in [23], following ratios are researched $H/W = 0.5$, 1, 2, and 4.

In the case of blocks, *i. e.* parallel notion of two streets of canyon type, for the width of canyon is taken the wholesome width of both streets of canyon type, including the object between those two streets. The numerical model is based on the 2-D, hydrostatic mesoscale model [24, 25], but the inelastic approximation is applied to the dynamic core and incorporates the single-layer urban canopy model [26]. The inelastic equations of motion, based on the hydrostatic assumption by [27], are:

$$\frac{\partial u}{\partial t}+u\frac{\partial u}{\partial x}+w\frac{\partial u}{\partial z}=fv-\Theta\frac{\partial \pi'}{\partial x}+\frac{\partial}{\partial x}\left(K_{\mathrm{H}}\frac{\partial u}{\partial x}\right)+\frac{\partial}{\partial z}\left(K_{\mathrm{m}}\frac{\partial w}{\partial x}\right) \tag{4}$$

$$\frac{\partial v}{\partial t}+u\frac{\partial v}{\partial x}+w\frac{\partial u}{\partial z}=-f(u-u_{\mathrm{G}})+\frac{\partial}{\partial x}\left(K_{\mathrm{H}}\frac{\partial v}{\partial x}\right)+\frac{\partial}{\partial z}\left(K_{\mathrm{m}}\frac{\partial w}{\partial z}\right) \tag{5}$$

The hydrostatic equation is:

$$\frac{\partial \pi'}{\partial z}=g\frac{\theta'}{\Theta^2} \tag{6}$$

and the continuity equation is:

$$\frac{\partial \rho_0 u}{\partial x}+\frac{\partial \rho_0 w}{\partial z}=0 \tag{7}$$

where the symbols *u, v, w, x, z, f, g*, and θ have their conventional meaning, u_{G} is the adequate component of geostrophic wind velocity, K_{H} – the horizontal exchange coefficient, K_{m} is the vertical exchange coefficient of momentum, and θ' – the perturbation potential temperature from mean potential temperature Θ. Here π is the Exner's function, and π' is its perturbation from mean Exner's function Π, and ρ_0 is the mean fluid density.

The thermodynamic equation is:

$$\frac{\partial \theta'}{\partial t}+u\frac{\partial \theta'}{\partial x}+w\frac{\partial \theta'}{\partial z}=\frac{\partial}{\partial x}\left(K_{\mathrm{H}}\frac{\partial \theta'}{\partial x}\right)+\frac{\partial}{\partial z}\left(K_{\mathrm{H}}\frac{\partial \theta'}{\partial z}\right)+Q_{\mathrm{RCOOL}} \tag{8}$$

where K_{H} is the vertical exchange coefficient of heat and Q_{RCOOL} – the radiative cooling term. The equation for specific humidity q_v is:

$$\frac{\partial q_v}{\partial t}+u\frac{\partial q_v}{\partial x}+w\frac{\partial q_v}{\partial x}=\frac{\partial}{\partial x}\left(K_{\mathrm{H}}\frac{\partial q_v}{\partial x}\right)+\frac{\partial}{\partial z}\left(K_{\mathrm{H}}\frac{\partial q_v}{\partial z}\right) \tag{9}$$

Exner's function is defined:

$$\pi=c_p\left(\frac{p}{p_{00}}\right)^{\frac{\mathrm{R_d}}{c_p}} \tag{10}$$

where p_{00} is the reference pressure, $\mathrm{R_d}$ – the gas constant for air, and c_p – the specific heat of the air. The vertical co-ordinate of the model is possible to be transformed from z to z^*, and to be written in a terrain-following co-ordinate system in order to consider the terrain effect in the model. The vertical co-ordinate z^* is defined:

$$z^*=z_{\mathrm{TOP}}\frac{z-z_{\mathrm{G}}}{z_{\mathrm{TOP}}-z_{\mathrm{G}}} \tag{11}$$

where z_{G} and z_{TOP} are ground elevation and height of the model atmosphere top, respectively.

The space and time horizons of canyon effect

Determination and analysis of objective function with analysis of parameters’ intervals, aiming to determine maximal allowed interval of objective function change, could be considered as a forces (denoted by letter *F* in following formula, intensity and direction of influence) which influence certain space in which the certain parameters (denoted by *P* in the following formula) are heeded and the time is also included as a parameter:

$$O = O\left(x, y, z, t, \sum_{i=1}^{n} F_i, \sum_{i=1}^{m} P_i\right) \tag{12}$$

Objective function, O, is dependent of the independent variables x, y, z, t (space and time), significant factors on the considered area and parameters which shall be harmonized. Spatial gradient of canyon effect could be described by derivative of function of space co-ordinates:

$$\frac{\partial S}{\partial x}, \quad \frac{\partial S}{\partial y}, \quad \frac{\partial S}{\partial z} \tag{13}$$

where S is the canyon effect thorough space.

Generally, could be stated that:

$$\frac{\partial S}{\partial x} \neq 0, \quad \frac{\partial S}{\partial y} \neq 0, \quad \frac{\partial S}{\partial z} \neq 0 \tag{14}$$

That means that canyon effect varies in space. Time gradient of canyon effect could be described by derivative of function of time:

$$\frac{\partial S}{\partial t} \tag{15}$$

Generally, could be stated that:

$$\frac{\partial S}{\partial t} \neq 0 \tag{16}$$

That means that canyon effect varies with time.

Modelling of the canyon type of streets and increase of the air contamination

When researching the contamination of the air in city streets of the canyon type, caused by traffic, the usual dispersion models developed for highways, do not give the satisfactory results. Therefore, for considering the streets of canyon type it is developed few models between which are the most common ones known under these acronyms: STRRET (or SRI), CPBM, CFD, and OSPM (and one close to this one, AEOLIUS) [28-34]. The mentioned models are used in different occasions, for example: controlling the air quality, developing the advanced strategies in traffic management, interpretation of measurements results, studies drafting about exposure of the urban population with different pollutants, foreseeing of contamination, *etc.* When the profiles of the streets are according to the space characteristics of the canyon type, *i. e.* when the buildings are sequentially directly along the street, the problem are multiplying because of the weak circulation [35].

In the streets of canyon type it is often found, as one of the most dangerous pollutants [36] represent polycyclic aromatic hydrocarbons: benzo pyrene, or shortly B(a)P. The B(a)P is a cancerous material that is derived from the gases of the cars and should not be in the air in the amount bigger than 0,1 ng/m. The experts from World Health Organization counted the risk unit for this substance: if B(a)P is present in the air more than 1 μg, each day during the year, for 70 years of human life, there is a possibility that out of 100.000 residents, 9 of them suffer from lung cancer. In our capital city it is noted a constant growth of the concentration of B(a)P; it exceeds the permitted limit and in some places even reaches the concentration of 1 μg. In autumn and winter period its presence it is even higher, because B(a)P issues also as a product of partial fossil fuels combustion. The biggest issue of the city is the contamination with micro particles which during the summer, when they should be at lowest, rise between 500-600 μg per cubic meter, when the allowed value is 120 μg.

The most common source of this type of contamination is city traffic, *i. e.* city buses which use diesel fuel for cars. In Serbia the leaded petrol is mostly used for cars, so alongside of pollution with mentioned substance the pollution with lead also appears. The most critical parts in Belgrade, where the contamination is higher than in some other parts are *dvojka circle** and the Despota Stefana street [37], which is the canyon type street, where the gases are withholded because the absence of wind. It is not only the passenger cars and cargo traffic (which is provided through the center because there is no traffic detours), but also because of old coal furnace (in winter time), which additionally pollutes the air.

Urban heath islands

Basic definitions and the nature of phenomenon

According to the assessments of the UN, in the beginning of the 21st century, around the half of human world population (about 3 billion people), will live in the urban environment. The number of people who live in the urban environment in the next 25 years will grow for additional two billions, according to estimation. Consequently, also the temperature of the air will rise in urban environment, due to increase in the number of residents, local effects of apartment heating, industry and traffic. The intensity of heath islands is defined as the difference in the temperature between urban area and its rural surrounding. Few factors that elucidate additional heating of cities are acknowledged [7]:

– increased absorption of short wave radiation,
– increased heat accumulation,
– anthropogenic heat production,
– lowered loses of long wave radiation,
– lowered evapotranspiration, and
– lowered loses of heat caused by low turbulence in urban canyons.

Other factors, as a synoptic weather conditions (wind velocity, height, and covering of clouds), topography and morphology of urban area, modify the magnitude of urban heat islands. According to [38] urban heat islands are the nightly phenomenon present at winter (when the difference between urban and rural temperature is 2 ºC) and also at summer (when the difference between urban and rural temperature is 5 ºC) mainly caused by urban geometry and thermal characteristics of used material. In the same time anthropogenic produced heat does not have significant role in developing urban heat islands effects. For example: in Rome the maximum average difference is in August and it is 4.2 ºC.

In [21] is stated that even in urban areas with 1000 citizens it is possible to register effects of urban heat islands. Among different models, the formula for calculating the heat-island intensity near sunset under cloudless skies conditions, as a function of number of residents, *i. e.* population and regional wind speed:

$$\mathrm{d}T = P^{0.25}(4U)^{-0.5} \tag{17}$$

* *Dvojka circle* is a local name for the central part of the city, marked with the tracks of tram No. 2, which mainly coincides with the zone of urban heat island.

where dT [K] is the island intensity, P – the number of residents, *i. e.* population, and U – the regional non-urban wind at a height of 10 m.

The influence of wind and population on heat-island intensity is given in tab. 1.

Table 1. The heat-island intensity depending on wind and population

U/P	1000	10000	100000	1000000	2000000
14	0.75	1.34	2.38	4.23	5.03
12	0.81	1.44	2.57	4.56	5.43
10	0.89	1.58	2.81	5.00	5.95
8	0.99	1.77	3.14	5.59	6.65
6	1.15	2.04	3.63	6.45	7.68
4	1.41	2.50	4.45	7.91	9.40
2	1.99	3.54	6.29	11.18	13.30

It is obvious that heat island intensity is inverse related to the wind speed and directly related to population. In addition, it is obvious that wind speed influences heat-island intensity stronger than increase of population.

The magnitude of urban warmth (usually expressed as the difference between highest and the background rural temperature, which is called the heat island intensity – $\Delta T_{\text{u-r}}$) could be up to 12 ºC [22, 39], which significantly influence health and quality life for urban population. Natural climate balancers as green spaces and parks could absorb until 80% of heat through soil humidity and vegetation. The temperature in the cities rises with the increase of the absorbing surfaces that hold the heat they receive during the whole day and emit it in their surroundings.

Agency for environment protection in USA defines these *urban heath islands* as a phenomenon, which appears when urban areas are warmer than its surroundings [40]. Radiation, thermal, and hydraulic characteristics of materials varies mainly depending of its kind: from materials made of stone, soil, vegetation, or water. In many, but not all urban areas, the space covered by vegetation decreases. That causes evapotranspiration (hidden heat flux) increasing heating of urban structure and air (sensitive heat flux). Still, the characteristics of construction materials differ [41].

For example, roof-covering materials – asphalt and ceramics tiles, straw coverings, corrugated iron/sheet metal – have very different radiation and conductivity characteristics, which significantly influence processes of heating and cooling. Other parts of objects, for example walls, are made from the material with different specifications, which have large influence on the cooling and heating processes, on a resulting temperature of the object and air inside of it, and therefore, on the wholesome micro-weather of the local level. Inside cities, the temperature difference between urban and rural shows an important space and weather variability.

The temperatures from one side of the street to other, from park to an industrial center or from one suburb to another can be largely different, as the nature of these differences is changed with time. In general, the biggest intra-urban temperature differences are linked with open sky and low wind speed. The bigger the number of air conditioners there is the higher the temperature arises that has a significant effect on local weather, which bring the implications for a human comfort and the need of cooling. On a higher level, the higher use of air conditioners results in higher emissions of harmful gasses through higher consumption of electric energy [42].

There are direct contributions to urban heating by climatic changes**.** Urban areas cover certain part of Earth's surface and it's thermal, cinematic, and humidity effects are spread by the wind even a few kilometers (space horizon). Indirectly, the gas emissions that cause the greenhouse effect from the construction and cities maintenance are big and increased; the gasses from urban regions are dominantly anthropogenic.

Furthermore, the warmer condition in many cities result in higher energy consumption and resources by residents (as an attempt to ease the heating effects), which also makes the urban population more vulnerable and pervious to the heat waves and other rather extreme time conditions. Hence, it is critical that cities and urbanization drivers have in mind these facts and to work together on developing the ways of reducing, and eventually eliminate, the global climate changes [43]. The existing urban environments will undergo diverse reconstructions and renovations. The decisions for the method by which these changes will be applied will affect the people living in buildings, local communities and whole cities. By combining them, they will have global implications and consequences [44, 45].

Space and time gradient of urban heat island

Space gradient of urban heat island could be explicated as:

$$\frac{\partial Q}{\partial x}, \quad \frac{\partial Q}{\partial y}, \quad \frac{\partial Q}{\partial z} \tag{18}$$

where Q is the function of urban heat, and (x, y, z) are spatial co-ordinates. Generally could be stated:

$$\frac{\partial Q}{\partial x} \neq 0, \quad \frac{\partial Q}{\partial y} \neq 0, \quad \frac{\partial Q}{\partial z} \neq 0 \tag{19}$$

This means that distribution of the heat is not homogeneous in space of urban area. Time gradient of urban heat island could be explicated:

$$\frac{\partial Q}{\partial t} \tag{20}$$

where Q is function of heat and t is time. Generally could be stated:

$$\frac{\partial Q}{\partial t} \neq 0 \tag{21}$$

This means that heat in urban area is not constant in time.

Results in solving the problem of heat in urban areas

To reduce problems of urban heat islands first is necessary to identify its structure. The main problems of urban area are the canyon effect and the increased temperature caused by buildings. Canyon effect appears when the stream of air in urban areas is obstructed by the disposition of buildings and orientations of streets. Urban heat islands are caused by heat absorbed by materials of buildings and its emission to environment.

Methods for reducing the negative consequences of canyon effect

If there exist relatively narrow streets and constructed objects placed sequent on the left and right sides of the street, with the altitude minimally equal to the half of the width of

the street, the problems with circulation appear, holding down the contaminating materials mostly caused by traffic. The most efficient solution method of the canyon effect problem is that in the urban environments do not project streets of canyon type. If those streets already exist, the possibilities of reducing the negative consequences of the canyon effect are searched for in the methods of eco remediation:
– construction of roof gardens method,
– construction of vertical gardens,
– placing the alleys, and
– construction of lawns.

Methods for urban heat islands effects mitigation

The effects of urban heath islands have direct and indirect consequences on life quality in the built environment. Direct consequence of temperature increase is the aim to reduce it, which is to be in accord with optimal conditions for human living and work, through activation of cooling systems, which increases the energy consumption and atmosphere contamination [46]. On the other hand, the cooling down of the already existing heat (absorbed by different material from which the buildings, roads and pavements are made) is not removed and it is not transformed into other useful forms, but it is reassigned in space and time. It could be said that cooling equipment utilized for eliminating the negative effects of the urban heat islands actually additionally increase their effects. The reassignment of the heat is done practically by supplying the optimal temperatures in work and living terms while the amount of heat in the environment is increasing [47].

Possible strategies for mitigation effects of urban heat islands are enhancement of shadow areas (enhancement of trees in urban areas) and utilization of bright colors of buildings' surfaces [48]. By utilizing the bright colors and increasing of albedo in cities, the consumption of energy in urban areas could be reduced. Bright surfaces also could last longer than conventional dark surfaces because they reflect radiation, which could destroy materials and they remain cold and have smaller thermal expansion and shrinkage.

Urban heat islands in urban environments largely come into existence because of continuous increase of total constructed surfaces, increase of concrete or glass surfaces, vertical façade and reducing of the open sky factor. The consequences are increased absorption of solar radiation, reduced loss of terrestrial radiation, reduced total turbulent heat transport and reduced wind speed.

Methods for soothing these negative effects can be searched for in the choices of the right materials with bigger reflection for buildings and roads, in high reflecting colors for cars, adequate projection of the gaps between the buildings, as well as variation of the objects heights (to reduce the canyon effect) [49]. Roof gardens are the good replacement for green on the ground for which there is less and less space. With cooling down and humoring the dry warm air, at least in the limited green parts of the community, the micro-weather will improve, and by that better and healthier environment for life.

Urban heat islands appear when the surface materials have following thermal characteristics: high heat capacity, higher heat conductivity, and bigger and increased surface heat capacity. That are cities or their parts with more impervious surfaces, where the greater coefficient of runoff, reduced evapotranspiration (hidden heat flux), with existence of human produced sources of energy (anthropogenic heat flux), electricity and burning of fossil fuels, heating and cooling systems, machinery, cars, canyon geometry of buildings, air pollution, and other numerous human activities, which produce air pollutants and dust in atmosphere, which cause greenhouse effects.

Methods and strategies for reducing the negative effects of urban heat islands can be searched for in the reduction of surface temperatures (in changing the material emission), improving the roof insulations, construction of porous pavements, local pools for precipitation retention and in total increase of green surfaces by building parks, vertical, and roof gardens.

Possible methods are also reduction of solar beam angle, need for passive cooling (hangings on windows, material changes), district systems for heating and cooling, combined heating and cooling systems, combined heating and electricity and cogeneration systems.

Constructed surfaces

Urban regions represent complexes of different materials and their combination distributed firstly with the aim to satisfy the human needs who live in that area, although these needs are often neglected if the constructed areas are viewed as morphological phenomena and if the visual qualities of urban space prevail. In urge to reach the functionality of constructed areas, different combinations of materials arise which have different heat characteristics (asphalt for roads, concrete, glass and metals for buildings and business facilities, *etc.*). In order to find out the characteristics of materials used in urban area different methods and measurements could be provided including development of them [50].

Largely present materials on static elements of urban areas are concrete, asphalt, glass, steel, on the moving elements – cars are metal and glass. Denominated materials sometimes all by themselves produce higher temperature and hold in the thermal energy given by the Sun. Constellation of these elements makes that today many urban environments become places with average temperatures significantly higher than their surroundings, becoming urban heat islands. In some cases, the layout of constructed objects in long, narrow streets with no wind with lots of traffic can additionally make the canyon effect and cause even bigger problems due to contaminated and heated air and noise.

Elements like bigger park surfaces, vertical and roof gardens and natural and planed water surfaces, affect the average temperatures of urban environments by, in large part, returning their temperatures to before existing natural ambient, *i. e.* with those temperatures that were in zero state of physical and social environment before creation of the city or/and they reduce it. The city planning as a complexity of the biotechnical systems, with dynamic balance of both elements in adequate space and time balance represents a challenge for modern science and praxis is the main subject of this paper. Important (necessary) factor of the analysis of constructed areas is the knowledge of used materials and their characteristics. The problem with determining the materials used in a single constructed area presents a big scope of information that needs to be collected due to different materials used in different time periods and constructional and architectural characteristics.

Due to that, the attempts are made based on spectral specifications of material gained by remote sensing to determine materials characteristic for a specific urban area. This approach has as its goal to, based on available information that are relatively easy and summarily collected, simplify and speed up the process of determining the materials used on a specific constructed area. However, the structure and layout of different materials on a specific area can in a large amount confuse when interpreting spectral shots so, here also, the studious and expert approach is needed.

Already in 19th century, it was noted that the constructed areas are warmer in regarding of those that were not [51]. This is because the construction materials absorb and hold in more of solar energy regarding to natural materials. In the literature, two basic reasons for this phenomenon are stated. The first one is that the most of constructed materials are opaque and watertight so there is no humidity that could absorb solar energy.

The second reason is that dark materials according to configurations that look like canyons (buildings and pavements) collect and keep in more of solar energy. Temperatures of dark and dry surfaces directly exposed to solar radiation can reach up to 88 °C during the day while surfaces with vegetation and humid terrain, under the same conditions, can reach only 18 °. Anthropogenic heat (one derived from humans), smaller wind speed and air contamination in constructed areas also contribute to this temperature increase (which is useful in colder cities and higher altitudes and latitudes).

Traffic

Organization and intensity of traffic in cities is a very important subject, from which greatly depends the quality of urban physical and social environment [52]. Negative effect of traffic in urban environments reflects in increase of the noise and increase of air contamination.

The researches show that 50% of air contamination in cities comes from traffic. In Serbia, for determining permitted concentrations of contaminating materials are used international directives, recommendations and regulations:
– European directive of air protection and monitoring of its quality in urban areas,
– recommendation of World Health Organization, and in force is also
– regulation of limitations of gas emissions and methods for measurements.

All of them regulate the air contamination area. Modern regulations from this domain used in Serbia are attuned with previous European regulations and those from World Health Organization, but not enough. It is still worked on harmonizing them with directives of the EU. By the regulation of limited emission values of harmful materials are legally defined limited daily values of individual pollutants concentration in air. Regard to other European cities, in Belgrade, the air quality is very low [53]. Bad qualities of fuels that have already been forbidden in EU, but in Serbia still are not. The following concentrations of pollutants in the air are limited daily values:
– total amounts of aero-sediments: 450 μg/m^2,
– lead (aero-sediment): 250/100 μg/m^2,
– cadmium (aero-sediment): 5/2 μg/m^2,
– zink (aero-sediment): 400/200 μg/m^2,
– soot: 50 μg/m^3,
– SO_2: 150 μg/m^3,
– NO_2: 150 μg/m^3,
– CO: 10 μg/m^3, and
– lead: 1,0 μg/m^3 [54, 55].

Air contamination can be inspected from three aspects: protection of human health, of ecosystem and material goods. Noise in the urban areas, mostly caused by traffic, has an irritating effect on humans and can slowly lead to many health issues and complications like low focus, fatigue, rapid pulse, and even high blood pressure. One of the methods used in big world metropolitan cities for reducing the negative effects of the noise is construction of green roofs.

Green roofs absorb sound by which they reduce the noise in their surroundings and improve noise protection of the rooms beneath the roof, but also it reduces the acoustical façade load from road traffic [56]. One of the examples of green roofs whose main function is noise reduction is the one placed on the airport building in Frankfurt, Germany the biggest and busiest in EU, and by that the big source of noise. On the airport building the green roof is situated of extensive type with substrate layer of 10 cm. The sound measured before and after its placement showed noise reduction of the minimum 5 dB [57].

Positive results from smart world practice

Possible benefits of blue green benefits utilization

In spite of the fact that not all benefits gained by utilization of blue and green resources in certain city could occur at the similar level in [58, 59] they are divided on the private and public and described in details.

Private benefits

Private benefits of smart blue green practice are as follows.

– Reduced energy consumption and temperature control (economic advantages for the building operator: saving 25% of the summer cooling demand on the upper floor was achieved under grass roof with 100 mm of growing medium. Although the thermal efficiency of green roofs is well documented, the thermal benefits of living walls are not as obvious at first glance, but are also considerable. Temperature drops of 2-11 ºC).
– Noise reduction trough insulation (green roof with a 12 cm substrate layer can reduce sound by 40 dB and a 20 cm substrate layer can reduce sound by 45-50 dB with the substrate tending to block lower frequencies and the plant blocking higher frequencies).
– Improved indoor air quality (vegetation captures airborne pollutants such as dust and pollen, and filters noxious gases and volatile organic compounds from carpets, furniture and fittings. Research on the Guelph-Humber Building wall has shown that the system can remove half of the benzene and toluene in the air during single pass and up to 90% of the formaldehyde).
– Cost reduction by integration with building systems, although not all buildings are designed with an holistic approach, integrating systems such as water management and power generation with green roofs and living walls can bring economic benefits to the building owner and occupier).
– Increased usable open space and human comfort (the convenience of city living is combined with the pleasures and benefits of outdoor living by incorporating a green roof into a city home).
– Protection of the building structure (studies, particularly in Germany, have indicated that roofs with built-up membrane systems can have a life expectancy at list twice, and usually three times, as long as usual or around 50 years, owing to protection from mechanical damage, including the impact of hail and wind-blown dust, from harmful ultraviolet radiation that breaks down many materials, and from extreme temperature differences.
– Direct sustainable action, which means that concrete measures undertaken could be treated as investment and are profitable.

Public benefits

Public benefits of smart blue green practice are:

– Reducing urban heat islands effect, (many worldwide studies conclude that temperatures can be elevated by approximately 9 ^{o}C because of reflective and dark surfaces that domi-

nate dense urban environments). However, the outside temperature can be reduced by around 5 ºC with the introduction of vegetation, according to some sources. A mesoscale atmospheric simulation modelling project for Toronto conducted by University of British Columbia indicated that green roof coverage of 50% could cool about third of the city by 2 ºC).
- Air pollution reduction (vegetation including green roofs and living walls reduces effect of CO_2 by increasing the CO_2/oxygen exchange through process of photosynthesis and reduces air pollution by removing airborne particulates from the air).
- Storm water management and improved water quality (one of the major environmental issues in cities worldwide is storm water management – waters' interception, collection, redirection, cleansing, and reuse. Green roofs and living walls can play a significant role in this process and become a major component of the water sensitive urban design.
- Improved public health and wellbeing (urban heat islands becomes one of Australia's major public health issues, especially during heatwave conditions).
- Urban agriculture opportunities (with an increasing costs of transporting food over long distances and a focus on reducing *food miles*, rooftops are being considered more seriously as open space that can be used for food production).
- Integration with landscape, biomass and biodiversity (with many governments programs to intensify densities and limit the physical footprint of cities, green roofs and living walls can help increase open space and biomass that might otherwise be lost in urban densification).
- Reclaiming urban wastelands.
- Adapting to climate change (carbon footprint).
- Contribution to aesthetic and urban design.

Bearing in mind mentioned benefits it is possible to conclude that possibilities for different economic analysis exist and justify the investments for effects of urban heat islands mitigation.

Urban park surfaces, vertical and roof gardens

The influence of trees and urban park surfaces on an ambient temperature and air quality is highly important. At the same time, there is an influence of the trees to an energetic consumption of constructions. The urbanization process changes thermal balance of an area creating the urban heat islands effect so the cities can be a few degrees warmer that surrounding rural areas. These increased heats can make cities uncomfortable for life and in the cases of heat waves. This can cause some serious health issues.

According to the results from the same city (the temperatures measured from the concrete and grass surfaces, with and without tree shadows, as well as on the asphalt and grass surfaces in urban parks) and the surfaces and shadows significantly affect the temperature as obtained by experiments and explained in [30]. The grass reduces surface temperature by 24 ºC while trees reduce by 19 ºC. The temperatures of concrete exposed to sun are increased from 2.3 to 2.6 times while in the shade are increased by only 1.3 to 1.6 times. Grass increases the temperature exposed to sun by 0.5 to 0.7 and 0.3 to 0.6 times when in shade. Spectral analysis is also used for efficient determining of the spread of vegetation in urban areas.

Green roofs can reduce heat, minimize heat absorbing surface, and by that effect on a better air quality. By acting collectively with other green elements, green roofs have more important role in climate changing of the cities in total. Unlike concrete roofs, during summer days the temperature of concrete or pebbly roofs can increase from 25 to 60 ºC (even up to 80 ºC) [60].

Research conducted in Singapore show: if the roof is covered with grass, the air temperature above that surface will not go above 25 ºC. The 20 cm of substrate with 20 to 40 cm tall grass will already have the same power of isolation as if we put fiberglass of 15 cm. The air in the rooms of buildings covered with green roof is 3 to 4 ºC cooler that the outside air, when the daily temperature is between 25 and 30 ºC shown by the researches done by comparing construction slab objects with or without placed green roof [61].

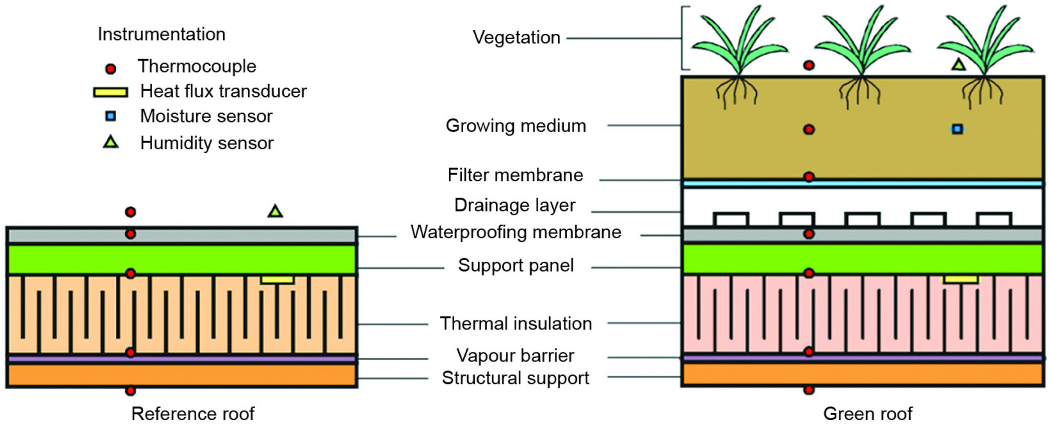

Figure 1. Roof slab construction without (reference roof) and with green roof [62]

Green roofs are used as a natural isolation of buildings. The study done by the National Research Council of Canada showed that by building green roof reduced daily energy demand to less than 1.5 kWH per day (5100 BTU per day) related to reference roof conditioning needed 6.0-7.5 kWh per day (20500-25600 BTU per day) which is a reduction of about 75%. Depending on the projected layer of roof gardens, fig. 1, it is possible to save up to 1 to 2 liters fuel oil by square meter of the roof [62].

Waters as a recourse in built environment

Urban water management is very complex and sensitive activity because of importance and scarce of this resource as well as because of different problems which could appear. Because of complexity of water flow in urban area, the *urban hydrology* as an applied science was developed and its role will increase [63]. In most urban areas, there is a problem with supplying the drinking water in quality and quantity sense , the problem of deficiency of total amount of water for all urban functions as well as the problem drainage of floods from roofs and streets in period of heavy rains [64].

Urban area also needs huge amount of technical water for flushing sewage, streets washing and watering of green surfaces including roof and wall gardens. This water could be provided from rainwater and/or from treated wastewater.

Water and vegetation of urban area are mutual interconnected. As the rain is necessary for survival of roof and wall gardens as well as park vegetation, in the same time green surfaces have their positive role both in mitigation of flood effects and purifying them.

Reducing of amount and slowing the flow of wastewater, rainwater as well as treating of water is one of main aims in urban areas. Green roofs could be one of good solution in this direction. Utilization of green roofs it is possible to retain 50-90% of average rainfall on the area, which they cover [65]. Through processes of transpiration and substrate evaporation, the main amount of water is fast returning in process of global water circulation. That way reduces process of runoff reducing possibilities of damages of drainage systems, and reducing possibilities of flood in urban area. Flow through sewage system is approximately reduced (in case of green roofs) for amount of 700 L/m^2 multiplied by area of green roofs per year [66]. At the same time the possibility of flooding sewage system and flooding urban areas is also reduced for same amount in case of sudden and heavy rainfall. Green roofs on new buildings and on buildings with huge roof surfaces, in design of sewage and drainage systems reduce dimension and/or number of channels and drains.

The average annual capacity of precipitation retention, *i. e.* the water tightness coefficient are in the direct functional independence of the type of projected garden roof, intensive or extensive, *i. e.* how thick is the substrate and the type of vegetation planted on the roof. Besides that, roof gardens as a natural filters reduce pollutants, which are transported by local drain systems and in the end flow in in surface waters. Besides that, they reduce the contamination with nitrogen, significantly caused by heavy traffic [67], the results of some studies show that some leftovers of heavy metals and other harmful materials, found in rainwater, dissolve faster in terrestrial substrate than in rivers [2]. It is estimated that over 95% of cadmium, copper and lead and 16% of zinc can be refined from rainwater via green roofs [60].

Water surfaces reduce the temperature in urban areas significantly and they can be natural and artificial creations.

Some cities are positioned optimally on the lakesides and riverbanks. In the same time, it is possible to project the artificial accumulations, rivers, pools and fountains, which can significantly ease the urban heat islands effect, which are the result of intensive urbanization.

Proposed mathematical model of blue green cities

From best available practice follows the model of blue green cities in literature known as *blue green dream* [68, 69] which is here also interpreted in mathematical way. When blue green cities are considered (water as well as vegetation), it is basic statement that their parallel existence is necessary for providing conditions for certain level of quality of life. Generally, it is possible to express the chain of dependence in following mathematical way:

$$\mathrm{G} = \Psi(\mathrm{B}) \tag{22}$$

where G is green, B – blue *i. e.* available resource for transformation to green, and Ψ – function which transforms blue to green resources.

Next step is to define the level of life quality according to blue and green resources in urban area in following way:

$$L_{\mathrm{q}} = \Theta\left[\mathrm{B}, \mathrm{G}, h(\mathrm{G}, \mathrm{B})\right] = \Theta\left[\mathrm{B}, \Psi(\mathrm{B}), h(\mathrm{G}, \mathrm{B})\right] \tag{23}$$

where L_a is the level of life quality in urban areas, Θ – the function which transforms blue and green resources to the level of life quality, and h(G, B) – the harmonization function of blue and green resources.

The optimizations of blue and green resources are necessary, but not sufficient conditions for providing desirable level of life quality in urban areas.

The blue resource is also complex function of different elements necessary for providing existence of green resources (water, air, light, fertilizers, *etc.*). Green in the same time has function to provide certain microclimatic parameter (temperatures and its variations, treatment, and mitigation of air pollution). According to that, function G could be defined on the certain level (*i. e.* on the level necessary for providing basic conditions for predefined level of life quality – enlarged for some reserve). That model, if started from needs, could determine the necessary levels of blue elements and forms of their transformations (selection of vegetation, their space distribution, their adaptation on seasonal variations, availability of blue resources *etc.*). This approach allows determination of needed blue resources and comparison with their availability. This could be shortly interpreted in following way:

$$\lim_{\mathrm{B}\to\mathrm{B}_0} \Psi(\mathrm{B}) = \mathrm{G_n} \tag{24}$$

where B_0 is the level of blue resources which provides the necessary level of green G_n (green needed).

Another approach could be if it is started from available blue resources with aim to maximize green component of built environment. If it is possible to obtain higher level of green component than needed, it is also possible to decrease it and determine the level of necessary blue resources. This case could be interpreted in following way:

$$\lim_{\mathrm{B}\to\mathrm{B}_a} \Psi(\mathrm{B}) = \mathrm{G_{max}} \tag{25}$$

where B_a is the level of available blue resources (blue available) which maximize the level of green G_{max} (green maximum). Difference between maximal and necessary level of green could result in decrease of utilization of blue resources, or to point out their scarcity.

The difference between necessary and maximal green resources could result in decrease of blue resources utilization (if the transformable function Ψ is known) in following way:

$$\mathrm{G_{max}} - \mathrm{G_n} = \Psi(\mathrm{B_a} - \mathrm{B}) \text{ in case } (\mathrm{G_{max}} \geq \mathrm{G_n}) \wedge (\mathrm{B_a} \geq \mathrm{B}) \tag{26}$$

and if the function Ψ is linear and for small increments:

$$\mathrm{G_{max}} - \mathrm{G_n} \leq \varepsilon \quad \text{and} \quad \mathrm{B_a} - \mathrm{B} \leq \delta \tag{27}$$

could be written:

$$\mathrm{G_{max}} - \mathrm{G_n} = \Psi(\mathrm{B_a}) - \Psi(\mathrm{B}); (\varepsilon \approx \delta) \tag{28}$$

In addition, it should be born in mind the energy needed for providing and sustaining the level of blue resources. Own consumption of blue resources sustainability shall be as small as possible in order to decrease its influence on blue and green resources.

Contribution of own consumption of resources sustainability could result, for example, in increasing canyon effect (in case of increasing population per meter square) or by urban heat islands effect which in turn will result with increase of blue resources and increase the need of green resources.

Conclusions

Urban areas are created and designed to satisfy contemporary essential, cultural and civilizations needs of their citizens, also produce some negative effects on the existential level. The extreme situation was in year 2003 when the heat wave caused a huge number of deaths and health problem to people across the EU.

Negative effects of urban areas were noticed at the beginning of the 19^{th} century and since that studied seriously. Since the second half of 20^{th} century, the comprehensive studies were conducted all over the world covering cities with different characteristics aiming to reduce negative effects of heat islands and canyon effects. Contemporary research proved that effects of heat islands have been recorded even for cities with 1000 citizens. This makes any effort for reducing negative effects of urban areas sensible.

Two general strategies were introduced in order to reduce negative effects in urban areas: albedo of constructive materials increasing and increasing of green and blue component of cities. Albedo reducing is based primarily on using white materials, while increasing green and blue component is related with enhancement of areas under different kinds of plant. The concept of blue and green resources is expressed in form of *blue green dream* [70] pointing strive of humans to band together contemporary way of life with healthy environment.

Blue green dream, of course, needs many resources and it is not achievable easily. But every city contains possibilities for improvement quality of life either by using strategies for albedo increasing or developing green component. The incentives for utilization those possibilities could be mandatory or voluntary, depending of economic power of local authority and population.

Bearing in mind complexity of human basic (biological), existential, civilization and cultural needs on the one side and technical systems necessary for providing basic functions in cites it could be stated that urban areas are complex biotechnical systems. Biotechnical system is very sensitive in the sense that some variations inside it could jeopardize human health and life. This fact strongly implies responsibility of experts, authorities and citizens to make any reasonable effort to reduce risks of negative effects in urban areas. Also, sustainability of cities is imperative aim because cities are designed and constructed to last for future generations.

Acknowledgment

The Ministry of Education, Science and Technological Development of Serbia, project No. 35030-3, supported this research.

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Paper submitted: May 30, 2017
Paper revised: February 23, 2018
Paper accepted: March 7, 2018