Reducing the impact of climate change by applying information technologies and measures for improving energy efficiency in urban planning

I. Marić, M. Pucar, B. Kovačević*

Institute of Architecture and Urban & Spatial Planning of Serbia, Bulevar kralja Aleksandra 73/II, Belgrade, Serbia

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ABSTRACT

The paper provides an overview of a part of research related to the analysis of information technologies and measures for improving the energy efficiency in urban planning that can contribute to mitigating the impact of climate change. The first part of the paper deals with problems supported by the numerous data on negative effects of climate change on the cities, such as urban heat islands, energy and ecological crisis. The second part of the paper proposes solutions that rely on information technologies which facilitate process of urban planning. Two projects related to the implementation of measures for improving the energy efficiency in urban planning were conducted within this research. The first one is considering the design of a spa centre in an undeveloped mountain landscape and the second one is dealing with reconstruction of a residential block in urban built environment. In the first case study, the proposed solutions rely on the information technologies, while in the second case study they rely on the implementation of measures for improving the energy efficiency in urban planning. The results show that the application of different measures in urban planning depends on the level of the built environment.

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1. Introduction

Over the last several decades, the information technologies have influenced architectural design and urban planning. With increase of awareness about climate change and its evident consequences, the influence of information technologies is becoming more important because they enable simple and faster problem solving with simulations and great number of variants. The negative effects of climate change manifested in cities with high population density include high energy consumption and huge concentrations of carbon dioxide emissions. The development and influence of information technologies in the context of climate change are less evident in the field of urbanism than in the field of architecture. In the book "Ecological Urbanism", the authors Mostafavi and Doherty [1] conclude the following: "While climate change, sustainable architecture and green technologies have become increasingly topics, issues about the sustainability of the city are much less developed". The information technologies in urbanism are primarily used in the infrastructure and transportation solutions, as well as in the use of renewable energy sources.

However, there are important steps forward in the process of urban planning, where new concepts of technological solutions and measures to increase energy efficiency find their application in the urban context.

On the other hand, the cities are recognized as promoters of the development directed towards the climate change mitigation. Many cities are joining together and with a serious organization and capital influence the development of information technologies. These actions are often a question of prestige not only when it comes to cities, but also when it comes to the less developed countries which would also like to support these actions. Many projects and initiatives are directed towards the issues related to the development of the information technologies which will facilitate the planning process at all levels, but also to the specific interventions in urban space if necessary.

The UN Habitat has initiated a project entitled "Cities and Climate Change Initiative". *The Assessment Report stated that properly planned cities* use spaces and energy in an efficient way by reducing the transportation and infrastructure, thus contributing to reducing the effects of climate change [2]. The Intergovernmental Panel on Climate Change (IPCC) has prepared a special study that considers the projection of these problems by linking the aspect of climate change and the infrastructure, demographic and energy aspects of urbanization [3].

* Corresponding author. Tel.: +381 11 3207 324; fax: +381 011 3370 203.
E-mail address: kovacevicbrankica@yahoo.com (B. Kovačević).

In this context, the paper provides the possibility of considering the effects of the use of information technologies in the process of urban planning conducted within two projects for two different environments—the first one is considering the design of a spa centre in an undeveloped mountain landscape and the second one is dealing with reconstruction of a residential block in an urban built environment. This paper will analyse how application of the information technologies and the 3D analyses and modelling in urban planning reduce energy consumption.

2. Cities and climate change: Interactions, negative phenomena—Causes and effect

2.1. Climate change

Climate change to a great extent depends on anthropogenic factors and directly influences the future development of human community on the planet Earth. Climate change has led, faster than predicted, to an increase in Earth's annual average temperatures, floods, soil erosion, hurricane winds, sea level rise, droughts, etc. Mankind faced with an abrupt climate change is responding in an inefficient and inadequate way. Nevertheless, many steps have been taken in the fields of architecture and urbanism. The concepts of sustainable, green, ecological and energy-efficient building design that could slow down the negative processes made under the influence of climate change have been promoted [4].

One of the key indicators of climate change is an increase in global average surface temperature by 0.65 °C measured for the last 50 years. In its 5th Assessment Report in 2013, the Intergovernmental Panel on Climate Change (IPCC) stated that "most of the observed increase in global average temperatures (which is more than 95%) since the mid-twentieth century is very likely due to the observed increase in anthropogenic GHG." In the same IPCC's Fifth Assessment Report, it was also concluded that global temperatures are likely to rise by 0.3 degrees to 4.8 °C by the end of the century, depending on how much the governments control the carbon emissions [3].

2.2. Energy and ecological crisis

Climate change on Earth and the global ecological crisis that have occurred as a result of an uncontrolled growth of cities, industrial development, inefficient technologies and an excessive use of fossil fuels present one of the greatest problems in this century. The consequences of global warming are not yet present to the extent that would initiate large-scale activities producing the quick and visible results. The changes are slow and according to the so-called Giddens's paradox, the significant progress will not occur as long as the consequences of global warming will not be felt in everyday life. For this reason, Giddens emphasizes the importance of joint action of modern technologies, the use of renewable energy sources, communication networks and functional social framework that would lead to a positive model, the so-called *low-carbon* life [5]. The air pollution from greenhouse gas emissions, depletion of ozone layer that protects the Earth's biosphere from a large part of the ultraviolet radiation, and the global warming are problems that threaten today's generations and, should such trend continue, it will threaten future generations as well.

The energy crisis is the next world's most pressing issue. It emerged in the seventies of the 20th century as a result of petroleum market disturbances. The fossil fuel reserves (discovered and probable) are limited, while according to the projections, and depending on the type of energy resource and consumption, it is possible that most of them will disappear by the middle of this century when the next energy crisis might occur [6].

The cities, especially megacities, as the biggest consumers of energy and natural resources, can contribute to the exhaustion of natural resources of the Planet. Their constant growth without support of both the social and the infrastructure systems is not sustainable. The cities that consume an enormously great amount of energy and matter require enormous support by different ecosystems, practically occupying 500–1000 times greater areas than themselves in order to be able to function [7]. The consumption of an enormously great amount of energy, water and all man-made resources results in a strong impact on the environment.

The energy crisis accompanied by ecological crisis has led to the general attitude that the current level and way of resource exploitation are unsustainable. Such conclusions clearly derive from the data on water and air pollution, changes in the chemical composition of the atmosphere, appearance of ozone holes, soil degradation, disappearance of certain plant and animal species, reduction in forest cover, etc.

Thus, the challenge lies in the answer to the two main questions: how to ensure sufficient amount of energy in future, and how to reduce negative environmental impacts from the use of traditional energy sources? The sustainable production and consumption of energy can be deemed as one of the most important ways in creating the green community. The ecological and economic crises have led to the acceptance of the concept of a limited amount of natural resources at the global and local levels. As the result, the concept of sustainable development emerged, which can be transposed to all segments of human activity, thus also to urban planning [6].

2.3. Urban heat island (UHI) effect

Many cities worldwide face the problems associated with the urban heat island effect and temperature inversions. The cities accumulate solar energy during the day and at night they emit energy in the atmosphere, thus disabling the cooling of the built environment. The values of night time urban air temperatures during the summer are several degrees centigrade higher compared to the surrounding countryside. As villages grow into cities, their average temperature increases 2 to 6 °C above that of the surrounding countryside [8]. This formation of heat islands primarily occurs in the cities located in valleys and areas where there is no air circulation and permanent ventilation.

This phenomenon also causes a temperature inversion and creates an invisible so-called membrane above the city. The polluted, warm air caused by emissions from industrial processes, heating and transportation remains below the so-called membrane line that separates two temperature inverse spaces and thus stays "trapped" in the lower layers of atmosphere, often causing a low visibility or fog. In case the stable weather conditions continue for another few days or even few weeks, the pollutant concentration may reach levels that pose a serious health risk [9].

In addition to the aforementioned, there are also a number of other causes of urban heat islands and temperature rise in settlements. They include the geographic position, the size of the city core, position of industrial zones and other branches of economy prevailing in a region, type of architectural and urban designs, type of urbanization and urban forms, massive and uncontrolled (often illegal) construction, way of land use, increasing amount of impervious surface due to urbanization, reduction in green space within the city's boundaries and surroundings, population growth and population social structure, etc.

All this leads to a series of negative effects such as: health problems, microclimatic changes, general summer temperature rise, increased consumption of energy for cooling, air pollution, as well as the occurrence of storm water in the urban and suburban settlements that often turn into a natural disaster causing human causalities and material damages.