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Impacts of integrated Blue-Green Infrastructure
on the Urban Design and Urban Ecosystem Services

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DECLARATION OF OWN WORK

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List of abbreviations

ASCII – unformatted data file
ASHRAE (American Society of Heating, Refrigerating and Air-Conditioning Engineers)
AST – Adaptation support Tool (Deltares, Utrecht)
BG – Blue and Green (components)
BGD Project – Blue Green Dream Project
BGI – Blue Green Infrastructure
BGS - Blue Green Solutions
BREEAM - Building Research Establishment Environmental Design
CC - Climate Change
CEMAT – Conferences of Council of Europe of Ministers Responsible for Regional Planning
CFD - Computational fluid dynamics
DEFRA – Department for Environment Food & Rural Affairs (UK)
EPA – USA Environmental Protection Agency
ESS- Ecosystem Services
EU – European Union
GI - Green Infrastructure
GIS – Geographic Information System
HABITAT - United Nations Conference on Human Settlements
ICL - Imperial College London
IM – Integrated modelling
IPCC – International Panel for Climate Change
LEED - Leadership in Energy and Environmental Assessment Method
Leonardo – software that visualises the ENVI-met results
MA – Millennium Ecosystem Assessments 2007
Met Office - UK Meteorological office
MGD – Millennium Development Goals
OECD – Organisation for Economic Cooperation and Development (FR)
PMV – Predicted Mean vote (thermal comfort)
PPC – Public Powered Corporation
SUDS - Sustainable Urban Drainage System
SWMM - Storm Water Management Model
TEEB - The Economics of Ecosystems and Biodiversity
UD – Urban Design
UHI – Urban Heat Island
UKEA – United Kingdom Environmental Agency
UMI - Urban Modelling Interface
UN – United Nations
UNCED – The United Nations Conference on Environment and Development
US – United States
WSUDS - Water Sensitive Urban Design
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Abstract

The city is the most complex human creation shaped over the centuries. The human-nature-city relationship is the basic principle of city development. The main scientific challenge of the current urban planning approach is recognized in a broken human-nature-city relationship whose degradation is amplified in 21st century by globalization and rapid climate change. This challenge is addressed in this thesis through the history of city transformation analyzed in literature review. The transformation impact on human-city-nature relationship helped to define the missed opportunities and proposed a new approach in the management of the natural resources and Ecosystem Services [ESS] in the city. The thesis is focused on the mitigation of the following ecosystem services: Urban Heat Island (UHI) and improvement of public amenities. Moreover, through addressing these ecosystem services, other ESS (water management and climate change adaptation and mitigation) are improved as well. The UHI is selected as one of the most significant principle that influences human comfort in open public spaces.

In order to increase the amenities in a city, a new approach is focused on the level of city blocks – neighbourhood level. This thesis translates and synthesizes literature knowledge into a new approach, and uses computer-based models to test them on two case studies and one demo site. The new methodology follows the rules of nature and affirms the potential of ESS. The integration of the blue [urban waters] and green [urban greenery] infrastructures is quantified by the use of the computer-based analysis of ESS indicators. The combined effects of the blue-green infrastructure reduce the degradation of living environment and increase amenities of open public space. The implementation and the testing of the theoretical models in practice, supported by computer modelling, confirm the above-mentioned statement. The results of the new methodology were tested on the demo site – Imperial College South Kensington Campus – in order to increase the amenities of the space. The quantification of the amenities is presented through the Predicted Mean Vote (PMV) indicator obtained by computer base modelling. The PMV of the demo site was improved in average by cc. 25%.

The main outputs of the thesis refer to the classification and the quantification of the integrated effects as new approaches that can improve the urban design process, especially in the aspect of sustainability. This should be applied in the early stage of planning – concept stage, which is one of the ideas presented in this thesis. The theoretical concept, modelling, and the computer-based experiment offer clear guidelines for the practice. This is an original scientific contribution. The benefits brought by BG infrastructure are expressed through the qualitative and quantitative parameters, showing the comfort level of human’s life in the city. The results of this thesis are shaped as the recommendations and guidelines for the reconstruction of urban settlements, offering new ways of integration. The most significant implications from work imply the interrelationship that promotes building with nature increases the resilience to climate extremes and the microclimate comfort of urban blocks. The integrative effect of the blue-green component is a new paradigm for sustainable design and the management of urban settlements in the 21st century. It presents an active effort to stop the anthropogenic separation of human beings and nature.

Keywords: Urban Design (UD), Integrative Modelling (IM), Blue Green Infrastructure (BGI), Ecosystem Services (ESS), and Climate Change (CC)
1. Introduction

This dissertation explores the effects of an integrated Blue Green Infrastructure and Ecosystem Services on urban design that improves the relationship between human, nature and city. In the process of searching for better-integrated solutions of urban design, it is necessary to evaluate both urban design theory and practice until today. What is important for this thesis is to find, analyse and compare the good solutions in which open public space are created in such a way that they preserve their relationship with nature and keep their human character. The criteria for the selection of good urban design solutions are defined by the following relationships:

- human-city,
- human-nature,
- nature-city,
- amenities,
- urban diversity.

This kind of research is necessary since the critical analysis of city development, urbanization processes and methodologies showed some inconsistency and problems in the formulation of open public spaces in contemporary society. Social and political changes significantly influence the content and function of open public spaces which lost human character, vitality, and mutual connection through the period of uncontrolled urbanization. The recognition of the problems that led to the degradation of urban environment created an opportunity to act preventively in the new era. Through the definition of three hypotheses a city’s adaptation to climate change can be facilitated, and its resilience can be significantly increased; the ability to improve the process of urban design can be increased; spatial patterns – recommendations and guidance for the regulation and the design of open public spaces can be defined. Through the definition of the aims we can maximize the comfort in urban space. These hypotheses and aims are used in order to enable the formulation of the new configuration at the level of open public spaces, but following the new Blue Green Dream Project (BGD) paradigm. All the above-mentioned steps, supported by scientific methods (such as the logical argumentation method, the scientific and critical method, the case study method and the empirical method) showed in which way the research was conducted.

The thesis research begins with a chapter from literature review based on the issues of urbanization and its processes (2.1.) which are seen as the causes of the problem of forming the present-day open public spaces. However, the problem is really complex, and it requires a more detailed look at the approach to the process of urbanization through history (from prehistoric settlements, Ancient town, Medieval town – feudal to Industrial city). The industrial city will be analysed in particular because it created the problem of vitality and humanity in open public spaces. The concluding remarks of this subsection (2.1.4.) have been defined as missed opportunities because they are actually an answer to the uncontrolled urban development, but at the same time they affect the increase of the city’s resistance to the ever-changing climate change. In that way, the idea of creating a new concept of a self-sustainable city that creates more humane relation between nature, human and city is promoted.

Section (2.2.) involves a critical overview of urban design concepts which promote the idea of a self-sustaining city, but which were developed from the need to re-consider the link between nature, human and city. This shows the necessity to formulate a new urban pattern that would meet the needs of the 21st-century man. By analysing the urban design concepts in theory and practice, it seems logical to start with Ebenezer Howard’s Garden City concept which inspired other researchers to develop it further.
From Howard’s concept we can see how he brought human back to focus and how the relation with nature is re-established again. In that way the city was going back to nature, promoting the idea of a self-sustaining city. Inspired by Howard’s concept of Garden City, Patrick Geddes created the 1925 Master Plan for Tel Aviv. He integrated human with city and human with nature. In that way, amenities increased to a higher level. Le Corbusier was also inspired by the relation between the city and nature, so he created a centralized and a vertical city – The Ville Contemporaine, Plan Voisin, and Cite Radieuse. His concept shows that the city that is in harmony with nature and human has never been realized because it was based on a strict division between zones: residential part, work and recreation. Unlike Le Corbusier, Frank Lloyd Wright, who was inspired by prairie, established the relation human-nature-city by creating a horizontal city called Broadacre City. His idea was that the city is subordinated to nature. Jane Jacobs gave a critical review of the above-mentioned urban design concepts pointing out that, besides the perceived relation human-nature-city, it is necessary to highlight the importance of urban diversity in creating the present-day open public spaces. All these urban design concepts enable us to understand the role of the human in the city.

A short review of Ecosystem services and its significance in this research process (2.3) helps us to understand the link between nature and human welfare which enables decision-makers to make the city life more sustainable. We can define ecosystem services as the starting point for further simulation, analysis, testing, modelling and making the experiments of urban practice principles. The principles of urban practice such as Sustainable Urban Drainage System (SUDS), Water Sensitive Urban Design (WSUDS) and Green Infrastructure (GI) are explained in section (2.4). By analysing these principles, we search for the practical and innovative solutions that can improve the sustainable development of the city and make the city more resilient to climate extremes. Section (3.3.) presents the guidelines for integrating the received knowledge about the process of urbanisation, urban design concepts, ecosystems services and urban principles into the new integrated philosophy of the development of the city. This is shown through the form of a table where the lessons learned about the development of the city and a critical review of the methodologies of urban design and its application in practice are integrated.

In order to create the framework for the application of BGD paradigm, it is necessary to test the selected case studies. This will be explained in chapter (4.0). The first step used in this process is to select the software that can respond to environmental design and planning as this is the focus of the thesis (4.1.). Two types of software that have been selected are the ENVIMET (a grid-based-three dimensional no hydrostatic model) and Leonardo (a visual representation of the results obtained by ENVIMET) which will be explained in section (3.2). An ENVIMET model is an effective tool used to evaluate the modification of the site layout and greening, and its validation will be described in section (3.2.1). One important aspect for choosing the ENVIMET is the file format of the simulation tool and this is the reason why the ENVIMET is used in this thesis.

In the next section of this chapter, the data analyses obtained by using the above-mentioned software are done through experiments and qualitative and quantitative indicators. The aim of the creation of this chapter is to form a scenario for the development of the experiment that is achieved through Case Studies (4.). The Case Study Belgrade Block 21 (4.1) tests the open public spaces located within open public block and built-in modern style. The Case Study Leskovac (4.2) analyses the open public spaces and the main square also built in modern style. These case studies quantified the indicators that were used for the demo site at Imperial College London Campus (illustrated in Chapter 5). It is used to test the hypothesis that refers to the principles of planning and the design of open public spaces in complex environment. ICL demo site generates quantitative results through the methodological approach and
the development of computer-based models. These outputs (explained in Chapter 5) are the subject of the optimization that can turn into guidelines and tools for architects and urban planners. The obtained results are shaped in the form of the recommendations and guidelines, principles and ways of creating the patterns and configuration of public space. By using Blue Green Infrastructure and the ESF, these results improve the design of open public spaces – a mutual relation between human, nature, and city.
1.1. Research Problem

The fast and intensive urbanization (Oke, 1973; World Bank, 2014) impoverishes and dehumanizes the cities around the world. The land use pattern of modern cities has dehumanized open public spaces – example of New York Central Park and High Line Park [see Fig. 1.1 and Fig. 1.2]. Human is often separated from nature, which reduces the standard and comfort of living and the interactions between people. Different social groups are separated in today’s cities. The concept-driven by the economy was often used in the urban practice of 20th century. Methodology and principles – consciously or not – have disregarded the human and his existential needs. In these concepts, the term more urban often means the loss of security and privacy, the reduction of comfort and the devastation of nature. By integrating nature and open public spaces, architects and urban planners can minimize the above-mentioned effects.

Fig. 1.1 The photography taken by Russian photographer, Sergey Semanov for 2012 Epson International Photographic Pano Award. Source: https://thepanawards.com/2012-winners-gallery/

Fig. 1.2 High Line New York [Source: https://s-media-cache-k0.pinimg.com/originals/1d/dc/83/1ddc83ecbee02edd31aa0d7c9763f1ad.jpg]
The scientific and professional community recognized the problem of urban expansion as a driver of comfort reduction (UN-Habitat, 2012). This research tries to answer the questions: Do we understand the city today and what do we expect from it? Urban design has become one of the key processes for adapting urban areas to climate change (Roger Evans Associates, 2007). It needs to a) integrate social, economic, ecological and cultural demands to create an environment suitable for a human settlement; b) protect natural resources, c) contribute to climate change protection. The focus of the urban design is shifting from a functionally orientated approach towards a more sensible, human-centred approach (Roger Evans Associates, 2007). As observed in modern urban design theory and practice, open public spaces are recognized to be the primary subject of urban transformations and renewal (Novakovic, 2014). Today some aspects of privately owned spaces, such as building facades/roofs or private gardens are considered to be a part of public spaces and therefore fall within the area of urban design. The new proposed urban design framework highlights the synergistic effects of the optimized and integrated ESS in urban areas. It mimics the laws of nature. Such transformations positively affect urban sustainability and the overall wellbeing in urban settlements. The innovative way of using nature and its resources can improve urban resilience to climate change and its extremes (Herzog & De Meuron, 2008) (see Fig. 1.3).

Fig. 1.3 NaturbadRiehen, Natural Swimming Pool, Riehen, Switzerland!Source:NaturbadRiehen, http://www.naturbadriehe.ch!.

Rapid and uncontrolled urbanization caused climate change with which an array of problems and challenges for urban areas raised. This involves urban heat island, pluvial flooding, the increase of air and noise pollution [pollution in general], the degradation of biodiversity, and the quality of life. All of them are caused by the ‘urban creep” phenomenon (Grant, 2012). These threats demand that the

1. This pool offers a natural water filtration [without chlorine] for approximately 2000 swimmers per day. Water is being treated series of sieves to filter grease, large particles and hair, then it goes to the area with plants such as water lilies and irises in aquatic sediments that filter and absorb bacteria and other compounds.

2. The environmental risks of urban creep. See more: http://ciwem.org
modern urban design practice rediscover the necessary connection with nature. An innovative planning and design method should bridge the missing link between the anthropogenic [human-made] infrastructure and natural areas – the urban water [Blue] systems and urban vegetated areas [green infrastructure]. The first step towards it is to set up the principles of bioclimatic architecture (Stanković and Stanković, 2009) which tries to reconcile nature and the built environment. The current state-of-the-art principles in urban planning (Water Sustainable Urban Drainage System, Green Infrastructure, etc.) are focused on the environmental and economic aspects, excluding the human-city relationship from the main focus. The knowledge gaps which this work is addressing are supposed to re-establish the harmony human-nature by maximizing and incorporating the synergy of Blue Green (BG) components into urban planning. This will create a pleasant, healthy, and stimulating environment for urban population (Maksimović, Stanković, Liu and Lalić, 2013).

The Blue Green Dream [BGD] project presents an inclusive approach that uses the latest technological developments in an ecology driven design. To achieve the innovative urban design and the sustainable management of urban environment, planners and designers need to understand and use modern analytic tools. It is necessary to analyse comprehensively physical processes to get an optimum solution via the use of parametric design software. This approach enables the creation of innovative and integrated solutions.

The Blue Green Dream Project is expected to reduce the cities’ vulnerability to climate change, extreme weather, and natural disasters:

- by improving the performance of urban ecosystems,
- by resulting in the reduction of flood and drought risk,
- the decrease of urban heat,
- the reduction in an array of pollution vectors [water, air, solid waste and noise],
- the reduction of resource [water and energy] requirements and
- the improvement of microclimate conditions, amenities, and urban health.

To achieve these objectives, special attention has to be given to the role of urban design professionals such as spatial planners, urban planners, architects, and landscape architects. This research is primarily directed towards them.
1.2. Introduction to Research Objectives

This PhD thesis is a part of the BGD Project at Imperial College London (ICL) that deals with the quantification and integration of Ecosystem Services [ESS] performance indicators into urban design practice. It is based on the relationships between the diverse components and functions of both the built environment and nature (Llewelyn and Davies, 2000). Where possible, the quantification of these interactions is beneficial. As it needs to cover a variety of domains such as resources, emissions, health, people, culture and habitat, an integration of all urban design components will result in a more sustainable urban settlement. As explained by Grant: ‘better cities will come with a new philosophy, which understands our place as part of nature, not as deluded creatures pretending to operate outside of it’ (Grant, 2012:6). Water Sensitive Urban Design [WSUD] (Bohl, 2010) and Green Infrastructure [GI] (Mell, 2010) are the most influential/powerful concepts in the regeneration of urban areas today. These approaches concentrate on the economic and environmental benefits and to a lesser extent, on the social benefits. However, they still use multi-criteria with the tick-box approach. The new BGD philosophy/paradigm goes a step further by incorporating the whole range of ESS interactions into urban design.

In order to highlight the adaptation of urban areas to climate change and the importance of ‘building with nature’, the far-reaching aim of this Project [therefore thesis] is to develop a framework for BGD based urban design, architecture and landscape architecture practice.

The ambitious aim of this innovative, integrated, and multidisciplinary BG approach is to be achieved through:

- an iterative process of computer modelling of the key ecosystem service performance indicators obtained by the proposed solutions, analyses and optimization of their interactions, and
- establishment of the protocols for achieving the positive urban transformations.

The ultimate objective of the above-mentioned process is to produce a framework for urban forms that are physically, socially, economically, and culturally sustainable and resilient to climate change and weather extremes. It is considered that ‘this may not change the way we look at things, but will change how the things work’ (Roger Evans Associates, 2007).
1.3. The Research Hypothesis, Principal Aim and Detailed Objectives

In accordance with the preliminary theoretical research and the initial assumptions, three research hypotheses were set and the research objectives were formulated:

- **First hypothesis**: Integral, reasonable and human-oriented urban design supported by blue and green infrastructure can facilitate a city’s adaptation to climate change and improve the amenities of open public spaces. While the use of the ESS in redesigning open public spaces encourages sustainability, it also increases the comfort and improves the users’ health.

- **Second hypothesis**: The critical review of urban theories and the phenomenon of open public spaces showed the lack of ability to address the complex needs of public life in the city. The new proposed methodology which includes ESS indicators in the earliest stages of urban planning will improve the process of urban design. This is the first step in the process of redesigning the present methodology of urban design by searching for more flexible mechanisms which meet the needs of various user groups and allow the monitoring of the quality of public life and open public spaces in the city.

- **Third hypothesis**: The final outcomes of the urban design can be improved by the constant cross-checking and quantification of the ESS indicators through computer based models during the process of designing open public spaces. It offers the opportunity for preventive actions in the process of urban design, ensures better applicability of the plan and project, as well as the control mechanisms used to satisfy the needs of many users. This can improve public life and enable the active participation of the users in the transformation of the form and function of open public spaces.

The proposed research offers the possibility to apply the proposed model and principles in practice and create the urban design of future public open spaces, as well as the redesign of the existing ones. This research is the basis for the education of future professionals in this field, with the intention to bring knowledge closer to urban practice and offer a way to apply the innovative BGD paradigm. Based on the above-mentioned hypothesis, the Principal Objective [the Aim] of this PhD research is to recognize and quantify the interactions of the BG elements and urban design [at the neighbourhood level] and analyse their influence on other ESS in order to maximize human comfort in urban spaces.

Detailed research objectives derived from the research hypothesis and the main objective are as follows:

a. Defining urban design discourse in the 21st century and recognizing essential principles in forming the relationships between physical structures and climate change – flexibility and comfort;

b. Systematically defining of the most relevant ecosystem services in urban areas and understanding which ones are directly influenced by BG solutions;

c. Analysing and quantifying the environmental performance indicators of individual blue and green elements and their mutual interactions on the selected demo site;

d. Identifying a suitable optimization method for solutions;

e. Creating guidelines for architects and planners to support them in creating better urban design of open public spaces;

f. Criticising the utopia suggested by the BGD paradigm [advantages and flaws limitations].
These objectives will be obtained by:

a1. Critical analysis of the current sustainable urban design and the development of the cities resistant to global climate change;
b1. Review of the current state of ecosystem services in urban design practices;
c1. Analysing and validating the potential of the BG solutions via both quantitative and qualitative indicators;
c2. Evaluation of an integrated approach through the verification of environmental, economic and social aspects of urban design;
c3. Reviewing methodologies used in urban design modelling related to ESS analysis;
c4. Performing computer modelling and simulation of the selected ESS to confirm and quantify the positive effects of the proposed ESS based design methodology;
d1. Optimization of the obtained results by using the comparison methods;
e1. From the applied methodology, derive guidelines for architects and spatial planners.
f1. Analysing the limitations and the potential application of the BGD philosophy

1.4. Scientific Research Methods and Techniques – General View and Concept

This is just an overview of the methodology used in this thesis, but its detailed explanation is elaborated in each chapter. In this section, a general overview will be presented through the methodology principles used in this thesis. The multidisciplinary nature and complexity of the topic of research demanded the choice of scientific method through pre-defined research goals. In that way it is possible to check the previously defined hypothesis. The research was conducted by combining a number of basic and specific scientific methods and techniques which are applied in the field of architecture, urbanism, social science and humanity. The scientific method as a research process based on the previous knowledge in the field of urban design with the aim to solve the perceived problems and get the new knowledge about it is used in this thesis. In order to get the structure of the thesis, it is necessary to use the analytical-synthetic methods. This method involves the analysis and understanding of individual concepts and theories in urban design. The combination of theoretical and empirical research [case study and demo site] is a way to test the hypotheses [explained in Chapter 2]. The theoretical part of the second Chapter and its conclusions are the basis for the further empirical research [conducted in Chapter 3 and 4]. In order to develop the thesis further, we used the following methods in that process:

- logical argumentation method,
- scientific and critical method (grounded method),
- case study method (case study), and
- empirical method (inductive-deductive method).

The logical argumentation method is generally applied to this thesis. This means that the research is based on theoretical clarity and precise arguments and their relations. Additionally, in the first two chapters of this thesis the method of scientific analysis, i.e. critical analysis of primary and secondary literature resources is used. Thus, the BGD concepts, the normative and the ideas of creating open urban spaces are compared with the same principles of the urbanism theory of 20th and 21st century. The grounded theory, as a part of the scientific analysis, shaped the hypotheses based on the previously collected information about the subject and the problems of the research. This method was used in the first chapter to define the urban design principles and elements and their interactions. In Chapter 3, the typological method classifies the indicators of open public spaces based on the literature review
[Chapter 2]. The conclusions of the typological method in chapter three created the parameters for the analysis of open public spaces. These analyses are performed by the use of the case study method.

The empirical method tests and confirms the third hypothesis that refers to the recommendations and guidelines for the design of open public spaces. The inductive-deductive method is used to define the design patterns of open public spaces that could improve human comfort. This is done by surveys, experiments, and simulations of two case studies [City of Belgrade and Leskovac] and one demo site [City of London].

The last chapter uses the method of critical analysis to show the results and conclusions of the above-mentioned methods in theory and practice. In that way, we test the hypotheses, suggest a new pattern and explain the limitations of the research.

In order to better understand the application of the scientific methods and techniques of the research, it is necessary to make a review of research as a way of scientific illustration (see Fig. 1.4). The illustration shows the research process which is unified by the analytical and synthetic method. This method means that it is necessary to analyse the theoretical and practical research that are further systematized by the scientific methods and techniques. We will start exploring the literature review whose subjects of research were: urbanisation and its processes; urban design concepts; ecosystem services and urban practice principles. The result of this theoretical research is the need for the creation of newly integrated philosophy of the city. This philosophy helps to prove the hypothesis one and it is a base for the further practical research. By the use of software, we will test the hypotheses two and three at specific sites. In this case, we will have two case studies: Block 21, Belgrade, Serbia and Main Square in Leskovac, Serbia. The obtained results of the case studies will prove the hypotheses two and three. In order to see the possibilities of the practical application of these hypotheses, we will confirm these hypotheses at specific demo site – Imperial College London. The obtained results of demo site will help to compose the conclusion of this thesis from which recommendations and guidelines for further research were created.
Impacts of integrated Blue Green Infrastructure on the Urban Design and Urban Ecosystem Services

THEORETICAL RESEARCH

- Urbanisation and its processes
  - Problems
  - Missed opportunities

- Urban Design Concepts
  - Traditional
  - Innovative

- Ecosystem Services
  - Traditional
  - Innovative

- Urban practice principles
  - Traditional
  - Innovative

METHODOLOGY

- New integrated philosophy of the city
  - Integrative Process
  - Provocative Hypothesis 1

- Techniques and software
  - Testing Hypothesis 2
  - Provocative Hypothesis 2

- Case Study - Belgrade
  - Provocative Hypothesis 2

- Case Study - Leskovac
  - Provocative Hypothesis 3

PRACTICE

Demo Site: Imperial College London

Contribution to knowledge
Recommendations and guidelines

Further directions to the work

Fig. 1.4 The research concept
1.5. New Knowledge and the Application of the Research Results in Theory and Practice

In theory and practice open public spaces in the city are not adequately validated and adapted to the users. Numerous mistakes that appeared in the process of planning and equipping open public spaces as a consequence have problematic solutions. These solutions are not previously checked and tested through software tools in order to define microclimate (especially thermal) comfort that is closely related to the users and their activities in the space. The results of this research prove that it is possible to make an integrated and human-oriented design of open public spaces. This means that the benefits from the nature (Ecosystem services) and blue and green principles have to be integrated and checked by the use of the software tools in order to act preventively on each plan solution. In that way we can correct the proposed solutions with the aim to create their better optimisation. The contribution of this thesis to new knowledge is reflected in theoretical and practical shifting of the boundaries in thinking about the creation of open public spaces as the key spaces for people’s activities in the city. In theoretical sense, we notice that if we want to improve the quality of life in the city we cannot act at the city level but at the neighbourhood level, where open public spaces are their key elements. For the better comfort of these spaces we think that it is necessary to create the relationship between man, nature and city according to the following criteria:

- human-city
- human-nature
- nature-city
- amenities
- urban diversity

These theoretical conclusions are the basis for the experimentation and practical action. We selected the two case studies built in modern period (Block 21, Belgrade, Serbia and Main Square in Leskovac, Serbia) in order to prove the previously defined hypothesis and test the theoretical contribution to the new knowledge. These two different case studies (tested by the software tools) led to different results, showing that each open public space has to be tested individually. These case studies are necessary for creating the solution scenario that will be tested at a demo site (Imperial College London) as a possible solution for the retrofitting of the open public spaces. Besides the parameters used for the case studies, the benefits from the nature (Ecosystem services) and blue and green infrastructure are applied to the solution scenario. In that way, we create an optimal solution at the plan level, and give a possibility for the retrofitting of the existing open public spaces.
2. Literature Review

2.1. Urbanization and its processes

In order to understand the complexity of the urbanization and the processes of its impact, we have to be aware that the threshold – more than 50% of the world’s population living in the cities – is crossed. However, there are differences in the urban population numbers in developing and developed countries. (see Graph. 2.1)

![Graph 2.1 2005-2010 Revision of World Urbanization Prospects © [Source: UN, Population Division of the Department of Economic and Social Affairs]](chart)

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</thead>
<tbody>
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<td>Sub-Saharan Africa</td>
<td>20.069</td>
<td>206.322</td>
<td>298.402</td>
<td>357.520</td>
<td>426.522</td>
<td>505.550</td>
<td>595.544</td>
<td>1,068.752</td>
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<td>Africa</td>
<td>33.004</td>
<td>288.402</td>
<td>400.651</td>
<td>470.827</td>
<td>551.552</td>
<td>642.423</td>
<td>744.485</td>
<td>1,264.629</td>
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<tr>
<td>Asia</td>
<td>245.052</td>
<td>1,392.232</td>
<td>1,847.733</td>
<td>2,082.161</td>
<td>2,304.715</td>
<td>2,512.033</td>
<td>2,702.525</td>
<td>3,309.694</td>
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<td>Europe</td>
<td>280.602</td>
<td>514.545</td>
<td>536.611</td>
<td>547.531</td>
<td>557.585</td>
<td>566.299</td>
<td>573.494</td>
<td>591.041</td>
</tr>
<tr>
<td>Latin America and the Caribbean</td>
<td>69.264</td>
<td>393.619</td>
<td>465.246</td>
<td>499.460</td>
<td>531.235</td>
<td>560.030</td>
<td>585.347</td>
<td>650.479</td>
</tr>
<tr>
<td>Caribbean</td>
<td>6.301</td>
<td>23.575</td>
<td>27.725</td>
<td>29.604</td>
<td>31.361</td>
<td>32.948</td>
<td>34.312</td>
<td>37.803</td>
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<tr>
<td>Central America</td>
<td>14.864</td>
<td>93.245</td>
<td>11.339</td>
<td>122.424</td>
<td>132.090</td>
<td>141.242</td>
<td>149.832</td>
<td>175.951</td>
</tr>
<tr>
<td>South America</td>
<td>48.099</td>
<td>276.800</td>
<td>325.183</td>
<td>347.432</td>
<td>367.785</td>
<td>385.840</td>
<td>401.202</td>
<td>436.725</td>
</tr>
<tr>
<td>Oceania</td>
<td>7.907</td>
<td>21.924</td>
<td>25.857</td>
<td>27.852</td>
<td>29.825</td>
<td>31.758</td>
<td>33.614</td>
<td>40.346</td>
</tr>
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</table>

Table 2.1 Percentage of urban population in the world [Source: UN, Population Division of the Department of Economic and Social Affairs]
An interesting fact is that in India, the percentage of population living in cities is 30%, which is around 300 million people [equivalent to the whole USA population in 2010]. The United Nations (UN) record the rapid increase in urbanization from 13% in 1900 to 50% in 2010, and the projection is that it will go up to 70% till 2050 (see Table 2.1).

The greatest environmental risk is the fact that in the next 40 years the accelerated urbanization will occur in Asian and African countries – the areas with the richest biodiversity (see Table 2.2). Hence, cities have to become the hubs of changes. If urbanization continues to happen spontaneously – in an unmanaged way – serious environmental problems could follow. Simon Christmas (DEFRA, 2007) explains how the environment is deteriorating, and how heavy pressure on natural resources is being placed. By 2030, 47% of the world population will live in the areas of high water stress (OECD, 2008), and significant amounts of agricultural land will be covered by urban development. Large increases in waste generation, water and soil pollution are just some of the consequences. Food production is expected to double by 2050 in order to meet the growing population’s dietary needs (SRC, 2012). This presents serious issues for food security, concerning the projected drop in the world’s agricultural production by 20-40%. It happened because of the current global droughts [percentage varies in different locations, depending on the severity and length of droughts] (Lim and Liu, 2010). By 2050 global energy demand will rise by 80% and the fresh water need is expected to increase by an additional 55%. If we compare the period between 1970 and 2004, the increase is recorded in energy sector [+145%], transport [+120%] and industry [+65%] (Jones, Lang, Patterson and Geyer, 2014). The greatest pressure was placed on spatial planners and governments to uphold the sustainability goals set by Millennium Development Goals [MDGs] (see Fig. 2.1):

### Table 2.2 Increase in world population living in cities [Source: UN, Population Division of the Department of Economic and Social Affairs]

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<tbody>
<tr>
<td>World</td>
<td>745.495</td>
<td>2,858.632</td>
<td>3,558.578</td>
<td>3,926.793</td>
<td>4,289.818</td>
<td>4,642.582</td>
<td>4,983.908</td>
<td>6,252.175</td>
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<tr>
<td>More developed regions</td>
<td>441.845</td>
<td>881.344</td>
<td>957.251</td>
<td>989.721</td>
<td>1,018.365</td>
<td>1,043.087</td>
<td>1,064.290</td>
<td>1,127.222</td>
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<tr>
<td>Less developed regions</td>
<td>303.650</td>
<td>1,977.289</td>
<td>2,601.326</td>
<td>2,937.072</td>
<td>3,271.453</td>
<td>3,599.515</td>
<td>3,919.618</td>
<td>5,124.953</td>
</tr>
<tr>
<td>Least developed countries</td>
<td>14.562</td>
<td>160.599</td>
<td>233.802</td>
<td>281.804</td>
<td>338.163</td>
<td>403.044</td>
<td>476.971</td>
<td>860.316</td>
</tr>
<tr>
<td>Less developed regions, excluding least developed countries</td>
<td>289.088</td>
<td>1,816.690</td>
<td>2,367.525</td>
<td>2,655.268</td>
<td>2,933.290</td>
<td>3,196.471</td>
<td>3,442.646</td>
<td>4,264.637</td>
</tr>
<tr>
<td>Less developed regions, excluding China</td>
<td>235.138</td>
<td>1,499.423</td>
<td>1,916.537</td>
<td>2,150.132</td>
<td>2,398.984</td>
<td>2,660.942</td>
<td>2,934.704</td>
<td>4,096.309</td>
</tr>
</tbody>
</table>

3. Organisation for Economic Cooperation and Development (Paris, France)
The increased frequency and variety of ecological problems which are present in urban settlements have shown that the spatial politics driven by social-economic component introduced after the WWII [neoliberal agenda] are ‘environmental enemies’ and could not be sustained anymore. The extensive use of resources and the pollution caused by uncontrolled, market-oriented development have brought natural disasters such as floods and droughts (Eraydin and Taşan-Kok, 2013). Urbanization is not only influencing the concentration of population, but also the changes in the land use pattern. Between 1970 and 2004, 40% of land pattern was changed, mainly resulting in the reduction of forest areas (Doýtsher, Kelly, Khouri, et al. 2010). This puts pressure on governments for serious reformation in order to be able to ensure the sustainable use of the remaining [already fragmented] land resources (El Sioufï, 2010). In order to understand urbanization better, a short chronological review of city development will be presented in this chapter. From the existence of caves to the first settlements, a man was trying to understand the laws of nature. The aim was to understand the bond human-nature-city though the time, and notice the role of BG component in it.

2.1.1. Historical Review of Urbanization

If the prehistoric period is excluded, when human attitude to his environment was passive, the history of human settlements is focused on the fact that natural environment was adapted to man’s needs. The relation between human and nature was always essential for the construction of a city. This approach is seen as crucial factor to the survival of the first human settlements, especially in rough climate (see Fig. 2.2).

![Diagram](Image)

Fig. 2.2. Basic aspects of the creation of human habitat

In the prehistoric period, a human did not understand the laws of nature, and did not try to change them. He looked for the naturally shaped shelters – caves. Nature dictated the life of the Palaeolithic man. There is still a mystery if the Palaeolithic human [600.000-10.000 B.C.] intentionally or not chose the caves with South or Southeast orientation, which provided better living comfort. He collected food and hunted near the cave. After the use of all the resources nearby, he moved to the next place. Unfortunately, this resource use principle has stayed until today.

General climate warming and the discovery of fire allowed humans to leave the caves and stay under the open sky. In that way first settlements were made. At that time the strength of nature was dominant, thus the bond between humans and nature remained strong. The oldest human settlement was discovered in 1967 by Serbian archaeologist and cultural anthropologist, Dragoslav Srejovic [1931-1996] at the bank of the Danube in Djerdap Gorge –Proto-Lepenski Vir, Lepenski Vir Ia-e, Lepenski
Vir II dating from 5300-4800 B.C. (Boric, 2015). Protolepenski Vir (see Fig. 2.3) was the first one where we can see the limitations in the number of habitants [3-4 biological families], communication and social order; the exploitation of goods was only from the immediate surroundings, and everybody had the same responsibilities and rights. The other settlement Lepenski Vir Ia-e, Lepenski Vir II is younger and already showed the first signs of spatial organization. They had over twenty buildings, and around a hundred habitants. These settlements had a large central square and the row buildings were formed around it. The division into two parts shows the presence of social and economic differences.

So the first human settlements were made in fertile valleys, the places suitable for living – rich in water, sunlight and greenery. During the prehistoric area, blue and green infrastructure was the existential minimum. The first cottage found in Lepenski Vir was proved to be the first anthropogenic shelter fully harmonized with and integrated in nature. Today, we have plenty of evidence that the first cities were made in river valleys, on sea and ocean shores or in their immediate vicinity. The development of cities was strongly influenced by the discovery of new tools and methods in food production: the plough, irrigation systems and livestock. By applying these innovations and their further expansion, there was significant progress in the ability of people to sustain themselves and reduce mortality rates. The extent of that was enough to push the relative growth of the human settlements in the longer term.

The first larger human settlements were in the valley of the Euphrates and Tigris (see Fig. 2.4). At that time, the largest granary of the world, which was known as ‘paradise on earth’ for many nations who settled here and lived [the Assyrians, Babylonians, Akkadians and Sumerians] in their own cities [Eridu, Ur, Uruk, Nippur, Lagash, Akkad, Mari, Borsippa, Babylon, Assur, Nineveh, Kish, Aleppo, Damascus and others]. The strong bond between humans and nature established the foundations of modern astronomy and astrology, which helped with the urban geometry of the city. The discovery of the wheel, plough, sail and irrigation systems resulted in the emancipation from nature – revolution in agriculture and trade. This ancient and highly developed civilization produced one of the seven wonders of antiquity: the Hanging Gardens of Babylon (Babylon, around 600 BC) (see Fig. 2.5 and 2.6). Here we can notice that water and vegetation [nature] were always a part of every human design and used to
increase the life comfort in the city. The records of Alexander the Great in 331 BC best witnessed about the culture and art of this nation. During his conquests he stated that he came to conquer the barbarians and found a civilization that is on a higher cultural level than my country (ancient Greece)’.

Fig. 2.4 Map of Mesopotamia  [Source: http://www.crystalinks.com/AkkadMap.jpg]

Fig. 2.5 and 2.6 Hanging Gardens of Babylon [Source: http://www.unmuseum.org/hangg_heemskerck.jpg and https://www.ancientworldwonders.com/uploads/hanging_gardens_of_babylon.jpg]
The next development in human settlements was created in the valley of the river Nile – Egypt (see Fig. 2.7). Human and natural elements [water and greenery] had the iconic relationship – became a condition for sustaining life. The urban culture of Egypt was composed of social and religious symbols such as gardens, temples with water and the pharaoh palace. In Egypt was present one of the first examples of urban pattern, which is directly formed by social status. Social stratification was transferred to urban city disposition. What differentiated Egypt’s settlements from others and placed them in the category of cities are: a significant proportion of their population was employed in activities that did not include the production of food and raw materials (although a part of the population still worked in agriculture); a separate political system; had markets.

Until the Ancient Greece, there were no significant changes in either the urban design or the social aspects. The history of Ancient Greece is extremely complex and it has given an outstanding contribution to architecture, urban planning, art, philosophy, literature and the democratic order of society. Its city fortresses – states were the centres of cultural, political and commercial life. Particularly interesting are the cities of Sparta as a military country and Athens as the centre of democracy and science. Greek philosophy develops in 6 B.C. as a reflection of high culture – the wisdom of the Hellenic World. In order to get the overview of the city creation process and the relationship human-nature in ancient Greece, we will quote some of the philosophers. Thales of Miletus (624-550.p.n.e.) explores and examines the antecedents of nature – water as a source of life and expounds on the water as the very beginning. Heraclitus of Ephesus (535.-475.p.n.e.) interprets nature as a ‘stage of constant change’ in which everything arises and disappears. The world is ruled by harmony which strikes a balance.

Philosophers Plato and Aristotle discussed the selection of the sites for the establishment of settlements and cities. They emphasized the need to plan the organization, the importance of good accessibility from the land and the need for protection from the wind. Socrates (469.-399.n.p.n.e.) opposes subjectivism and relativism. The ethical problem is placed in the centre of his philosophy. It refers to understanding the truth, and calls to listen to the nature and live in accordance with it. For the same problem, Aristotle (384.-323.p.n.e.) tries to cover Plato’s idealistic concept of linking the materialistic
interpretation. It makes Athens a constitution state that is based on the synthesis of all the experience of the rich Greek history and science. His famous thought is that the city must be such that the people who live there are not only safe but also happy – nature does nothing in vain.

Military and political leader Pericles (499.-429.p.n.e.) develops and establishes democracy in Athens, the cultural centre of the Greek world. He said that one who does not take part in the problems of the city nothing but a bad citizen. Hippodamus (about 510.p.n.e.) brought the construction of cities’ urban concept of orthogonal street network by the use of the systems for water supply and drainage. The shrine and public cultural facilities, as well as the residential areas occupied a special place. Agora – market – creates an open social space and increases the comfort of life. Hippocrates promoted the idea that the city has to work for all citizens and that it must be composed in accordance with the laws of beauty, harmony, and security.

Rome, Italy presents the next concepts in the city development (see Fig. 2.9). The urban culture of Rome was strongly influenced by nature. Its rectangular street grid, oriented north-south [cordo] and east-west [decumanus], with rectangular blocks, was placed towards the sun as a source of life. Such organization indirectly the special organization of many cities over the world. Rome took the concept of Greece square – agora – and developed it further. As the imperial power of Rome grew, the size of the city grew as well. The roads, aqueducts and other infrastructure had enabled the functionalities of Rome. By having good traffic infrastructure, Rome adopted the concept of a place for work and a place for living. The city was a place for work, trade and culture, whereas the inherited bond with nature was established at the edge of the city, in private villas and vineyards places for living. The higher society class only had a privilege to enjoy nature.

As it was noticed from the previous analysis of the development of the first human settlements until Rome, nature and the suitable natural conditions were a magnet for the city development. The cities of the old world [first settlements, then cities], had a significant social transformation. The concentration of people and resources resulted in the creation of strong social-economic structures which would become the centres of civilization and urban culture. Cultural and economic life shows unity and progress. The differentiation of the private and public space, the working and the living space and social inequality strongly influenced the development of urban settlements of this period. However, nature was neither forgotten nor neglected. Aristotle stated that a human is surrounded by nature and architecture, as a complement to nature. As for the social-economic point of view, the old world recorded the division of city residents to the poor and the rich, as a form of urban barbarism. The disintegration of the old world was caused by external and internal influences, the contrast and turmoil of the ruling class citizens and slaves. As an important period of civilization and its social system, it created the conditions for the emergence of the new order – the development of the feudal social system. The feudal fortress is the product of the new system.

After the fall of Roman Empire, the social opportunities were significantly changed. This period was known as the Middle Ages (5th – 15th century), and it was divided in the Early, Late and High Middle Ages. The division of the Roman Empire in the east and west encourages the development of Christianity. Migration, conflicts and insecurity were the characteristic of this social and political system known in Europe as the dark era in the development of humanity. The centre for urban civilization shifted to the east, with the two largest successors of the Roman Empire: Chinese and Turkish Empire. The medieval feudal city stems from the unique circumstances and its characteristics were a gate and a wall – contact and security. Feudal aristocracy and the Church, as the spiritual authority, dominated the
feudal society. Clergy from their mystical sanctuaries establishes the authority over the military, and a ruler from his fortress maintains the political and administrative power by force. The wars between cities, religious turmoil and conflicts, primitivism and violence stopped the development and suppressed cultural and civilization values. Urban body was too weak to bring together the institutions that gathered and organized urban populations. The Early Middle Ages is often called the Dark Ages or the dark times – it is related to the great migration of peoples of Europe and the collapse of the Western Roman Empire – decline of Europe. Lewis Mumford writes that the monotonous ritual of the old temple, coercion and violence of the old citadel, wary introversion and isolation to which old magical superstitions give permanent form are all components that remained at the core of the medieval town. In this period, nature was forgotten and not relevant to the urban philosophy.

In the late Middle Ages, the Romanesque period [11th-12th century] stood out, causing a deeper crisis and social stratification between citizens and feudal aristocracy. In that way, the church gained a significant position in society, which encouraged the development of a new style – Gothic [12th–14th century]. This was one of the most important artistic styles after Classical antiquity in Europe. New life philosophies, which were looking for change, were being born. It did not have a finished model and orientation for further development, but also promoted the return of antique models. However, the stunning architectural objects and styles of this period were not sufficient for the renewal of life in cities. The deep crisis, wanton enrichment of the ruling structures, extravagance and corruption invaded the church, the noble and royal capital that could no longer sustain the life of the medieval city. The medieval period passed in social and power struggle. The cultural and urban development, together with nature, was completely deserted.

At the end of 14th century, when Feudalism began to weaken, a new movement – the Renaissance arose [a rebirth of culture and science]. It was created through the penetration of humanism, influenced the development of education, material and spiritual culture, as well as construction. As one of the most creative periods, it broke the relationship with philosophy of the Middle Ages. This period enabled all the citizens to participate actively in the general and cultural development of the city. Basic human freedom and creativity managed to prevail dogmatism and open space creative optimism and humanism. Openness and the freedom of organization of space, squares and streets that leave the orthogonal plan contributions are the Renaissance architectural practices. Radiating plan is typical of the Renaissance and is based on the integration of the old and new town with public square with the obelisk becoming the most distinctive feature.
The idea of the ideal city of the Renaissance was inspired by the teaching of Greek philosophers Plato and Aristotle. They sought to unite the beauty, functionality and rationality in harmony and aesthetics idealization. The city transformation continued into the Baroque. The Baroque dynamic space combines architecture and sculpture, a significant design element is the water that is placed in a fountain. Michelangelo’s influence and Bernini’s work contributed to the development of Rome as ‘the focal stage of Baroque’ (see Fig. 2.8).

Classicism was a reaction to the excess and baroque pomposity. As a part of the overall cultural transformation, it emphasizes the importance of intellectual effort in building a new world, looking for the balance and harmony of nature and art. A park is dominated by the green structures and water. This is a time of new ideas, developed urban planning, large-scale plans, a sense of space, construction of squares, parks – linking the urban structure and nature.

From the Renaissance through the Baroque, to the classicism after the exhausting conflicts and wars, it was marked as the beginning of their better and freer life and intellectual triumph. The critical analysis of consciousness of this period created a need to preserve nature and its components – greenery and water. Fitting architecture in nature caused the changes of the city forms. One of the steps in creating this involved the destruction of the wall in order to establish stability and equilibrium. Exceptional architecture, sculpture, theology and philosophy with perspective, geometry and light that are dominant elements of architecture of the city produced a new artistic culture. The human was a measure of all the things, including the aesthetic values. In his book *Space, Time and Architecture – The Growth of New Tradition*, Sigfried Giedion identified the need for the new understanding of space by saying that: one of the great triumphs of the baroque mind was to organize the space, turning it into something continuous and reducing it to a measure and order. According to him, the concept of space is always
associated with the concepts of movement and time. In this period, the relationship with the old forms was broken. This was the beginning of a new phase in the development of the city and design. This refers to the creation of open public spaces – squares and streets – with their buildings, fountains and sculptures. They became constitutive elements of the new urban culture. The rapid population growth of the cities, together with economic and social transformation, changed urban structure at the end of this period. Numerous discoveries enabled the development of science and industry, which contributed to technology success.

At the end of the 16th century, the centre of colonial government moved to the north, to the Netherlands and England. Technological innovations, together with the resources from the newly conquered areas and political changes, led to the disintegration of the feudal system. Increased domestic productivity resulted in an increase in living standard. This initiated the relocation of the population from the countryside to the city. The invention of the steam engine and its application increased agricultural production but also the need for industrial labour in the cities. At that time, England experienced industrial and urban revolution. In 1750 London reached the figure of 750,000 inhabitants, with an average annual growth rate -10% urban population. Only Beijing was larger than London in terms of population. In approximately 1800s Beijing and London reached one million inhabitants and became the first million cities in the world.

The process of industrialization was one of the strongest drivers of the city development on the global scene. New technical innovations of the late 18th and early 19th century were the precondition for the development of the industrial revolution. The way of production was significantly changed and the rapid development of industry caused the negative changes in the creation of the city. Changing the relationship between production and consumption enabled the individuals to gain capital and in that way they could control the processes in the society. This initiated the creation of young bourgeoisie which established a new system in society – capitalism. However, this system could not stabilize the society in which dissatisfaction was present. The inability to provide subsistence minimum for life always created the revolt among the people.

The capital and the power of each individual encouraged the rapid urbanization and city growth. The new industry was focused on profit and did not want to control city development. In that way, the drastic spatial changes occurred, such as changing the relationship between rural and urban populations. The law of market encouraged the people from the countryside to move to the city. This disturbed the already established social balance. All the activities supported industrial production. New market relations and greed for money disrupted people’s lives. As the most active work force left the countryside, it became abandoned and easily started decaying. Unfortunately, this process is still going on. In his book The City in History: Its Origins, Its Transformations and Its Prospects, Lewis Mumford (1961) explained this process by saying that: human qualities did not have space in capitalism. In his terms, the only accepted qualities were greed and desire for money. In the city of this period overcrowding and the lack of utility infrastructure became dominant. Public and residential areas of the city got depressive forms. In spite of this, the industrial city developed and became more indipendent as it was the centre of financial power. At the same time, bourgeois society moved outside the city centre in order to enjoy the potentials of the nature. In his book Space, Time and Evolution, The Growth of a New Tradition, Sigfried Gideon (1967) said that: the most striking result of the Industrial Revolution was the destruction of the inner peace and human security. With the beginning of 20th century, a new chapter of industrialized city where everything was a subject of production and enrichment was opened. While celebrating new technologies under the motto – the rational use of city property, the nature was
devastated and mostly replaced by built structures. Human vision of human and society was replaced by a machine and the rule of profit. Civil society of that time was forced to search constantly how it would get out of the crisis and social problems. In response to difficult situation in the cities new utopia movements appeared together with reformers Robert Owen, Charles Fourier, Etienne Cabet and Henri de Saint-Simon who opened space for new visionary ideas. In order to better understand the utopian reaction and the principle of urbanization, the development of industrial city is explained in detail in the following chapter.

2.1.2. Industrial Cities

The rapid development of technology and industry continued during 20th century, which resulted in the phenomenon of rapid urbanization. At the same time, the search for new models of city life continued. In order to respond to this phenomenon, it was necessary to perceive the problems and the missed opportunities of the industrial city. In theory and practice, the human dimension of life was affirmed, while the utopian theories showed the need to preserve the nature. Theory and concepts of urban planning reviewed the efficiency of city functions. Favorable nature condition and technology improvement were the precondition for the development of the first largest cities in the world such as London and Beijing, which reached 10,000,000 inhabitants. In his book *Principes de géographie humaine*, Paul Vidal de La Blache (Paris: Armand Colin, 1921) explained that: wasteland, forests, fields and fallow fields merged into an indivisible unit, and a human always brings a memory of the nature with him. The nature was an unbreakable relationship between the city and the countryside. The city was collective as a place where most people lived during this period and still live. There were significant changes in the level of urbanisation which are still present – between developed and present-day less developed countries. The intensive process of urbanisation followed the expansion of the Industrial Revolution in Europe and North America. The number of cities grew rapidly.

By the end of the 19th century, there were 16 million-cities worldwide, out of which 12 were in Europe and one in North America (New York). At that time, about 50% of the population of England lived in cities. 20th century led to the emergence of megalopolises. The industrial revolution did not spread to the countries of Latin America and Africa, which were the only source of raw materials and labour for Europe. Over time, there was uneven and slow urban development. In colonial areas, large port cities developed, and they served for the export to the colonial powers. Except port cities, there were no other urban centres. Rural populations mostly inhabited port cities, and this trend is in many cases present today. In fact, the highest urban growth is now recorded in the areas where the level of urbanization is the lowest. The increasing pressure generated strong growth of the world’s population and strengthened the industrialization and economic changes. Thus today we have a trend of the transfer of population from rural to urban areas in developing countries, especially in Bombay, Nairobi and Mexico City. At the same time, highly urbanized countries, including England and the United States (US), reached the saturation point, because most of the inhabitants of these countries already live in cities. However, another trend occurred in these countries, and that is the relocation of the city to the countryside.

2.1.3. Problems

In order to surmise the perceived problems of the urbanisation of man’s first residence to industrial city, it was necessary to consider the chronological development of the society and settlements. The appearance of man, the development of his conscious and culture attract the attention of many scientists
around the world. For this research, we used the data from the Palaeolithic when, while living in a cave, a human showed a certain degree of intelligence and artistic sensibility that he expressed through the drawing on walls and ceilings. Architecture as a human science tends to define the problems in the development of society and settlements as missed opportunities – challenges. This thesis researches these problems and transforms them into the potentials necessary for further city development. In this way, we try to expand our cognitions of the subject of this research. In this research process, the relationships nature-city, city-man and human-nature are evaluated, so life comfort and urban diversity are the parameters of these relationships, including a mutual relationship of man-to-man.

In architecture history, common life of people living in caves and natural shelters was not researched enough. It was believed that the people of this period did not develop enough construction power so they reacted instinctively. Fear of nature and its power forced the people to seek for natural shelters. This created a dilemma that raised many questions: How did a human find a cave? Was it a man’s choice? What did it offer to him? How did he define its position? Why? Our cognition shows that the man’s life in a cave was healthy. The reason can be found in the micro-climate condition that prevails in this region (constant temperature and high humidity, the presence of aerosols and negative ionisation). The cave was and still is a place free of allergens and pathogens – a healthy place for human life. If we add to these favourable conditions the environmental potentials that offered a plenty of food, the life in this place was pleasant. It is evident that a cave human searched for stimulating place to live, forming family groups. The logical question is whether a human of this period recognize the favourable condition of this life or not? Until now, unveiled remains of human habitation in the cave confirm that the cave man knew how to recognize south and southeast oriented caves, as one of the elements of their comfort. There was no scientific evidence of the fact that he did it. Alternative history claims that instinct and intuition are the internal gift, spiritual, mental and physical dimension of the cave man. As a rational being, a human mastered senses, feelings, and ability to comfortably use the energy of the Earth. Many scientists now claims that human time in untouched nature stimulated the cave human to improve his own physical and mental health. In that way, the human lifted the immunity and gained more confidence. Was this crucial or the human had some knowledge about the treatment of natural radioactivity in the rare caves? There is a dilemma: What happened with the presence of CO2 and pollution that penetrated from the external environment into the cave? The organic relationship between architecture, human and nature with their mutual understanding and the selection of a quality place in nature was decisive for man’s further development. If we add to this the unexplained drawings on the walls and ceilings of the cave, man’s life of this period was pleasant and diverse, rich with experiences and events that he wanted to record for new generations. Nowadays science is still searching for the secrets of this age. What we can confirm with certainty is that there are numerous missed opportunities closely related to comfort and diversity, as well as the relationship between human and nature. It is necessary to continue the research of this archaeological treasure in order to quantitatively and qualitatively use the perceived potential for further social development.

Man’s confidence, knowledge about agriculture, weapons for hunting and building contribute to the comfortable way of living. However, discovery of fire (science interprets it as technology, while religion as a power of fire)⁴ forced the human to leave the cave. He settled down under the sky (outdoors) in

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⁴ In science fire was breakthrough that offers the progress. This is approved through numerous inventions and increased level of human comfort. In religion it is believed that the impure forces gave fire to human to destroy himself. Proof of this is the ignition and deforestation for the purpose of agricultural production and the creation of the settlement that might a cause of a great natural disaster. Similar to that, it is the invention of firearms and other forms of violence. Council fire in Orthodox religion is a proof of beliefs, for instance, lighting 33 candles on Great Saturday at Christ’s tomb in Jerusalem is miracle even today.
order to enable new life in nature for the much greater community. However, the human was still in proximity of the cave, for instance, the first settlement Lepenski Vir (6,500 – 5,500 BC). It is known that the first knowledge about building principles was used for the glorification of cult of the dead. Material evidence of these monuments are the megalithic structures scattered around the world. In the Neolithic megaliths were: cemeteries, monuments and observatories. They were made of huge pieces of rock stacked without mortar. In order to create these structures, people joined their efforts, and in that way the community was formed. The motive for the creation of community was present in religion. It is should be noted, from that period until today, that the level of sea is significantly changed. In that way, a significant part of these monuments were flooded – lost. Simultaneously with these processes, the first cities (Mesopotamia, Egypt, Greece, and Rome) were formed in the river valleys that were rich with blue and green components of nature. This is a piece of evidence that nature and its potentials are a requirement for the city creation. Architecture and urban structures of the city are integrated into nature and they are intertwined. The relationship between the city and the human is more complex and social segregation is present. The improvement of this relationship was firstly seen in Athens, as a centre of democracy. The relationship between human and nature was strong and it measured life comfort. Urban diversity was dominant and in balance with the social class. Gardens, orchards, parks and other places with green and blue elements were for relaxation. The measurable indicators of this urban experience were not record.

The disintegration of the Roman Empire created the Middle Ages which was full of conflicts. Great Migration of nations (lasted 5 centuries) led to the creation of a feudal system and changed the concept of the city. The city was actually a fortress, dividing life into outside and inside of it. Nobility was a class that enjoyed all the resources of the city fortress. Serfs lived modestly and often on the edge of existence. Manufactory and the middle class strengthened gradually. In order to protect their capital and their own lives, the middle class fought for their position in the city. All other members of society were left to themselves – outside of the fortress – so they were prey for invaders and thieves. The relationship human – nature in a city fortress was reduced to the subsistence minimum. The wall of city fortress was an edge and a barrier towards nature from which invaders and danger were coming. Life comfort in a city fortress was measured by money and the position in the society. Urban diversity got significance in the late Middle Ages – Gothic. The measurable indicators of this urban experience were not recorded.

With the arrival of Renaissance, the revival in the science and art occurred. Feudal relations were broken because they were burdened with dogmas and beliefs. A new class – young bourgeoisie- was formed. It encouraged manufactory production, banking and trade. City fortress began to open to the surroundings – nature. The city also developed on the other side of the wall. There was no condition for rich class to enjoy the city centre. They moved to the countryside, building private villas in order to relax in nature. The phenomenon of water was reused in the form of fountains and etc. Like comfort and urban diversity were present in rulers’ Baroque gardens. The measurable indicators of this urban experience were not recorded.

Industrial revolution improved manufactory production and transformed it into industry. Individuals were the ones who controlled the money and they turned into the powerful owners of capital. They occupied significant positions in the society. This was the beginning of the creation of a new system – capitalism. In an industrial city, nature was significantly destroyed and transformed into built environment. The relationship between humans and nature was lost in an industrial city. The humans felt isolated. Citizen’s life comfort was reduced to the subsistence minimum. At the same time, rich capitalist lived in luxurious suburbs and the countryside. The class segregation influenced the loss of
urban diversity. Measurable indicators of this urban experience were not record. All this led to the need to search for a new phenomenon – extreme urbanisation – which is the subject of the following section.

2.1.3.1. Urbanization

The problem of urbanization was mentioned for the first time in UN-Habitat published 1976 as a problem of ‘urban expansion’. The same topic appeared at ‘UNCED Rio Summit 1992’, where the concept of ‘sustainable human settlement’ was presented. Habitat II adopted the concept in 1996, where once again the problem of urban growth and the need to find new ways for ‘sustainable urbanization’ was highlighted. ‘City’ is a complex system, which is represented by different urban patterns and spatial, cultural and social dynamics. Economic growth and the increase in population have always been followed by urban change. After the postmodern period and the restriction of global economics [globalization of the economics] a new market-driven society – neo-liberalism – was established [ ]. The neo-liberalization and market-friendly policies since the late 1970s have influenced social, economic and political processes, permeated urban development, and pushed planning practices in a market-oriented direction. As urban planning became increasingly market-oriented and entrepreneurial, it became less capable to cope with the vulnerability of the cities. Short- or medium-term planning gradually replaced long-range, end-state planning (Healey and Williams, 1993; Taşan-Kok, 2008), and finally shifted the focus from planning to projects scope (Healey and Williams 1993; Taşan-Kok, 2008).

The proposed new paradigm should focus on the alternate means of addressing the human need for a more adaptive and reorganizational capacity in urban systems. In other words, there is a need for changes, not only in the focus, but also in the way of thinking [Grant, 2012]. Although the world has come a long way on this matter, the problem of climate change makes this matter urgent. Urban environments are facing evident consequences of climate change. Both people and built infrastructure are affected (Gill et al., 2007). Due to rapid [uncontrolled] urbanization [Habitat II, 1996] and climate changes, urban areas are going to face several serious problems. The biggest one on the global scale is the prediction of sea level rise. For example, if the sea level rises by just one meter, Buenos Aires, Rio de Janeiro, Los Angeles, New York, Alexandria Egypt, Mumbai, Dhaka, Shanghai, and Tokyo are just some of the coastal cities that will be affected (See Fig. 2.9) (Williams, 2002).

Fig. 2.8. Map of the world showing in light blue those areas that would be affected if all ice caps melted, causing the rise in global sea level up to 100m; [Source: Laurence Williams [2002], An End to Global Warming]

5. The Second United Nations Conference on Human Settlements was held in Istanbul, Turkey
The most common [local] weather [climate] variables which will affect urban environment are the rise in air temperature, increased precipitation [rainfall], loss of biodiversity, etc., (El Sioufi, 2010). Different environmental models predict, in the long term that mean values of air temperature may rise between 1.4°C and 5.8°C by the end of this century (See Fig. 2.10).

![Graph showing global surface warming](Source: [earthobservatory.nasa.gov/Features/GlobalWarming/page5.php](http://earthobservatory.nasa.gov/Features/GlobalWarming/page5.php))

The evidence of such changes is mounting. Broad-scale climate systems may already harm human health, including mortality and morbidity from extreme heat, cold, drought or storms, changes in air and water qualities, as well as changes in the ecology of the infectious diseases. It is evident that the extremes of both air temperature and precipitation are increasing in both magnitude and duration, causing inter alia more severe droughts and all sorts of floods [pluvial, fluvial, coastal and groundwater]. We have been witnessing more frequent flooding and droughts in the last couple of years, which are causing problems with water and energy supply and food security. The most striking recent example of this was the heat wave in 2003 [average temperature 3.50°C above normal lead to approximately 22,000 to 45,000 heat-related deaths across Europe].

<table>
<thead>
<tr>
<th>No</th>
<th>Year</th>
<th>Event</th>
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<tr>
<td>1</td>
<td>2008</td>
<td>Destruction of New Orleans, USA Caused by hurricane Katrina</td>
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<tr>
<td>2</td>
<td>2009</td>
<td>Fluvial floods in central Europe [more than once]</td>
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<td>3</td>
<td>2012/2014</td>
<td>Pluvial Floods in UK,</td>
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<td>4</td>
<td>2012</td>
<td>Combination of pluvial and fluvial flood in Huston, USA</td>
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<td>5</td>
<td>2012</td>
<td>Earthquake and tsunami induced coastal flooding an destruction of nuclear power plant in Fukushima,</td>
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<tr>
<td>6</td>
<td>2013</td>
<td>Air pollution spells in Beijing and other cities in China and in Singapore,</td>
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<tr>
<td>7</td>
<td>2013</td>
<td>Tidal surge New York,</td>
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<td>8</td>
<td>2013</td>
<td>Flooding in Philippines,</td>
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<td>9</td>
<td>2014</td>
<td>Balkan floods [Bosnian and Herzegovina, Serbia, Croatia, Slovenia]</td>
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Table 2.3 Recent natural and anthropogenic disasters in world [Table made by the Author]
In the last couple of years, the scientific community has debated the human factor in climate change. As soon as people gain knowledge about how to build, they seem to become reckless and forget about the environment and nature. Those aggressive and careless actions have led to climate changes with the consequences that are evident today (See Table 2.3).

Although 1st International Panel on Climate Change [IPCC] Report in 1990, states: 'the general amplitude of the increase in warming of the planet is comparable to one that occurs with the natural variability of the climate', their language has slightly changed in 2nd Report in 1995. They started to recognize the possibility of human influence and the responsibility for climate changes. The milestone was set in 2001 with the publishing of their third IPCC Report and the clear statement that there are convincing indicators of human influence on the planet’s climate. The 4th Report in 2007, had a shocking declaration: the most (>50%) of the observed increase in global average temperature since the mid-twentieth century is very likely [confidence level >90%] to be caused by the increase in anthropogenic [human] greenhouse gas concentrations (IPCC, 2013). Before the Industrial Revolution and the era of fossil fuels, human settlements were comparably smaller, thus their impact on the nature was negligible. It means that nature was able to cope with the previous levels of resource exploitation. However, with population growth, society continued to rely on the unsustainable exploitation of natural resources, allowing our footprint on global environment to become so large as to risk triggering irreversible environmental changes. The question is: ‘do we have knowledge [wisdom] and willingness to reverse this trend?’ A new approach is needed – the one that is going to maintain the living conditions in the cities as comfortable and efficient as they were, plus provide the controlled and sustainable consumptions of natural resources. The Ecosystem Services based approach in urban design is rapidly emerging as a potential solution in 21st century. The International Panel on Climate Change [IPCC] in 1988 acknowledged that environmental problems are not local ones and cannot be treated as such. Conventional engineering solutions only displace the knock-on effects on Ecosystem Service elsewhere, rather than solve the problem. Scientists have realized that urban growth and the degradation of biodiversity have led to the collapse of ecosystems in and around urban areas, reducing the capability of nature to provide basic goods and services that humans are relying on (Millennium Assessment, 2005). The new Ecosystem Services based the approach on the design and management of the cities is trying to help in the adaptation to climate changes and major environmental pressures (Eraydın and Taşan-Kok, 2013). It represents the concept where human settlements and their dwellers relay on the ‘free’ goods and services provided by nature (Grant, 2012). One of the ways to do this is the implementation of Blue-Green Infrastructure [BGI] – sustainable management of water and green infrastructure. Although the greening of cities alone will not solve problems, it is a behaviour shift in the design and maintenance of the built environment. Modern urban development has to retreat the lost contacts with nature and find the innovative planning and design methods that will provide the sustainable links between urban water and green areas in the future [sustainable] human settlements.

In the last century many wars were waged over fossil fuels, whereas this century could be defined as a battle for clean water. By using the synergy of urban water [blue] systems and urban vegetated areas [green infrastructure], the harmony with nature could be re-established and pleasant, healthy and stimulating urban places could be provided. The Blue-Green Dream Project promotes such holistic approach. The goal is to improve local environments through maximizing the synergy of blue and green systems across different urban scales (Maksimović, Stanković, Liu and Lalic, 2013). It redefines the urban and architectural design procedures by applying Blue-Green Systems/solutions [BGS] and by using an integrated modelling system in different stages of the design process to achieve optimal solutions for all relevant stakeholders.
Modern trends in the development of information and communication technologies have a direct impact on all the areas of human activity. The ability to create virtual reality by relying on the available software tools and the development of the environment presents a challenge to the designers of the built environment. The inherent complexity, present in the phenomena that belong to the real world, imposes modelling and simulation as an indispensable mechanism in the preventive assessment of today's construction and urban enterprise. Nowadays there are a number of software tools which, to a lesser or greater extent, provide support to the experimentation in the field of architectural design and urban planning (Aibar and Bijeker, 1997). By selecting a set of properties of space and block as the basic element of structuring the built environment, different aspects of the relationship of space and human in contemporary urban development can be simulated (Boubkeri, 2008; Conzen and Conzen 2004; Hawkes 1996).

Therefore, the management of cities in a sustainable manner is a unique opportunity. Cities are expanding far beyond their administrative boundaries and capacities (Doytsher, Kelly and Khouri, 2010) and have problems to provide essential services such as electricity and water to all residents. In addition, Doytsher points out that the current lack of city administration led to energy insecurity and serious pollution related to it. For example, the Public Power Corporation [PPC] plant in Kozani, Greece has to pay 2.2 billion euros fee to EU because of its carbon emissions. Road traffic is one of the largest sources of pollution in the UK [Environmental Agency - UKEA] which affects air quality, noise and climate change [22% of total UK CO2 emissions]. This is why EU Commission [Directive 1008/50 / EC] fined UK with more than £ 300 million a year. London has a serious problem with the quality of water mainly caused by sewage overflow. Waste management in cities is also a major problem. By 2005 Athens produced 6,000 tons of garbage a day, requiring 1,102 landfills to maintain it.

Another problem of urbanization is the fact that the amount of land covered by urban areas is growing faster than the size of urban population. Urban population is expected to double between 2000 and 2030 [from 2.84 to 4.9 billion people], and the total built area is predicted to triple in the same period (Elmqvist, Fragkias & Goodness, 2013). Following these facts, major reconstruction [increase in density] of the existing urban areas [or creation of new ones] is inevitable. This will bring great wealth and economic development, and create the phenomenon of megacities – places with a population of more than 10 million people (Doytsher, Kelly & Khouri, 2010). Currently there are 19 megacities in the world and that number is expected to reach 27 by 2020.

In many cultures, the objects were built (and are still being built) with the awareness of the limitations imposed by local climatic conditions (Kostof, 1991 and 1992). The processes of urbanization affect every city, which in its urban code bears the traces of the past that are woven into its identity. In order to better understand the process of the urbanization of today’s city and its impacts on the forms of human activity, we will use one of the city definitions given by John Stow, an honest observer of Elizabethan London, who says:

People gather in cities and community groups because of the sincerity and the public good, rarely because of trade that goes with cities, society and the company. First, people are moving away from this close cooperation of barbaric strength and desire, to gentleness of manners, humanity and justice ... Good behaviour is called urban, because that is found in the cities, but not beyond. To conclude, it is often said that it is easier to control people by faith, that they care about the way they look in other people's eyes, and that the example easier to lead to justice and that the shame keeps them not to hurt others.

As states and kingdoms besides God cannot have a secure foundation of love and good will of human to his fellow man, and in the cities, people-together and joining, forge alliances, establish communities and corporations.
In order to survive, the city must be made in a way that it restores the original values of its origin, subjective feeling of the benefits to people and communities with nature and its processes. The role of the architect is all the more critical because he must not act hastily, but understand the complex relationships, look for new ways and properly interpret them. This was a clearly warning by Lewis Mumford (1968) who said that:

... The city needs to return to his mother's, life functions, autonomous activities and symbiotic relationships that have long neglected and suppressed ...were fruitless even after nearly four decades. This gives us enough to show that the changes in today's cities, slow and difficult to achieve and that are dependent on human behaviour models. Functional segregation of the city today is the basis for dehumanization and clear break relation human-city and man-man.

BGD paradigm offers a new approach to the efficient design and management of the urban environment: the one that maximizes ecosystem services minimizes negative environmental impacts and increases ‘cities’ resilience. It combines nature and technology-based solutions to avoid the further fragmentation of ecosystems in urban areas and hence increases ecological functionality of a city as a whole. The sustainability of BG solutions can be quantified through ESS performance indicators such as energy efficiency [reduction of demand], water supply [reduce, reuse and recycle], urban microclimate [improving], food security [provide], biodiversity [assure], etc. (Maksimović, Bozovic, Zivkovic, 2014). This thesis will rely on the BGD philosophy and offer a new concept of urban design based on ESS. While searching for possible solutions to improve the process of urbanization, different aspects in the development of modern cities have been analysed with the aim to detect problems and mark the missed opportunities.
2.1.3.2. City Development

In order to engage in the detailed study of various aspects of the development of today’s city, it is necessary to briefly consider a few concepts – theoretical investigations of the city, such as:

- City as a complex system of urban phenomena,
- Urban form as a form of morphological categories, which is a synthesis of all the structural elements involved in the creation of urban space,
- Urban transformation as a process that deals with the changes of shape through time and space
- Urban form that affects the quality of urban space,
- Influential factors as a type of driving forces which are the smallest structural units of urban form,

In his long and complex research of a significant number of cities around the world, Greek researcher Doxiadis established a new science – ekistics [1942], which offered three basic morphological stages:

- City of the past, which is a static city-polis that includes all the morphological stages of the history of civilization, to the beginning of the impact of modern technology, science and industry.
- City today, a dynamic city – Dinapolis, which survived metropolis and metropolitan areas, to megapolis.
- The city of tomorrow, Ecumenopolis, which aims at merging with Dinapolis, dinametropolis and dinamegapolis that marked the end of the 20th century (Doxiadis, 1968; Doxiadis, 1970:145).

The second decade of the 21st century (now city) marks a strong trend of urbanization. To respond to this trend, international association of sustainable cities (SCI) in Vancouver, Canada was established, and is connected with the Centre for Sustainable Community Development at Simon Fraser University in order to bring change to urban sustainability. By building human capacity in cities, it improved effective cooperation and accelerated the development process. This study used the benefits derived from the nature of the ESF in order to check their effects through case studies, and identify the available resources integrated into blue green infrastructure in order to identify and implement the solutions that are in harmony with nature and its laws and which are likely to achieve the objectives and a healthier community in the city. These case studies – models – are the means of communication as an incentive for action and opening a range of topics. Camilo Sitte (1967:37) argued that the city needs to act educationally on the needs of a great mass of population every day and at every time. Mumford (1968) goes a step further in the cultural and educational mission of the city improvements, and concludes that particular strength of his approach is to educate what the city as a whole means. All people do not perceive and experience the world around them in the same way. Green infrastructure is an existential demand in the horizontal and vertical imperative of the citizens of today’s city. It is a logical combination of natural and urban spaces that relaxes and rehabilitates a modern human as a natural and social being. After analysing these aspects, the need for recording the problems and missed opportunities in today’s cities occurred.
2.1.3.3. Contemporary City

Let’s start with the question: Where are the problems and how they arise? The critics of today’s city sent a unique message about the anonymity and impersonality of people. It is expressed through the monotony of their existence and creativity, which is reflected in the lack of structure and impersonality. The phenomenon of alienation is one of the important characteristics of our time. Consequently, it led to the gap between human and nature, between human and society, between human and human as the result of globalization and disrupting the natural balance (Herbert, 1971:14). When it comes to the crisis of urban consciousness or city estranged from a man, we have to accept the definition that above all the city is the most complex human creation and has to think about its citizens, to fulfill their requirements and preserve their identity.

Today’s cities do not have diversity, uniqueness and monotony, so citizens are feeling like strangers, and the city is alienated from the environment and nature. New cities are speaking the same language; it is less possible to distinguish one from other (Papnek, 1992 and 1966). Today, globalization celebrates its planetary success and is present in all spheres of social life. The world has become universally called global age. Konrad Wachsmann, German architect, believes that it would be a great misfortune if the local culture-now were destroyed by the nation-state in the name of European integration or globalization.

The dramatic problem arises with human dealing with technological challenges. Heidegger explained the importance of modern techniques and gave them a metaphysical meaning (Heidegger, 1972:121). Modern technology has transformed the nature of the project into a heartless manipulation of industrial human to satisfy his will to power. Modern human is a threat to his being as he breaks his relation with the environment. An important feature of our time in the sphere of human activity was marked by the phenomenon of alienation which is the source of the process of dehumanization and the act of the awareness of the crisis of urban practices.

Accelerated process of urbanization and the uncontrolled growth of cities change the earth’s climate. Environmental and energy crisis, industrial expansion, inefficient technologies and excessive use of fossil fuels are just a part of the biggest problems of society at the beginning of the new millennium. Intergovernmental Panel on Climate Change (IPCC) states that urban settlements, among all the systems created by man, are the most sensitive to climate change. This study provides some of the possible solutions through an innovative methodology BGD [climate-responsible planning], design and construction of settlements, with the emphasis on self-sustainable development and preventive actions in an open area of the city.
2.1.4. Missed Opportunities

In these concluding remarks, the results – missed opportunities related to the urbanisation and its processes – are summarized. At the same time, we search for new directions of the research of urban city design by the use of BG infrastructure and Eco-system services. In that way, we try to answer the following question: is it possible to transform the perceived problems into challenges – the potentials of the further development? These problems brought with them the consequences which influence the process of urbanisation. The outline of the research required the consideration of all the aspects from man’s life in the cave to the present-day city. These considerations are defined as guidelines for the creation of new urban city design. This helped to summarize the complex thinking and relationship nature – human – city.

The first historical overview of urbanisation included the complex period from man’s first life in the cave to the creation of the feudal city. During that period, numerous problems in the relationship nature-city were noted. The potentials of nature and blue-green components used by Ancient Greece and the Baroque were not sufficiently investigated. Classical segregation and social processes flattered the relationship city-man. There was a bright example such as democratic principle of social development of Ancient Greece which might humanise this relationship but it did not. The relationship human – nature was strong in this period, while the relationship nature – architecture of the human was changed. Urban diversity under the influence of social processes was devastated. In that way, the given opportunity which would integrate architecture with nature was not used. The measurable indicators of this urban experience were not recorded. The relationship man-to-man began to be more and more complex, and the possible solutions might be found in humane principles of Ancient Greece. The Industrial Revolution implied the expansion of urbanisation and the creation of industrial city.

Nature was significantly destroyed in industrial cities, and it was changed into built environment. This implies uncontrolled expansion of the city towards green areas. The relationship nature – city experienced the greatest crisis. The human isolated himself from the nature and the city. Life comfort was reduced to the subsistence minimum. The migration from the countryside to the city with the lack of concern about the planned development of the city led to a new phenomenon – extreme urbanisation. The measurable indicators of this urban experience were not recorded, but they appeared in a form of utopias as a movement which searches for better life. Market conditions defined the relationship man-to-man.

A small number of people had the opportunity to enjoy life comfort in the city. Only privileged ones can enjoy urban diversity and nature – mostly on the outskirt of the city. All these processes initiated the need to think carefully about the further development of the city. In that way, we search for a new phenomenon of extreme urbanisation.

The concept of extreme urbanization appeared firstly in the second half of the 20th century (1976). The expansion of an industrial city also continued in the 20th century. The problematic relationship nature-city, which was quantified in the field of spatial planning, became the subject of new filed environmental protection. The new field called the conventions on sustainable development (Rio, 1992) were accepted as a response to the uncontrolled city development. The climate change is increasingly prominent. Weather extremes and floods left numerous consequences on the city, human life, material goods and society in general. This creates the need to quantify the benefits of the nature for the first time (Millennium Goals, 2011) known as Eco-system services. In order to prevent these processes of destruction, we defined and recorded the misled opportunities. This initiated the need to
have control over these processes in order to reduce the vulnerability of the city and increase the resilience to climate extremes. The use of the concept of renewable energy encourages urban diversity and sustainability of the city. In spite of this fact, the cities continue to spread. These processes threaten that the whole world becomes a global village. The relationship human-city is made more complicated with these processes. The citizens are dissatisfied with city conditions and the relation of the city towards them. Mobility enables them to change the city in which they live, which causes migrations. This creates tensions in society because the citizens isolate themselves from the nature and from each other. New urban methodology and concepts do not have potentials to solve the complex needs of society. So we search for the possible solution – the concept of sustainable city. It has to satisfy the relationship nature-man-city. In order to secure comfort and healthy life, the sustainable city has to be a stimulating place – integrated with the nature. Urban diversity and human relationship have to be dominant within this concept.

The concept of sustainable in theory and practice is reduced to the renewable sources of energy. The sustainable principles have been amended (CEMAT-Ljubljana 2003). By defining the term ekistics, Constantinos Aspistolou Duxiadi (1968 and 1970) considered the morphological phase in city development. According to Duxiadi, there is a difference between the city of the past – static city – and the contemporary city – dynamic city, and the city of the future that connects the urban area and megacities into one unit – global village. This confirms that it is very hard to control the city and predict its life in the future. It is expected that the city of the 21st century will use the principles of the nature and BG infrastructure and Ecosystem services in order to create a better nature-city relationship, offering more humane and comfortable city life. The relationship city–man must always be in favour of the man. Urban diversity and nature must be integrated in open urban spaces as a supplement to everyday life. The relationships human-nature and man-man are always questionable. Instead of alienation and stress, a model of unity and integration with nature should be offered to contemporary human. It is recommended to use a logical combination of nature and urban space that relaxes and rehabilitates a human as a natural and social being.

The process of globalization in contemporary city disturbs the natural balance and breaks the relationship nature – city. Alienation, impersonality and anonymity are the problems of contemporary city which should be solved immediately. If we add to this the monotony of architectural and urban structures and the loss of identity and regional peculiarities, it is understandable that the phenomenon of alienation becomes dominant. Already disturbed relationship human-nature, human-city, and man-to-man leads to the fact that the citizens feel like foreigners in their own city. Technological challenges of contemporary city have to be used in terms of the increase of city comfort, urban diversity and the integration of citizens with the nature instead of being used for the purpose of alienation. BG infrastructure and Ecosystem services offer more qualitative relationships between the people and nature in a new way. The measurable indicators of this urban experience of BGD project can act preventively in the area of public open spaces in the city, testing the level of comfort and the application of urban plan and project. The subject of the further research is the level of conductivity of urban design concept and its principles in practice. Missed opportunities of the process of urbanisation should be supplemented with relevant cognition from the field of urban design, which is the subject of the following chapter.
2.2. Urban Design Concepts

UN Habitat predicts that by 2050 a whopping 5.3 billion people, or 70% of the world’s population, will live in urban areas. The fact is that one hundred largest (global cities) now participate in 30% of the entire world economy, and that the total number of population, especially in China and India, will be significantly increased. This indicates that life in cities and their peripheries need to be understood and interpreted in new ways (Bojanić & Đokić, 2011). This chapter has the aim to analyse the development of different approaches of urban design at city level. It is not possible to form the new way of thinking about the cities that have their own sustainability without thinking about the planet Earth on a global level.

The role of all the actors involved in ‘making the sustainable city’ becomes more complicated and responsible. We live in 21st century with the intention to create self-sustaining city. Sustainable urban design has a tendency to connect nature, people and places – create a new urban pattern. In his book The City in History, Lewis Mumford (1961) explained this by saying that: we crossed the road slowly, from the city that symbolises the world to the world that becomes a global city in accordance with many practical aspects. In order to understand these urban processes, it is necessary to get to know the development of the urban design of 20th century and its methodologies. There is no pattern to create a sustainable city, but there are elements that define the level of sustainably. In the process of creating the sustainable city, we have to understand urban environment, ecological problems and social-intellectual norms filled with many changeable financial and political parameters in the society. We expect that the sustainable cities are open, transparent and establish a relationship with their citizens. The cities should compete between each other in terms of the quality of life, the richness of cultural content, and the possibilities of using open space and nature. In order to establish the balance between nature and the urban design of the sustainable city, it is necessary to explain its complex relationship with its surroundings. In that process we have to use knowledge, be patient, be persistent and wise in order to make the city a more comfortable place to live and less vulnerable to climate extremes. Every mistake costs a lot in this process. This research examines the relationships nature-human-city, expecting that the result of this relationship will create humane, healthy, and comfortable city with recognizable identity. The evaluation of these relationships exceeds the aspects of spatial and traffic regulations, architectural design and economic development.

We use the experience of the BGD project that promotes new integrative principles. This thesis offers an innovative approach to a way of evaluating the existing urban concepts and defining measurable parameters for creating the new ones. In this project we search for the ways to transform this vision into a new guidance – give our contribution to knowledge. In that way, blue-green infrastructure and Eco-system services could improve urban design in theory and practice. The experience of the past of the city development shows that the accent should be on open public spaces but not on the whole city. These micro units are the parts of an integrative process that we used in creating the sustainable city. We examined open public urban spaces in order to provide better and more comfortable life to society. We often discuss Eco-system services as the benefits of nature on the abstract level. In order to define the role of Eco-system services in open public spaces, we have to check the quantitative and qualitative parameters of nature.

Analysing urban design concepts in theory and practice gives the solution of the above-mentioned problems. It is logical to begin with Ebenezer Howard’s Garden City whose concept inspired many urban planners and architects to develop it further. His focus was on the social reform and the decentralization of the city in order to enable people to enjoy nature but, at the same time, they can
control the volume of industry. His ideas became reality through creating two cities in England during his life (Letchworth and Welwyn). Inspired by Howard’s concept and his ideas of the integration of the city and nature, Patrick Geddes created his own concept applied in Tel-Aviv. Le Corbusier, who was also inspired by the relationship city-nature, created the centralized and vertical city –The Ville Contemporaine, Plan Voisin and the Cité Radieuse, while Frank Lloyd Wright solved this relationship by creating the horizontal city—The Broadacre City. Jane Jacobs gave a critical review of the above-mentioned concepts, showing the importance of urban diversity in creating the present-day cities. All this was necessary in order to define the position of the human – how he feels – in the city.

2.2.1. The Garden City [Ebenezer Howard]

‘Hands are hungry for toil, and lands are starving for labour’. Ben Tillett

The Garden City is ‘planned and self-contained communities surrounded by greenbelts, […] containing carefully balanced areas of residences, industry and agriculture’. The British Town planner Ebenezer Howard (1850 -1928) designed it. Edward Bellamy’s novel Looking Backward and Henry George’s work Progress and Poverty inspired him. It was firstly promoted in his book Tomorrow: A Peaceful Path to Social Reform (1898) and reissued later in 1902 in the book called Garden Cities of To-morrow, where he showed his concern for overcrowded London in which he lived. He was more interested in the political, social and economic reforms of the city [including ownership, finance, and housing rents] than its physical form – architecture. Nevertheless, the social, political and economic aspects of Howard’s vision were barely understood. They had less impact than his idea that “the free gifts of Nature” could be designed into the fabric of a decentralized metropolis which continues to reverberate in planning circles across the World (American Planning Associations, 2006:17). His utopian concept for garden cities was created from the need to improve the quality of urban life that ‘had become marred by overcrowding and congestion due to uncontrolled growth since the Industrial Revolution’. This was the response to the poor living conditions of workers in the process of industrialization in English cities, especially London [bad flats and illness among workers – residents of slums in the city centre]. By using the words of Dean Farrar, Howard noticed that: ‘We are becoming a land of great cities. Villages are stationary or receding; cities are enormously increasing’ (1902: 11). So it was necessary to find a way to answer this question – ‘how to restore the people to land’ (Howard, 1902: 13). The answer was to make a plan of ‘radical de-concentration of industrial cities’ and the creation of self-sufficient satellite cities in order to stop the swallowing of London’s teeming slums (American Planning Associations, 2006:17). This involves the need to reconsider the fact – what actually drew the people into the cities –by defining all possible causes of that as ‘attractions’. Thus ‘each city may be regarded as a magnet, each person as a needle’ according to Howard (1902:14). In this case, the magnet is used as a symbol for ‘spontaneous movement of the people from our crowded cities to the bosom of our kindly mother earth ... the source of life, of happiness, of wealth, and of power’ (1902:15). Howard considers the town and the country as two magnets that are shown in his diagram (see Fig. 2.11). The Town magnet, as ‘a symbol of society’, shows the advantages of urban life such as ‘high wages, opportunities for employment, tempting prospects of advancement’ that ‘are largely counterbalanced by high rents and prices’ (Howard, 1902: 16). The Country magnet, as a symbol of God’s love and care for man, describes the characteristics of

7. See more, ‘Garden City Movement’. In New World Encyclopedia. Available at:http://www.newworldencyclopedia.org/entry/Urbaneization
8. See more, ‘Garden City, Urban Planning’. In Encyclopaedia Britannica. Available at:https://www.britannica.com/topic/garden-city-urban-planning
rural life with ‘beautiful vistas, lordly parks, violet-scented woods, fresh air, sound of rippling water’, but its value falls because of the lack of social aspects (Howard, 1902: 16).

As we can see, the advantages of the Town and of the Country magnet always have their corresponding drawbacks that reduce their values and quality. Howards explains this saying that:

… neither the Town magnet nor the Country magnet represents the full plan and purpose of nature. Human society and the beauty of nature are meant to be enjoyed together. The two magnets must be made one. As human and woman by their varied gifts and faculties supplement each other, so should town and country (1902:17).

‘Town and Country must be married’ in order to be able to create a new hope, a new life, a new civilization’ (Howard, 1902: 18). Being inspired by this, Howard integrates the Town with the Country magnet, creating the third one: Town-Country magnet where ‘all the advantages of the most energetic and active town life, with all the beauty and delight of the country’ are put together (1902: 15). In that way, all the drawbacks that the Town and the Country create separately are eliminated. Howard’s ideal garden city would be built ‘on land belonging to the local community and developed in public interest’ (Ward, Ed., 1992:28). The reduction of land private ownership allows low rents for working people and creates a sense of community – feeling of belonging. Each garden city would be located on 6,000 acres [ca 24,000 square kilometres], which involves the city area [1,000 arches=ca 4,000 square kilometres] and agricultural land [5,000 arches=ca 24,000 square kilometres] which supply fruit, vegetables and
dairy products for the town. The maximum population of the people who would live in the garden city is 32,000 [around 30,000 people in the city itself and about 2,000 people in the agricultural land] (Howard, 1902: 23). Limited in the area and population and socially and culturally balanced, the garden city is ‘large enough to have the benefits of concentration but small enough to remain close to countryside’ (American Planning Associations, 2006:17). The circular layout of the city was ‘enveloped and restricted by a green belt that offered clean air and the space for agriculture and recreational pursuits’ (Langmead and Garnaut, 2001:129). This is shown in the diagrams created by Howard (see Fig. 2.12), representing the ground plan of the completely municipal area with the town in the centre; (see Fig. 2.13), representing one section of the town.

Fig. 2.12 Ground plan of the whole municipal area with the town in the centre designed by Howard [Source: Howards, E. (1902), Garden Cities of To-morrow]
The city was divided into six equal parts or wards, separated by six magnificent boulevards [each 120 feet wide = 36.5 meters], with a central park in the centre and a designated area for municipal buildings [such as town hall, principal concert and lecture hall, theatre, library, museum, picture-gallery, and hospital], dwellings, churches, schools and playgrounds (Langmead and Garnaut, 2001:129). All the facilities are within walking distance from each house. It was important to ‘brings [them] near to every dweller in the town – the furthest removed inhabitant being within 600 yards’ (Howard, 1902: 23). On the outer ring of the town is the industrial sector [e.g. factories, warehouses, dairies, a market, coal yards or timber yards] separated from the residential areas in order to isolate them from noise and pollution (Howard, 1902: 25). In that way, goods are loaded directly into trucks from the warehouses and workshops, which reduces the traffic on the roads of the town.

When the population reaches its limit [= 32,000], a new garden city is built up nearby ‘forming a cluster of satellite communities – social cities – interconnected by a rapid-transit system’ (Langmead and Garnaut, 2001:129). Howards explains this saying that:

> the city will grow ‘by establishing another city some little distance beyond its own zone of ‘country’, so that the new town may have a zone of country of its own....for administrative purposes it would be two cities; but the inhabitants of the one could reach the other in a very few minutes; for rapid transit would be specially provided for, and thus the people of the two towns would in reality represent one community. (1902:125-130).

All the cities would be grouped around a larger central city with the maximum population of 38,000 that is shown in the diagram (see Fig. 2.14 and 2.15). The railway provided a direct connection between each satellite city and the Central City. Preserving a belt of country round the cities was always kept in mind. For Howard, this is the principle on which all towns should grow.
The principal characteristics of Howard’s concept for garden city were:

- the purchase of a large area of agricultural land within a ring fence;
- the planning of a compact town surrounded by a wide rural belt [a farmer now has a market close to his doors];
- the accommodation for residents, industry, and agriculture within the town;
- the limitation of the extent of the town and the prevention of encroachment upon the rural belt;
- and the natural rise in land values to be used for the town’s own general welfare.

How Howard’s concept of garden city had been developed further in England and whether the newly created garden city was accepted or moved away from his vision can be seen in the following section.

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In order to bring his utopian vision of garden city into reality in the twentieth century in England, Howard needed to find financial support to buy some agricultural land where it would be built. He believed that the presence of a large population increases the value of the soil so ‘it is obvious that a migration of population on any considerable scale to any particular area will be certainly attended with a corresponding rise in the value of land…’ (Howard, 1902: 21). To implement this he lectured, he interviewed influential people, and formed a Garden City Association’ in 1899 [later known as the Town and Country Planning Association] (Bonham-Carter, 1951: 363). His supporters were not only ordinary investors, but people who were impressed by the social value of his concept and were ready to risk and invest their money in the project. The two primary aims of this organization were: to promote the ideas presented in Howard’s book and ‘set into motion the plans for the building of the first garden city’ (Ward, 1992:188). This might be seen as the first step in the application of the Garden City theory in practice. However, the whole process was not easy, as the members of the Garden City Association were better at promoting the ideas of garden city movement than their implementation – they were more ‘talkers’ than ‘doers’ (Ward, 1992:188). This resulted in the failure to raise the money for garden city project. Having learned a lesson from this experience, the members decided to present the garden city concept to wider audience at two well-publicized national conferences, the first was in Bourneville in 1901, and the second one was at Port Sunlight in the following year. Both conferences had a significant influence on the formulation of the first garden city – Letchworth – as the whole concept was well-presented in the press and new members joined the organization. These were the decisive steps in promoting the garden city concept, which later led to the establishment of Letchworth. Shortly after the Port Sunlight conference in 1902, the Garden Cites Association promoted a Pioneer Company Ltd., and under Ralph Neville’s leadership who was the chairperson of the Garden City association and who appointed Thomas Adam as full-time Secretary, the company won the support of the industrialists like Edward and George Cadbury, Alfred Harmsworth, W. L. Lever and T. W. Idris (Ward, 1992:188). The purpose of its establishment was to find a suitable site for building the first garden city, and ‘5,000 £ was subscribed for investigating available estates’ (Gladstone Culpin, 2015:30). A green field site near Letchworth in Hertfordshire was selected as a potential land for the implementation of Howard’s idea of the garden city. The evolution of Letchworth was not the preoccupation of the Association as the principal aim was to develop the concept wider and increase the interest in it. This was Thomas Adams’s idea, who was wondering ‘whether the future of Association would be bound up with the fortunes of Letchworth or it should concentrate on pursuing broader aims’ (Ward, 1992:189). It was important not only to develop an autonomous settlement like Letchworth but also to improve the standard of development in new suburban extensions. This can be seen in Culpin’s diagram where, besides Letchworth Garden city, other garden suburbs and villages are termed. This initiated the formulation of other garden cities in England such as Welwyn that will be discussed in the following section.
Established in 1902, Garden City Pioneer Company Ltd. had a responsibility to find a site where the first garden city would be built. After reviewing a number of sites, the company bought 3,818 acres of land near Letchworth in North Hertfordshire, 35 miles north of London. So Letchworth is the first British planned garden city that was founded in 1903 and was much copied elsewhere as an early example of urban planning that brought together community management and economic sustainability. It has to be remembered that ‘the date when Letchworth Garden City was founded, no town planning legislation existed in Great Britain and there were no professional town planners’ (Bonham-Carter, 1951: 362). Howard’s concept was seen as a new and innovative style of town planning that increases its value (Morrison, 2016: 197). One of the main objects of the company stated in the Memorandum of the Association is:

> to promote and further the distribution of the industrial population upon the land upon the lines suggested in Ebenezer Howard’s book entitled ‘Garden Cities of Tomorrow’ and to form a garden city (that is to say) a town or settlement for agricultural, industrial, commercial and residential purposes or any of them in accordance with Mr. Howard’s scheme or any modification thereof (Bonham-Carter, 1951: 363).

When the company purchased the land, it was purely agricultural with a population of 400 inhabitants. Before any building was erected on the site, a noted architect and town planner Raymond Unwin and his partner Parker Bari designed the plan of the future town. They were forced to leave Howard’s concentric and symmetric model plan and sought ‘a more subtle organic sense of order as suggested by the terrain’ (see Fig. 2.16) (Fishman, 1982: 68). Following Howard’s concept of separating the town from the surrounding countryside, the land near Letchworth was divided into the central town area [1250 acres] and the surrounding agricultural belt [2,800 acres] that provided jobs and food and ‘would act as a permanent girdle to the town’ (Bradbury, 2015). In the process of defining the plan of Letchworth,
Unwin and Park took into consideration the advantages of hills, streams, an old Roman road, and even larger trees. The town was formulated at the highest and flattest point of the land where the structures of the built town were defined by the infrastructure, the railway and the road. Edgar Bonham-Carter, the chairman of the first garden city [1929-1940] claimed in the article entitled Planning and Development of Letchworth Garden City that: the plan of zoning a town into separate areas such as for residence, for shops, for factories, for civic centre and for open spaces was a new idea at that time (Bonham-Carter, 1951). Nevertheless, he was not aware of the Renaissance and Early Modern Zoning theories such as theories that were new to Great Britain and very appropriate for this form of urban planning and cooperative society that desired to have a degree of self-sufficiency (Morrison, 2016: 197). Compared with Horward’s original plan, it became apparent that the residential and industrial zones were not sufficient, so they were more spacious in the case of Letchworth Garden City than it was intended. As stated in the original plan, the industrial zone could be increased when necessary, but an increase may cause injuries to residential area. Letchworth is an industrial city, and its development and expansion primarily depended on its industries. The realization of Letchworth proceeded with difficulty. Many entrepreneurs felt that the location was not at all attractive. It was very difficult to motivate industrial manufacturers to relocate their businesses from a big city and schedule them at a certain distance from it. It is known that the industry is closely connected with a great city as a potential market and a source of labour. Industry, instead of forming a uniform periphery to Howard’s circle, was grouped into industrial park adjacent to the power plant and railroad (Bradbury, 2015). The population was not ready to leave big cities, and the garden city was colonized more slowly than what Howard thought [approximately from 30,000 to 35,000 persons]. The population of Letchworth did not significantly magnify until the Second World War, after a few settlements were added to Letchworth [1947, 1961 and 1971]. Nowadays the population of Letchworth is around 33,600 people.

The principle of community management is one of the basic principles of the garden city but it was obtained in its pure form – not fully implemented – in case of Letchworth. Suggested by Howard, the Garden city would be financed through a ‘Rate-Rent’ system which brought together financing for the community service (rate), with a return for those who financially support the development of the city (rent). Leased plots for houses and farms were rental incomes that would be invested back in the community. This means that that the citizens would be able to buy the estate after seven years and from the first Garden City Ltd under whose ownership it was first (Awan, N., Schneider, T. and Till, J., 2011:168). However, this plan was abandoned with the formulation of the company that ran almost all the aspects of life in newly formed Letchworth until 1945, when it was replaced by a public body Letchworth Garden City Corporation. Therefore, the citizens were shareholders and they had the right to say how much money would be used – in theory Letchworth was owned by citizens (Awan, N., Schneider, T. and Till, J., 2011:168). Letchworth is a unique city where the entire income from the use of land is devoted to the welfare of the local community. After more than a hundred years, the community management still broadly follows these principles.

Howard had to be satisfied with the results, although one important goal was not reached. As compromised by the need to find investment and industry, Letchworth failed to provide cheap housing for the poorest workers (Ravetz, 2003: 63). ‘The town had no room for its own building workers who had to find lodgings outside. Despite all the above-mentioned facts, the success of Letchworth is unquestionable and it might be seen in the formulation of ‘New Towns’ (Bradbury, 2015).
Despite the positive achievements with Letchworth, garden city enthusiasts did not get immediate financial support from the Government for creating the next line of garden cities. Due to the lack of support, ‘Frederic James Osborn, a colleague of Howard and his eventual successor at the Garden City Association’ spent much time ‘lobbying, lecturing and propagandizing’ the garden city concept (Waterford, 2015:82). Counselled by Howard, he recalled that: ‘...you are wasting your time. If you wait for the authorities to build new towns you will be older than Methuselah before they start. The only way to get anything done is to do it yourself’ (Orlans, 2013: 11). Frustrated by this fact, in 1919, Howard bought a land – an area of woodlands and opened fields at Welwyn in Hertfordshire, between Letchworth and London with money desperately and successfully borrowed from his friends in order to house his second garden city (see Fig. 2.17). Built on 3000 acres, Welwyn was smaller than Letchworth, half-size than it was originally proposed by Howard. Despite the limitation, Welwyn fulfilled Howard’s essential principles: ‘a rail link, town square, and parkway formed the central core of the plan, flanked by industrial and residential components, surrounded by agriculture belt’ (Pregill and Volkman, 1999:274). It was built on the experience that Howard gained through the process of creating
Letchworth. Howard and a new group of associates established a private town corporation – Welwyn Garden City Limited – to purchase and dispense the land that was selected as suitable for the second garden city experiment. This group was more ‘determined to control the inflation of land values, a condition that plagued Letchworth’ (Girling and Helphand, 1996: 57). Louis de Soissons, a Canadian-born architect designed a plan, and he lived in the town together with Howard and other directors during its development. The railway divided the town into four quadrants. It was composed of the compact town centre and a large industrial area. Each quadrants was further subdivided, each of it had a centre of its own including shops, public call and playground. Welwyn’s plan was more sophisticated than Letchworth and radically differed from the theoretical diagram of the garden city proposed by Howard. Welwyn was only some fifteen miles south of Letchworth, which was struggling into existence at that early date (Larson, ed., 1999:59).The reason why Welwyn did not become self-sustaining is that it was only 20 miles from London (Waterford, 2015:82). Welwyn was not architecturally interesting as Letchworth, but unlike it, quality housing for poor workers was provided. Since it is closer to London than Letchworth, Welwyn was growing rapidly, attracting a lot of industrial manufacturers and new families. For the same reason, Welwyn had a higher proportion of residents who daily commute to London. For some members of the Association, Welwyn was more a satellite city than a real garden city. From the big city physically separated by a green belt, the city – satellite is a lower urban form in relation to the garden city because it implies economic dependence on the central city (Pepper, 1978: 324). Marked as a middle class commuter suburb, ‘Welwyn was […] a step further from Howard’s original idealism, and a step towards the central planning of new towns that started in 1946(Hardy, 2012: 79).
2.2.2. Urban Master Plan for Tel-Aviv, 1925 [Patrick Geddes]

Fig. 2.18 Urban master plan for Tel-Aviv (1925) by Geddes
[Source: https://bcrf.revues.org/docannexe/image/872/img-1.jpg]
Tel Aviv that took shape from the mid-1920s onwards, grew according to an urban master plan of the biologist, sociologist, geographer and town planner – Patrick Geddes [1854-1932] (Welter, 2009). The plan involved building the city for 100,000 inhabitants – in 1925 there were only 25,000. The plan rested on Geddes’s 1915 synergistic concept of large-scale regional planning called a valley region or valley section (see Fig. 2.18). This concept was created out of the necessity to integrate urban and rural ways of living into a regional civilization (Welter, 2009:95). This region-city model was Geddes’s vision of the future cities that ‘evolved out of history and were not created with a single stroke or by a revolution’ (Welter, 2009:95). It was necessary to think about history, nature of place and natural geography of place when building the city explained in Geddes’s Cities in Evolution. Thus Geddes 1925 master plan was focused on both the development of modern Tel-Aviv and the preservation of its foundations created deeply in history (Welter, 2009:95). He linked together the new Tel-Aviv proposed by him with ‘the original neighbourhood of Ahuzat Bayit [later Tel-Aviv], the ancient city of Jaffa, and the latter’s outlying neighbourhoods’ (Welter, 2009:110). Geddes used the old city as the foundation from which the new one was developed. So the old city was not treated as the background separated from the new city or residues of the earlier times that were not in correlation with the new one. The city must exist through the cycle of history on which it should primarily rest according to Geddes. Both city and history exist through the memories of its inhabitants and urban planners who participate through studying and occupying the past buildings (Welter, 2009:110). This was deeply integrated into Geddes’s master plan of Tel-Aviv. The new city was built on ‘sand dunes, orange groves, and vineyards, all slated to disappear’ but it should not be seen as ‘proverbial clean state’ that is a vision of many urban planners (Welter, 2009:110). In comparison to other modern urban planners, the Geddes’s ideal city of the future became real. His multidisciplinary approach was like a way of studying human interaction with its environment.

The basic layout of his 1925 master plan was composed of North-South and East-West cross streets intersected by narrow access streets called ‘homeways’. Large North-South main boulevards, as the extension of the existing streets in the South, were the main communication arteries with the main commercial activities and five-storey buildings. Geddes called them ‘mainways’, showing that in the plan, the streets are divided into categories according to their frequency. This street grid forms large home blocks that stretch from north to south – there were 60 of them in his plan, but not all of them were built as it was previously planned. Home blocks were distinctive in design and shape, forming an instant recognition of place and home for which Geddes stood for. The orientation of the block maximized the number of lots used for domestic buildings whose front facades the west in order to capture fresh air from the ocean. For Geddes, it was necessary to provide ‘a good air circulation from terrestrial and ocean winds by limiting buildings to two or three stories, and by defining specific street widths’ (Büro für Restaurierungsberatung et al., 2015:18). This enabled all the citizens to have light and air that was necessary for each individual in the city. Each block and small-scale domestic building as a standard building type was formed around a central open space. This internal space must be used to enlarge the house plot or to provide space for a garden, a playground, or a tennis court (Welter, 2009:104). There were narrow rose and vine lanes places between neighbouring plots that the inhabitants of outer rows used to access the central space. This was Geddes’s solution against the use of fences among the neighbours’ gardens. Inspired by Howard’s Garden City idea, Geddes initially imagined Tel-Aviv as a garden city of fruit describing all private gardens, the lanes as ‘greened spaces filled with fruit trees, mulberry trees, vegetables, flowers and decorative plants’ (Welter, 2009:104). The reason for this was primarily economic, as Geddes believed that maintaining the central gardens, leisure grounds and playgrounds was much cheaper than building the streets (Welter, 2009:106). Every
centimetre of the land was carefully used, defining it as either private or public (Hertzberger, 2010:85). This involves the careful and sensitive measurement of unit depth, front and back garden, street channels in order to provide the comfort to inhabitants of the city.

A detached or semi-detached house with maximum of two storeys and a flat roof with a partial sun room was a standard building type (Welter, 2009:102). These domestic houses were used for the isolation from dust and noise, so there was no need for building high walls and fences in order to separate the house from the streets. Dwellings were formed in two rows along the outline of each block. The access of outer rows was directly from the street, whilst the minor streets that run through the block led to inner rows, encompassing the central garden. In that way, he managed to create small communities within a larger city, enabling half of all dwelling to be located in the silence of the interior of each block (Welter, 2009:102). One of the four characteristics of Geddes’s urban master plan, besides north-south and east-west streets and narrow home ways, large blocks, detached and semi-detached domestic dwellings, was a spatial concentration of cultural institutions such as theatre, museums, opera and educational institutions. Grouped together, these cultural institutions create a civic centre distinguished from the town itself. These institutions preserve the history of the place, so it is necessary to build them in close proximity that required the area to be large enough. For Geddes, every city must have a central city feature as the link between new and old parts of the city (Welter, 2009:107). The central feature of the civic centre is a hexagonal square around which Geddes envisioned ‘four-storey, architecturally unified buildings with shops and offices on the first two to three floors with apartments above’ (Welter, 2009:107).

Despite the fact that most features of Geddes’s master plan were implemented, in 1930s there was a need for some amendments and compromises due to high density of Tel-Aviv’s population caused by steady flow of immigrants. The cultural institutions were located in the area of Tel-Aviv proposed by Geddes, but their number and position were changed. These changes implied an increase in the building height and permitted the owners to build on a larger portion of their plots (Büro für Restaurierungsberatung et al., 2015:19). However, Geddes’s plan of Tel-Aviv stayed basically intact and did not lose the power over the years – although these slight amendments were applied. The importance of Geddes’s plan is in idea that it would not replace the city of the past but continue it. The idea that is still functioning well after seventy-five years shows that his urban design was developed in the right direction (Hertzberger, 2010:86).
Le Corbusier’s urban projects ‘were inextricably linked to Paris’ which was seen ‘as economic centre, national capital and hub of a colonial system’ (Curtis, 2001: 60). Paris was also interesting for Le Corbusier due to the fact that it ‘already contained a collage of earlier planning strategies’ (Curtis, 2001: 60). The idea of his projects was to solve ‘the social problems of immediate post-war years in France: the shortage of housing, the flood of people from country to town, the over congestion of traffic in Paris, the need to regenerate industry and attract foreign capital, but also accommodate radical reforms’ (Curtis, 2001: 60). He developed many of his ideas through direct observation of the city of past and present. Work on his idea of low-cost housing led him to F.W Taylor’s theory on efficiency in mass production which helped him to further develop an outline of ‘machine à habiter’ [The house is a thinking machine]. This explains Le Corbusier’s need to see the image of the city as a huge machine. In order to create a prototype of how the future city would look like, for Le Corbusier it was necessary to combine individual and community, privacy and social life, nature and city. While searching for the appropriate balance between the countryside and the city, he produced several versions of the modern city as the critique of the clogged nineteenth-century city (see Fig. 2.19):

- The Ville Contemporaine [1922],
- Plan Voisin [1925] and,
• the Ville Radieuse [1933].

Le Corbusier’s Ville Contemporaine exhibited at the Salon d’Automne of 1922 was a city model for almost three million people who would live and work in a group of identical sixty-storey tall glass apartment buildings located in a large park and encircled by lower zig-zag apartment blocks. While working on this project, he took into consideration the following elements: management, manufacturing, transport, habitation and leisure, each operating in its own zones, showing the characteristics of an industrial town in general (Curtis, 2001: 61). Upward construction with the use of steel, concrete and mass-production techniques was the way to create city density (Curtis, 2001: 61). The city plan of the Ville Contemporaine would include 24 glass skyscrapers, each 800 foot high [243.84 meters] with a cruciform in plan, lined up in a way to make a monumental unity [see Fig.2.19]. Each apartment in the tall buildings would have its own private garden. The park and unimpeded traffic would occupy the space left between the tall glass buildings. Greenery was an important component of Le Corbusier’s plan for the Ville Contemporaine, as most of the area is reserved for lawns, gardens, tennis courts, boulevards and parks (Curtis, 2001: 62). For Le Corbusier, the park presented the lungs of the city, enabling its citizens to breathe normally. Le Corbusier reintegrated country and city, creating a city with a vast park (Curtis, 1982: 165). He thought that ‘technology guided by the right framework, had the power to reintegrate people with a natural harmony’ (Curtis, 2001: 64). Striking alleyways and diseased streets of the Paris of the 1920s, noticed by Le Corbusier, ‘were replaced by a new hierarchy of circulation running from freeways for fast traffic to straight roads lined by trees in residential areas’ (Curtis, 2001: 63). In that way, the traditional street of Paris was demolished (Curtis, 1982: 165). The mechanized traffic was separated from the pedestrians by the use of pilotis, leaving the entire ground floor free, while buildings would be lifted up (Curtis, 1982: 165). The Ville Contemporaine was ‘for white-collar workers – managers and bureaucrats; manufacturing workers and lower classes were sequestered in separate areas beyond a green belt’ (Curtis, 2001: 61). The highest floors would be reserved for the city elite – philosophers, artists, businessmen and technocrats – enabling them to see the city life that would go around them. Le Corbusier believed in the elite of technocrats as they could provide ‘wealth and employment, but whose cultivation and public spiritedness were to edify the social realm and put restraints upon the chaos of laissez-faire [let it/them do]’ (Curtis, 2001: 63). Despite the fact that it is not allowed to workers to stay in the white-collar paradise, there is no class segregation. The Ville Contemporaine gives us an image of centralized power created by focal geometries and radiating axes where ‘essential’ joys of light, space and greenery were provided. So there was no need to restore the city to suburban or to decentralize it as Le Corbusier, with his anti-urban approach, did not want to waste good land. Even though Le Corbusier thought that the imaginary plan on imaginary location might be buildable, it did not attract as much attention as he wanted.

He made the next proposal for the next version of his modern city – the Plan Veisin – exhibited at the Exposition des Arts Decoratifs of 1925, ‘reminding average Parisian of his constant daily frustrations in overcrowded city’ (Curtis, 2001: 65). ‘He painted a picture of cramped, badly lit and ventilated apartments of inadequate plumbing and sewers; of hours wasted in overcrowded metros; of the lack of decent amenities for sport, recreation and relaxation’ (Curtis, 2001: 65). In order to attract more attention than his earlier city plan, he took a much more provocative approach. His proposal involved the destruction of a large part of central Paris between Montmartre and the river Seine and then its replacement with a business district of skyscrapers, cruciform in plan and surrounded by parkland (Watkin, 2005: 611). This implies that 5% of the area of central Paris would be built, while the rest of 95% would be free, creating a super density of 32,000 inhabitants per hectare (Le Corbusier, 1967: 206). This was achieved in a way that ‘acres and acres of old Paris had simply bulldozed out of existence to accommodate what was, in effect, a heavy-handed intrusion of piece of the plan of modern city’ into
an actual urban and historical setting’ (Curtis, 2001: 64). Most viewers were shocked by this idea, but at the same time, this reaction was expected as Le Corbusier’s plan for the reconstruction of central Paris was ‘a complete rebuffal of all that existed’ (Pimlott, 2007: 32). The plan included a multi-level traffic intersection that appeared ‘for the first time in the world’ [this note was added in 1964](Le Corbusier, 1967: 206). This involves segregating pedestrian paths from the roadways and creating an elaborate road network. He supported this thought with the idea that it was necessary to make a radical approach in order to decongest Paris traffic. Le Corbusier believed that ‘each age evolves its own types and that this was now the era of the skyscrapers (Curtis, 2001: 64). The cruciform glass skyscrapers that received light might be a great potential for mass-production (Scharoun, 2012:100). Groups of lower-rise zig-zag apartment blocks, set back from the street, were interspersed among skyscrapers which was not the case in his previous concept of modern city. Le Corbusier paid attention to all classes, classifying them into: rich [who would get richer through the enhancement of their land values], the middle class which would have better apartments with roof terraces and parks whilst the poor’s destiny was less certain (Curtis, 2001: 65). But the class equivalence present in his previous plan was not seen in the Plan Voisin. As no doubt Le Corbusier expected, no one hurried to implement the Plan Voisin, but he continued working on the variations of the idea and recruiting followers. This plan, like Le Corbusier’s other Paris urban master plans, always provoked debate but they were never realized.

Even though the previous projects remained un-built, Le Corbusier did not stop working on his city of the future, creating a new plan called Ville Radieuse [the Radiant City]. The plan was similar to his earlier plans – Contemporary City and Plan Voisin – but the only difference is seen in the idea that family size was a measure of a residence size rather than income and social position that were present in the previous concepts. This idea was published in his book of the same name – the Radiant City – in 1933. For Le Corbusier, it was important not only to provide better living condition for its inhabitant but to create a better society. In his search for a new kind of city, various diemmas for which he tried to find possible solutions were always present:

‘To live, to laugh, to be master in one’s own home, to open one’s eyes to the light of day, to the light of the sun, to look out on green leaves, and blue sky. Nothing of all that for the human who lives in a city (Le Corbusier, 1967: 91).

‘The world is sick. A readjustment has become necessary. Readjustment? No that is too tame. It is the possibility of a great adventure that lies before mankind: the building of a whole new world... because there is no time to be lost (Le Corbusier, 1967: 92).

Le Corbusier was wandering how anyone can live in the existing cities where there is so little light and greenery and so much noise, pollution and traffic congestions. Thus it is necessary to rebuild the cities because they ‘are too old; they are crumbling away; they are uninhabitable; they are full of lurking diseases; it is impossible to move around in them any more: traffic has reached its ceiling, and the reign of speed is leading to total immobility’ (Le Corbusier, 1967: 94). In order to solve these problems of the present cities, Le Corbusier’s city ‘is much less spread out than the present one; the distances within it are therefore shorter, which means more rest and more energy for work every day’ (Le Corbusier, 1967: 94). In other words, the city is ‘purged, contracts and raises skywards’. In this way, suburbs and dormitory towns, as the characteristic of the Garden City, would be eliminated as well as the transportation crises. The new city is arranged in a Cartesian grid as a result of the repetition that gives an opportunity to the city to function as a ‘living machine’. The population density of new Le Corbusier’s city would be from three to six times greater than it was idealistically proposed by urban authorities. The intensification of population density occurred with reason because it increases the value of the ground (Le Corbusier, 1967: 94). Population density of 3,200 to the hectare was proposed for the
business area, and around 1,000 in the residential section. Zoning is the base of Le Corbusier’s plan, clearly dividing it into the commercial, business, entertainment and residential districts. The business district made up of monolithic mega – skyscrapers constructed of steel and glass, all reaching 220-metre of height and accommodating five to eight hundred thousand people, is placed in the city centre. These skyscrapers ‘are all built in the shape of a cross in order to avoid the central courtyard: there are no courtyards anywhere’ (Le Corbusier, 1967: 132). ‘This form provides the maximum possible area of occurred, the maximum area of windows, the maximum quantity of light and the maximum of stability (Le Corbusier, 1967: 132). Impervious to all outside noise, the apartment with a sheet of glass that constitutes one entire wall provides a magnificent vista of a park, the sky and the sun. In the city centre is also located the main transportation ‘from which a vast underground system would transport citizens from and to surrounding housing districts’.10 The transportation network is the foundation of the city with the following categorization:

- classification of speeds [high speed vehicle travelling at 80 km an hour] never meet pedestrians
- creation of one-way traffic,
- high-speed vehicles must all be employed for specifically designated purposes,
- the function of heavy vehicles,
- the liberation of pedestrians (Le Corbusier, 1967: 123).

This division was necessary, as the previous ideas of the street that we already know must be abolished as wheels replaced our legs. Some of the reasons are that they became narrower and more dangerous with the speed increase and the idea that the traffic line must run directly along the houses (Le Corbusier, 1967: 124). Thus the streets that already existed in the present cities would disappear, allowing the space for parks with trees, lawns, lakes, sports grounds and playgrounds. The entire ground surface would be reserved for the pedestrians who never meet the vehicle inside the city whilst the mechanical transportation network would be created as a completely separate unit. There are cars, of course, but they would be placed in the air.

The residential district would contain the pre-fabricated apartment building known as Unité. As Le Corbusier said, ‘houses must no longer be built with stone, with bricks, with cement, with sand and water; they must be built inside, in factories’ (Le Corbusier, 1967: 96). So mass production of the individual houses would definitely bring the price down. Reaching the height of fifty meters, apartment houses would accommodate 2,700 inhabitants, presenting an idea of a vertical village. Each residential unit [Unité] would be connected with the next one, forming a ribbon of housing across the city (Le Corbusier, 1967: 113). Each apartment houses raised on pylons would enable people to move across the city in all directions. Thus houses would cover only 11.4 per cent of the surface of the residential areas, leaving 88.6 per cent opened to the sky. Sporting activities would take place directly outside the house, eliminating courtyards that usually blocked the resident’s view. The park between Units allowed the citizens to have a maximum of natural daylight, a minimum of noise and recreation facilities at their doorsteps. Fourteen square meters of floor space enabled pre occupant [average worker] to have a properly equipped home.

The Radiant City was a green city that enabled each citizen to have a room with sunlight, looking at trees and the sky. In this way, the liberty of each individual that was missing in the present city concept was achieved. The cost of living was reduced, breaking the shackles of poverty in which the present city was chained. This was the outline of the Radiant City. The dignity, action, health, serenity, and joy in

living were present in this concept. It was a gift to all the citizens provided by modern technology and the age of the cars that arrived. Le Corbusier’s radical, strict and nearly totalitarian principles closely linked to order, symmetry and standardization had an influence on modern urban planning and led to the development of new high-density housing typologies. As we can see, Le Corbusier’s ideas of proposing order together with the issues of healthy living, traffic, noise, public space and transportation is still the major concern of city planners today.
2.2.4. The Broadacre City, 1932 – 1959 [Frank Lloyd Wright]

‘The principle of architecture are simply the principles of life. Just as a house built on makeshift foundations cannot stand, so life set on makeshift character in a makeshift country cannot endure’.

Wright, The Disappearing City, 1932.11

The creation of Broadacre City [1930-1935] enabled Frank Lloyd Wright [1869-1958] to ‘pursue the subject of a new American urbanism’ (Stephen, ed., 2004:175). It was also a ‘response to Le Corbusier’s plan and was his own vision of the English garden city’ (Happen, 1998: 81). The invitation to present the 1930 Khan lecture at the Princeton University was an initial step to further develop his vision of the regeneration of the physical and social state of the present cities of America that were previously seen by Wright as ‘ugly, congested, dirty, badly administrated, and economic disaster’ (Stephen, ed., 2004:175). The idea of the Broadacre City as a concluding section was firstly rejected by the publisher in Wright’s autobiography, but ‘it is produced as a pamphlet titled The Disappearing City (Stephen, ed., 2004:175) (see Fig. 2.20) This pamphlet might be divided into two halves.

The first half explains the philosophy of the city changes that occurred and its present ills, united under five titles:

- economic [drawn from the analytical and curative ideas of Henry George]

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• suppression of human individuality
• urban concentrations and the inhuman vertical city ['The city of the future would not be vertical but horizontal' (Rybczynski, 1996:229)].
• the failure to embrace modern resources [for example, telecommunications, mechanical systems, and new building materials], and
• chaotic automobile traffic (Stephen, ed., 2004:175).

In this half of the Disappearing City, Wright anticipated the decentralization – spreading the urbanization over landscape. For Wright, ‘the crowding and verticality of dense urban core was unnatural, and he believed that centralization, brought about by industrialization and increased bureaucracy, was the antithesis of human individuality and freedom’ (Marter, ed., 2011:334). The change in creating city concept – going from centralization to decentralization – was initiated by universal automobile ownership (Barnett, 2016: 161). Thus man-movement was also utterly changed in the following ways:

• given electrification, distances are all but annihilated so far as communication goes,
• given the automatons of machinery and human labour disappears relativity,
• given mechanical mobilization, the steamship, airship, automobile, and mechanical human, sphere of movement immeasurably widens by way of comparative flight,
• given modern architecture and a human seen as the noble features of the ground.

Wright accepted these changes of man-movement, categorically refusing an idea of the present modern cities as an unnatural and inhuman environment for their citizens (Barnett, 2016: 161). The life of the city and its proportions was more humane before the arrival of universal and standardized mechanization. Urbanism became largely irrelevant with the advent of technologies such as electricity, communication, food preservation, mass production and above all, automobile (Marter, ed., 2011:334). The consequence might be seen in the formulation of the overcrowded city ‘with its traffic reduced to gridlock, its air polluted, its ghetto breeding crime and the homeless’ (Happen, 1998: 81). As Wright said, the present city, ‘in the light of our new opportunities, has become a structure in distribution and transport; a handicap in production; and imposition upon family life’ (Wright, c1932: 35) including the railroad that is ‘too limited in movement, too expensively clumsy and too slow in operation’ (Wright, c1932: 44). This happened in modern cities as the citizens are distanced from the nature, despite the fact that ‘the people are products of the nature, their health and vision depend on their roots in the earth’ (Happen, 1998: 81). If there is no nature, there is no balance, which is necessary for people’s lives. In order to restore the balance and provide a healthy alternative, Wright creates the Broadacre City in a way that people would live in the country and work in a human-scale natural environment (Happen, 1998: 81).

‘Wright’s architecture played anaesthetic role’ in the development of the Broadacre City where he did not allow the use of historicizing ornament in order to concentrate on architectural integration: ‘the site with building, the materials with the landscape, and the people with their environment’ (Marter, ed., 2011:335). He argued that ‘no free human in modern America needs to ‘box up’ or ‘hole in’ any longer for ‘protection’ in any building or burrow in any city whatever’ (Wright, c1932: 39). It is necessary to use all the available resources in power and materials that are already in our hands. These modern gifts of glass, these modern gifts of steel-in-tension, and these modern gifts of electro-magnetic science’ present a new era as soon as we start using it according to ancient principle and new form ideas (Wright, c1932: 39-40). In this way, these resources become our means for creating modern city life.
The second half of *the Disappearing City* offers some suggestions of the city rectification mostly based on Henry George’s social and economic observations and it explains the significance of individuality in contrast to the collectivism and the dominating authority of the government and church (Stephen, ed., 2004:175). Broadacre City ‘is the logical extension of Garden city ideal’ where the difference between them is made in a way that Wright’s view was mostly based on individual rather than cooperative action (Lang, 1994: 49). As Wright said, ‘we are going to call this city for the individual the Broadacre City because it is based upon a minimum of an acre to the family’ (Wright, c1932: 17) to ‘live on and farm, and home would be more than 10 mile from the workplace’ (Marter, ed., 2011:334). Wright proposed that in addition to home gardens, ‘farm life would be grouped in units of three-, five- or ten-acre farms where production is proscribed in a way that everything would be related to highway traffic markets and with the aim to produce fresh every hour (Wright, c1932:66). Each person would grow their own food on their land, which means creating completely decentralized series of small farms through the city. Farming which is closely correlated with production and sale would exist side by side with other forms of work and recreation. Factories would be split into smaller ones in order to be closer to their workers – the need to shrink the distance from home to work and vice versa. Offices would be also smaller and decentralized, as telecommunication would allow many people to work from home.

All this caused the change of the scale of spacing, from the idea that ground space was reckoned by the square foot in the City of Yesterday to the ideas that it is measured by the acre – an acre to the family – in the City of Tomorrow – the Broadacre City (Wright, c1932: 43). The measurements would be made according to ‘the human seated in his motor car with its powers being the unit of that standard rather than the human standing on his legs or his limitation in a trap hitched to a horse’ (Wright, c1932: 54). This is a new standard of measurements in the planning of the new city. Wright also did not accept an idea of curving streets of American and English garden suburbs design, proposing lower density (Barnett, 2016: 161). The city plan was divided it into five zones [see Fig.] grouping mostly similar uses of land:

- industrial and mercantile land use of small factories and roadside markets,
- agricultural uses of land – principally owned by small farmers,
- residential uses of land interspersed with elementary schools – the largest section
- civic and cultural uses of land including sport facilities, clinics, county government, and services, theatres and institutions of higher education,
- recreational uses of land – almost a green belt interspersed with larger and most expensive houses (Shumsky, 1996:116).

For Wright, arranging and integrating the diversified land uses was necessary in order to provide ‘all forms of production, distribution, self-improvement, enjoyment’ to the citizens ‘within a radius of a hundred and fifty miles of his home now easily and speedily available by means of his car or his plane’ (Wright, c1932: 44). This makes it possible only if we imagine spacious landscape highways and great highways. Spacious highways are without grade crossing, ‘by pass’ living areas, telegraph and telephone poles and wires, blazing bill boards, while the great ones are ‘safe in width and grade, bright with wayside flowers, cool with shade trees, joined at intervals with fields from which the safe, noiseless transport planes take off and land’ (Wright, c1932: 44). Thus broad and safe highways, together with automobiles would be the most important components responsible for modern urban sprawl.

Housing was ‘a heart of the Broadacre City project’ (Stephen, ed., 2004:175). ‘Usonian house’ (Wright, c1932: 32) was a basic residential unit where ‘the home would be an indoor garden, the garden an outdoor house’ (Wright, c1932: 44). ‘Instead of concentrating people in the apartment’s blocks, the
Boradacre City dispersed them in individual houses on one-acre lots (Rybczynski, 1996: 229). The Broadacre city plan was made for an imaginary site where each city and village might correspond to this unique environment (Stephen, ed., 2004:175). In his own word, the city proposal was to be 'everywhere or nowhere' (Shumsky, 1996:116). It is a 'schematic representation of a relatively low-density continuous urban area' (Shumsky, 1996:116). This means that centralized facilities such as single dominant industry, cultural quarter, railroad station and airport were avoided [except the university as collective functions] (Pearman, 2004:87). For instance, the great railway station, as a form of centralization, would have gone as they would be no longer possible and desirable, and instead of that there would be more minor stations in the Broadacre City (Wright, c1932: 51).

The model of the Broadacre city, as a prototype of 4 square mile section, was designed as 'a modulator for the convenience and for the flexibility of future development' (Happen, 1998: 81). Twelve-foot-square model of what the city might look was exhibited at Rockefeller Centre in April-May 1935, together with displayed panels with illustrations and texts and several models of possible buildings [see Fig. 2.10]. It could accommodate 1,400 families, where overall density would include almost two acres per family, even though one-third of area was devoted to non-residential land uses (Shumsky, 1996:116). As we can see, Wright accurately predicted:

'Many of the aspects in which modern life has been affected by universal car ownership'. He foresaw increased traffic congestion in urban centres, and superhighways he proposed more or less came into being. His preference for horizontally and his proposal to build outwards rather than upwards have been realized in what is now termed 'sprawl' (Marter, ed., 2011:335).

Wright thought of the Broadacre city in the last twenty years of his life although his project remained unrealized and most of architecture critics refused to take his ideas seriously. But most of things proposed by Wright are familiar to us today.

2.2.5. Urban Diversity, 1961 [Jane Jacobs]

In her book The Death and Life of Great American cities published in 1961, Jane Jacobs discussed an idea of 'how cities work in real life?', trying to 'learn what principles of planning and what practices in rebuilding can promote social and economic vitality in cities' (Jacobs, 1961:4). Death mentioned in the title of her book is caused by the elimination of pedestrian activities. Instead of that, it created high-way constructions and large scale and low-income projects that 'became worse centres of delinquency, vandalism and general social hopelessness' (Jacobs, 1961:4). The term life involves the presence of the pedestrians all the time during the day that Jacobs was trying to achieve by creating 'sidewalk ballets' as a way to describe the complex interactions on the city streets. All of this is actually explained in order to find a way how to promote city life. In her opinion, city problems lay in the fact that 'nobody cared what the citizens need' (Jacobs, 1961:15) when building the place, when creating isolated and unnatural urban places that gradually and slowly destroy city communities and economies. Among the principles already used to build the city, she took into consideration urban renewal as the principle that kills economic diversity and the separate use [residential, commercial and industrial] that is most common in the process of city planning. In order to avoid these principles, the cities have to be laboratories on the basis of which city planning should form and test its theories (Jacobs, 1961:6). Not all the cities are lively and bustling, there are some which are lifeless. In other words, 'cities are natural generators of diversity and prolific incubators of new enterprises and ideas of all kind' (Jacobs, 1961:145), but not universally so. Jacobs attempted to find a solution for this by proposing four indispensable conditions to generate diversity city districts:
1. **Mixed land use:** ‘The district…must serve more than one primary function; preferably more than two. These must insure the presence of people who go outdoors on different schedules and are in the place for different purposes, but who are able to use many facilities in common’,

2. **Small blocks:** Most blocks must be short; that is, streets and opportunities to turn corners must be frequent

3. **Buildings from many different eras:** ‘The district must be mingled buildings that vary in age and condition, including a good proportion of old ones so that they vary in the economic yield that they must produce. This mingling must be fairly close-grained’

4. **Sufficient building densities:** ‘There must be a sufficiently dense concentration of people for whatever purpose they may be there. This includes dense concentration in the case of people who are there because of residence’ (Jacobs, 1961:150-151).

All four conditions in combination are necessary to generate city diversity composed of different people with different tastes, skills and needs, while the absence of any of them would decrease city potential (Jacobs, 1961:151). Thus the city would provide ‘a variety of cultural opportunities, a variety of scenes and a variety in its population and other users’ (Jacobs, 1961:148). In that way, the city would satisfy the needs of each citizen.

**Mixed land neighbourhoods with commercial, residential and industrial buildings** enable the vibrancy of the streets during the different parts of the day, preventing the existence of ‘the streets that are busy part of the time and then empty abruptly’ (Jacobs, 1961:35). This is possible to achieve if the streets have the following qualities:

- **an effective demarcation between public and private space**
- **basic supply of eyes and activities:** ‘there must be eyes upon the street, eye belonging to those we might call the natural proprietors of the streets. The buildings on a street equipped to handle strangers and to ensure safety must be oriented to the street.
- **more users: The sidewalk must have users** on it fairly continuously, both to add to the number of effective eyes on the street and to induce the people in buildings along the street to watch sidewalks in sufficient number (Jacobs, 1961:35).

It is important to attract different people [company employees, residents and visitors] to use the streets at different time for different purposes because the used street is the safe one. This creates the trust between the users of city streets. A certain residential and business district should not be reserved only for its residents, but should provide activities that would attract more visitors, as well as workers to come back after the end of the workday. So mixed land uses both primary [dwellings, offices, factories, entertainment, education and recreation…] and secondary [enterprises developed according to primary use] bring people in and out and puts them on the street at the same time.

For Jacobs, there is a need to create **small and pedestrian-friendly blocks and frequent streets** as the existing super long blocks reduce the number of people who decide to walk, preventing the creation of economically vibrant and mixed-use neighbourhoods. People would always try to find an extra passage into those too long blocks. Jacobs discussed the consequence of the long blocks in the following way:

> …they are apt to thwart effective mixture…they automatically sort people into path that meet to infrequently, so that different uses very near each other geographically are, in practical effect, literally blocked off from one another(Jacobs, 1961:181).

Thus long blocks, in their nature, reduce the potential of the city, offering only isolation, separation, small or special enterprises. The isolated district street neighbourhoods created by forming long blocks
should be eliminated mostly due to the need to prevent the people from exploring them and constrict economic effects. They need to be mixed with each other to provide more possibilities to each pedestrians that ‘bent on different purposes, appearing at different time, using the same street’ (Jacobs, 1961:181). Small/short blocks are exhilarating, they enable pedestrians to interact with one another, encouraging the opening of new business and giving the area the diversity character. They decrease a travel distance that results in the appearance of more intersections and slows down cars. Multiple routes to choose are offered to each human in the city, instead of using the same path to a given destination – a monotonous walk. The increase of the routes available for each citizen leads to the creation of more feasible spots for commerce – reason to walk and explore the blocks. Relatively dense environment that includes between 100 and 200 dwellings per acre also increases the number of pedestrians on the sidewalks and eyes on the street. So in that way ‘neighbourhood would literally have opened’ to each pedestrian on the street thanks to the development of foot traffic and commerce pedestrians.

Cities need old buildings such as ‘museum piece old buildings, not old buildings in an excellent and expensive state of rehabilitation’ (Jacobs, 1961:187). The existence of only new buildings in the city means that they are reserved only for those who can support the high costs of new constructions. To have a city either with old or new buildings is a complete failure. Jacobs explains the need for the mix of the old and new buildings and types that cater to high- and low-rent tenants in the following way:

Chain stores, chain restaurants and hanks go into new construction. But neighbourhood bars, foreign restaurants and pawn shops go into older buildings. Supermarkets and shoe stores often go into new buildings; good bookstores and antique dealers seldom do. Well-subsidized opera and art museums often go into new buildings. But the unformalized feeders of the arts – studios, galleries, stores for musical instruments and art supplies, backrooms where the low earning power of a seat and a table can absorb uneconomic discussion – these go into old buildings (Jacobs, 1961:188).

This shows that ‘old ideas can sometimes use new buildings’ but ‘new ideas must use old buildings’ (Jacobs, 1961:188). Buildings should be mixed with regard to age and types in order to ensure diverse economic activity and promote coexistence of high-low-income residence & jobs.

Cities must have a sufficiently dense concentration of people in order to create the critical vital mass. The concentration of people involves not only the people who live in the district and form a large share of the people who use its streets, parks and enterprises, but other users, who work and visit a district for entertainment, might also contribute significantly to concentration (Jacobs, 1961:201). It is necessary to supplement the district with other uses, for instance, to have enough buildings to go to, in order to attract the people who live outside the district to visit it, spreading on the streets through the different hours of the day. High/dense dwelling density has a bad name in planning theory because of the fact that the terms high density and overcrowding of dwellings are in most cases confused. High density means large number of dwellings per acre of land, while overcrowding refers to too many people in a dwelling for the number of rooms it has (Jacobs, 1961:205). According to this, high density has nothing do with the term overcrowding. Thus a dense and diverse concentration of people is necessary to offer a decent chance to develop city life.

Flourishing city diversity proposed by Jacobs involves the combination of mixed uses, small blocks, frequent streets, and a mixture of buildings of all ages and types and the dense concentration of the users. Term diversity usually looks ugly (Jacobs, 1961:223). The reason for that lies in the fact that city diversity is messy in appearance in comparison to places imprinted with homogeneity of uses that looks much better (Jacobs, 1961:223). The monotony and repetition of sameness is not leading to anywhere,
as for instance, the north is the same as south or east as west (Jacobs, 1961:223-224). This is a kind of chaos as it is difficult to orientate in the place and make a difference between the same or similar parts of the cities. This might be one of the reasons, why Jacobs propagates urban diversity.

2.2.6. Status of Urban Concepts

All the above-mentioned concepts of urban design will be surmised in this section, beginning with Howard’s idea of the Garden city as a base for the further development of other concepts and possible solutions to problems caused by the creation of industrial city. Despite being highly influential – further developed across the world and had impact on future urban planning – Howard’s ideas were implemented only in two real garden cities in Great Britain – Letchworth and Welwyn garden cities. ‘Other developments, such as Hampstead Garden Suburb, turned into blends of garden city and conventional suburbs’ (Girardet, 1992:54). The need to reform land initiates the creation of a concept of communal ownership - and move working classes from high-density cities to lower density suburban settlements. This became Howard’s legacy (Couch, 2016: 29). The idea was to ‘dismantle the existing conurbations’ and replace them with a group of smaller, separate cities but socially and economically integrated ‘garden cities’ built at low densities and incorporating a large area of green space’ (Couch, 2016: 29). Howard’s approach was not anti-urban, as he believed that the industry is an integral part of city life and prosperity (Pile, S., Brook, C. and Mooney, G., 2006:230). Even though garden city concept had a clear definition, it is misunderstood and misused even today and identified with the idea of green suburban areas (Stenholm , 2015:96). Garden suburbs are contrary to Howard’s idea of garden city – they are ‘built of the outskirt of the city without any selections of industry’ and ‘dependent on reliable transport, allowing workers to commute to the city’ (Waterford, 2015:84). Garden suburbs were not a part of Howard’s plan. In his introductory essay to Garden City of Tomorrow Lewis Mumford said that: ‘Garden city is not a suburb but the antithesis of a suburb: not a rural retreat, but a more integrated foundation for an effective urban life (Waterford, 2015:84).

There are some problems with Howard’s concept. The strict control of further development of garden cities would be necessary in order to limit the size and population density of these cities and their spread to surrounding farmlands (Frey, 2003:78). The physical limitation – railway – would ‘destroy the functional and environmental balance between the city and its hinterland’. This might result in a limited number of services and facilities in each independent city because there is no higher-level unity between them and the provision centre. In addition, this would decrease the quality of life in garden city.

After the realization of garden cities – Letchworth and Welwyn– and in the second half of the twentieth century, Howard’s influence declined, because life in the garden city had many shortcomings such as:

- public transport was expensive and insufficient due to the low population density;
- local industries did not manage to secure employment for all residents, and many of them travelled to work in larger centres;
- insufficiently developed mechanisms to protect against monopolies.

His theoretical and practical contributions to urban planning were important, but he could not stop the appearance of extreme urbanisation. In the industrial city, the concentration of population and capital is still noticeable. The gravitational force of the metropolitan centre of the economy aimed at making money, with the ultimate goal of trade with high rents and expensive overcrowding was misunderstood during the process of suburbanization (Mumford, 1968). London congestion is not reduced, but more than two million people in English ‘new cities’ live in very good housing and environmental conditions.
Howard’s concept has undoubtedly had a significant impact on the valuable judgments of experts, especially on raising environmental awareness of individuals. The concept of garden city is a variant of the ‘sustainable city’ (Pušić, 2001: 206), which also includes the limitation to growth, the functional structure of organization, the ecological balance, the concept of the public good and public interest, the developed civil society, and the citizens’ participation in decision-making. The principle of sustainability in the planning and the development of cities (Río, 1992) is a regionalist idea whose essential characteristics are local autonomy and decentralization. Howard’s holistic approach consistently fits into the concept of sustainable development. In addition to environmental, it also includes social, economic, political and cultural aspects and we can say that the idea of the garden city was much more than a utopian vision.

Inspired by Howard’s concept of the Garden City, Geddes created 1925 Urban Master Plan of Tel-Aviv as his own way to integrate city with nature. Many urban planners of that time treated an unbuilt area as clean, empty and free for any intervention. Geddes observed the future area of possible construction of Tel-Aviv in different ways. For him, Tel-Aviv would be integrated into ‘sand dunes, orange groves, and vineyards’, showing us that nature was a part of the city and still is (Welter, 2009:110). As he integrated the city with nature, he perceived the need to create the link between the old and the newly built Tel-Aviv. This was achieved in a way that the civic centre was formed around a hexagonal square which presented the connecting element between the old and the newly built city. By establishing the above-mentioned relationship, Geddes enabled that each citizen is entitled to sun, vista and fresh air. This was possible by the creation of large blocks in South-North direction, with two rows of buildings limited height. These blocks protected the citizens from noise and dust. The central place of each block was the park that created an intimate relationship between the neighbours who avoid making fences and walls between them. Unlike many urban concepts, Geddes’ urban master plan of Tel-Aviv was implemented with small amendments, showing the good direction of the development of his idea.

Le Corbusier worked on his famous concepts of the vertical city [The Ville Contemporaine [1922], Plan Voisin [1925] and, the Ville Radieuse [1933]] for many years. In order to improve these concepts, he used radical, unpredictable and usually contradictory attitudes. In that process, he was fascinated by machines and traffic, while constantly examining the relationship between nature and city. This relationship was achieved in a way that he left the entire ground floor free in order to enable the space for lawns, gardens, tennis courts, boulevards and parks. Instead of the horizontal expansion of the city, he decided to build dominant glass skyscrapers whose ground floor was free [as the skyscrapers were built on pilotis]. The base of Le Corbusier’s plans was the clear division of city function into commercial, business, entertainment and residential districts, which were mutually connected by traffic network. This was the principal meaning of the Athens Grapher from 1933. This division was in function to enable each citizen to enjoy sun, fresh air, vista and silence, protecting him from little light, the lack of greenery, enhanced noise and traffic congestion. With the intention to achieve the previously set up aims, he had a radical approach to destroy the already existing part of the city in order to build a new one in that place. The reason for this is that he believed that old cities could be healed by urban reconstruction. In that process, he was also arrogant, ignoring the need of citizens to be involved in city planning. In that way, he broke the relationship between the cities of the past and the newly created ones. The same thing happened with the traffic, where he solved it separately from the function of the buildings that were supposed to be serviced by it. In order to shorten the travelling time between home and work, he gave advantage to cars, forgetting the distances that had to be crossed by the pedestrians. These were some of the disadvantages because of which his projects remained unrealized.
Frank Lloyd Wright noticed that American cities of that time were 'ugly, congested, dirty, badly administrated, and economic disaster' (Stephen, ed., 2004:175). The reason for this might be seen in: economy; the suppression of human individuality; urban concentration and inhuman vertical city; the failure to embrace modern resources and chaotic automobile traffic (Stephen, ed., 2004:175). In order to improve the concept of these cities, he thought that European concept [Le Corbusier’s vertical city] was not applied here. So he suggested the development of American cities horizontally. Instead of urban centralization, he anticipated the decentralization – spreading the urbanization over landscape. This was his version of English garden city with the aim to preserve the independent life spirit of American farmers. He was aware of the fact that the citizens were distanced from the nature. Because of that, he wanted to correct this fact, showing that ‘people are products of the nature; their health and vision depend on their roots in the earth’ (Happen, 1998: 81). All this happened as man-movement was utterly changed with the improvement of industrialization, electrification, traffic mobility and modern architecture. This initiated the creation of new measurements in the planning of the new city. The measurements were made in accordance with the human seated in his motor car but not as it used to be in the past ‘the human standing on his legs or his limitation in a trap hitched to a horse’ (Wright, c1932: 54). This caused the creation of broad and safe highways around which the cities were created. The concept of horizontal city was composed of five zones: industrial, agricultural, residential, civic and cultural and recreational (Shumsky, 1996:116). The Broadacre city plan was made for an imaginary site, which has never been realized.

Jane Jacobs’s book entitled The Death and Life of Great American cities was significant in the process of urban city planning and its renewal as it clearly defined two terms death, with which the cities of that time were faced. She defined the term life through the presence of the pedestrians all the time during the day. Opposite of life is the death that she explained through the elimination of pedestrian activities. In that way, she searched for possible ways how to promote city life. In her opinion, the main problem is that ‘nobody cared what the citizens need’ (Jacobs, 1961:15) when building the place. This resulted in the creation of isolated and unnatural urban places that gradually and slowly destroyed city communities and economies. The factors that might contribute to that, according to Jacobs, are urban renewal as the principle that kills economic diversity and the separate use [residential, commercial and industrial]. In order to resolve the above-mentioned problems, she proposed four indispensable conditions to generate the diversity of city districts: mixed land used; small and pedestrian-friendly blocks and frequent street; buildings from many different eras and sufficient building densities. Mixed land use provides the vitality of the street during the different parts of the day. Small and pedestrian-friendly blocks and frequent streets enable pedestrians to interact with one another, encouraging them to walk and explore economically vibrant and mixed-use neighbourhoods, while long blocks offered isolation, separation, small or special enterprises. The link between the old and the new parts of the city was indispensable in order to exchange ideas and encourage the vitality of everyday activities of city life as well as the integration of different social groups. In urban practice, the terms are often wrongly understood as high density and overcrowding. High density means a large number of dwellings per acre of land, while overcrowding refers to too many people in a dwelling for the number of rooms it has (Jacobs, 1961:205). All these conditions have to be used together in order to enable the city to have the diversity that Jacobs talked about.

By summarising the above-mentioned concepts of urban design, we understand that the researchers were focused on their own ideas while searching for the ways to humanize the city. In this process, they neglected open public spaces which are meeting places on a daily basis. Activating these spaces created the need to form the community that can improve the quality of life. In urban practice these spaces are
usually considered as spaces for everyday communication, so for this reason they are neglected and without spatial design. For the citizens, these places are important as they enable them to meet and communicate with other people, initiating the need for talks about actual social issues and common aims in order to improve their life space. Urban planners did not perceive this human component and they excluded it from the process of urban design. Open urban space is an important connecting element of the mixed functions in the city, offering its potential to the citizens.

2.3. Urban Practice Principles based on Ecosystem Services

In this section, the urban principles of blue and green infrastructure and BGD urban planning framework will be researched. Analysing urban principles helps to perceive the problems and missed opportunities in order to transform them into potentials – benefits – for ecosystem development in the future. During that process, we search for practical and innovative solutions that could improve the sustainable development of the city and region (territory) and make them resilient to climate extremes. The subject of the research involves the development process of blue infrastructure (from traditional principles via Sustainable Urban Drainage System (SUDS), Water Sensitive Urban Design (WSUD) to sponge city) and the effects of green infrastructure (that is supported by blue component) and BGD urban planning framework. The aim of this research is to discover the new ways of urban design that will provide a comfortable and healthy life of the people in the city and region in a more natural way. The conducted research enables us to expand our cognition of urban principles in order to apply the BGD vision in the practice.

People used and still use the capital of nature (ecosystem). The term ecosystem implies that it is ‘a dynamic complex of plant, animal, and microorganism communities and the non-living environment, interacting as a functional unit’ (MA, 2005, 49). A human being is always a part of an ecosystem. In order to define an ecosystem properly, it is necessary to make a strong relationship between its components and a weak relationship between its boundaries. The encounter of many discontinuities is called a useful ecosystem boundary. In order to use properly the benefits obtained from an ecosystem, we have to find their common name. The concept of ecosystem services is relatively recent, firstly used in the late 1960s (King 1966; Helliwell 1969). Research conducted on ecosystem services has grown rapidly within the last decade (Costanza et al. 1997; Daily 1997; Daily et al. 2000; de Groot et al. 2002). Costanza and his colleagues (1997) considered natural and human-modified ecosystem as the sources of ecosystem services. Daily used term ‘services’ to explain that it is necessary to ‘encompass the tangible and the intangible benefits that human obtain from ecosystem, mostly seen separately as ‘goods’ and ‘services’’ (MA, 2005:55-56). It was easier for understanding to use terms ‘goods’, ‘services’ and ‘cultural benefits’ separately. Millennium Ecosystem Assessment 2000 united all these benefits into one term - ecosystem services. As it was hard to define whether benefits provided by an ecosystem are ‘goods’ or ‘services’, MA defines ecosystem services as the benefits that people obtained from an ecosystem. This definition was derived from the two common references and representative definitions (MA 2005, 53-54):
1. Ecosystem services are the conditions and processes through which natural ecosystems and the species that make them up, sustain and fulfil human life. They maintain biodiversity and the production of ecosystem goods, such as seafood, forage timber, biomass fuel, natural fibre, and many pharmaceuticals, industrial products, and their precursors (Daily 1997: 3)

2. Ecosystem goods (such as food) and services (such as waste assimilation) represent the benefits human populations derive, directly or indirectly, from ecosystem functions (Costanza et al. 1997, 253).

The MA has created a well-known categorization of ecosystem services that is accepted by TEEB and UK Environmental Agencies [EA]. They have divided all the ecosystem services into four groups (see Fig. 2.21):

- **provisioning services**, which refer to the ecosystems’ ability to generate essential goods such as timber, fuel, food and fibre;
- **regulating services**, which refer to the regulation of climate or the water cycle;
- **cultural services**, which provide humans with recreational, spiritual and aesthetic values;
- **supporting services**, such as pollination, population control, soil formation and other ecological properties upon which life depends - Millennium Assessment (MA), 2005.

Provisioning services, regulating services and cultural services have a direct influence on people, while supporting services are necessary for the maintenance of the previously mentioned services.

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**Ecosystem Services classification**

by TEEB & MA:

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![Ecosystem Services classification](image)

- **Provisioning Services**: food, water, timber, fuel
- **Supporting Services**: soil formation, photosynthesis, nutrition, cycling
- **Regulating Services**: affect/climate, flood, diseases, regulating/waste, water quality
- **Cultural Services**: recreation, aesthetic, spiritual benefits

Fig. 2.21 – Ecosystem services

Ecosystem services can be used to describe the connections between nature and human welfare (Millennium Assessment, 2005). Humankind health and well-being depend on services provided by ecosystems and their components: water, soil, nutrients and living organisms. They support and improve the quality of life and without them, the planet Earth would be uninhabitable. Fig. 2.22 describes how strong the relationship between the categories of ecosystem services and components of human well-being is. In order to make this relationship function, socioeconomic factors which are supposed to mediate this relationship should not reduce the potential of ecosystem services and well-being. In other words, this means that if the potential of ecosystem services is reduced, we have to exchange it with another system or we have to compensate it with the services from other categories. In that way, the intensity of the relationship between ecosystem services and human well-being remains unchanged i.e. it does not affect the socioeconomic relationship. It is evident in the figure that the strength of the relationship and the potential of mediation are applied differently in diverse ecosystems and regions.
The ecosystem is usually made of a number of various regions such as natural forest, costal and irrigated agriculture, wetland and urban areas (see Fig. 2.23). Any region of Earth produces a number of services which affect human well-being (Millenium Assessment, 2005: 61). The use of the various strategies and invovations influence the quality and quantity of the capacity of the ecosystem services. This means that ecosystem services recive the flow of energy, water, nutrions, pollutants, species introductions, migration and dispersal from the regions with which they have connections and release these regions from the materials which they have in themselves.
Biodiversity as 'the variability among living organism' is a part of an ecosystem and is the source of many ecosystem goods, such as food and genetic resources (Millenium Assessment, 2005:49). The changes that occurred in biodiversity might influence the supply of ecosystem services. In other words, every change in the number of species and goods means the reduction of the quality of ecosystem services. There are indirect and direct drivers that influence biodiversity. The indirect drivers of change are demographic, sociopolitical, scientific, technological, cultural and religious (upper right corner of the Fig. 2.24) that led to changes, directly influencing the ecosystem services such as: changes in local land use and cover, species introduction or removal, technology adaptation and use, external inputs, harvest and resource consumption, climate change and natural, physical and biological drivers (lower right corner of the Fig. 2.24). The changes of ecosystem services affect human well-being.
Fig. 2.24 Human well-being, Ecosystem services, Indirect drivers of change and direct drivers of change [Source: MA Report, 2004]

However, our dependence on these ecosystems has not prevented us from stressing them and reducing their capacity to meet our needs (Millennium Assessment, 2005). If human pressure on the ecosystems exceeds certain thresholds, ecosystems may flip to an alternative stable state. We have to ensure that human activities, urban planning and urban development do not place ecosystems at risk. Robert Solow (Solow, 1974; Costanza and Daly, 1992; Cleveland and Ruth, 1997; Gómez-Baggethun et al, 2010; Honey-Roses, 2012) said:

‘If it is very easy to substitute other factors for natural resources, then in principle there is no ‘problem’. The world can, in effect, get along without natural resources, so exhaustion is just an event, not a catastrophe’.

Research of ecosystem services took off because it held the potential to tie together the ‘development’ and ‘conservation’ objectives (Honey-Rosés, 2012). Ecosystem services could be seen as a new way of talking about an old idea. However, the advocates of research into ecosystem services suggest that the conceptual frameworks used in the past are insufficient to manage ecosystem services today (Daily and Matson 2008, Liu et al. 2010). Grey infrastructure in all major cities presents a good example. Previous
great engineering solutions are insufficient today because of their monc-cultural character. Modern society needs a new multi-cultural approach in order to deal with the uncertainty of climate changes. Ecosystem services based approach is bringing together ecosystem beneficiaries with ecosystem service providers, and promising to open up new opportunities for conservation. This is highly recognized and accepted by conservation organizations to advance their goal of habitat conservation. However, their application in urban and developed areas remained scant (Grant, 2012).

Honey-Roses argues that there are mainly two factors that limited the application of the ideas about ecosystem services (Honey-Rosés, 2012). Researchers ignored the opportunities to find and exploit ecosystem services in urban and technologically advanced landscape and thus have not dedicated sufficient attention to studying the demand for ecosystem services.

Biologists developed the notion of ecosystem services, and it was often viewed that in urban areas technology can substitute for services previously obtained by nature. In urban areas, priority was given to the engineering systems. It is agreed that there is no necessary exclusion between these human and naturally made ecosystems. Rather, the new technologies could be complementary to ecosystem management. Sometimes the value of ecosystem services co-evolves with technical increase. Finally, new technologies and engineering structures can generate only more reliance on the ecosystem services, not less.

Technology has always been meditating the relationship between humans and natural ecosystems and the services they provide. It has been used to improve social and economic life by maximizing the exploitation of all benefits that ecosystems can provide. In order to enhance agricultural production, Egypt used an irrigation system to harvest water from the Nile. For the same cause, mechanization is used in agriculture. Unfortunately, technology is too often seen as a suitable substitute for natural services. The difference between technologically driven-engineering monc-cultural solutions and multi-functional natural ESS-based solutions shows that technology cannot and should not replace nature (Maksimović, Božović & Živković, 2014). Ecosystems provide many services simultaneously, while technology is usually designed for only one problem. Nature has been hailed as financially superior due to lower capital investments and lower maintenance costs (Chichilinsky and Heal, 1998).

The assessment of the ecosystem, the supply of ecosystem services and their relationship to human well-being require an integrative approach. Ecosystem services, as a link between nature and human welfare, enable decision-makers to make city life more sustainable. In that way the services would have the highest value or those which are reduced would create a sustainable link that is sustainable. Taking into consideration the specificity of the city complex and ecosystem – nature, this research explores the ways of coordinating Ecosystem services and optimizing their synergy effects on people and city life. Ecosystem services are the staring point for the further simulation, analysis, testing, modeling and making the experiments of urban practice principle. This will be explained in the following section.

2.3.1. Sustainable Urban Drainage System and Water Sensitive Urban Design

Before the creation of the Sustainable Urban Drainage System (SUDS) in the city development (see Fig. 2.26), there were other city concepts for the supply of water such as water supply city (hydraulic supplying), sewered city (supplying by the use of separate sewerage schemes) and drained city (supplying by the use of drainage channelization) (Maksimović, Kurian and Ardakanian, 2014).
Sustainable Urban Drainage System (SUDS) is an alternative to the above-mentioned traditional drainage systems designed to efficiently manage the drainage of water into urban environment. SUDS is created from the need to solve the current problems of insufficient and separated central drainage systems that present-day cities deal with. Increased urbanisation and the constant expansion of the city at the expense of green areas additionally burdened the traditional drainage systems, as surface water does not have possibility of absorption into the soil. If we add to this the influence of climate changes with a higher intensity of rainfall, the risk of flooding is increased, causing various damage. Besides storms, there are long and dry periods that cause the problems of water security and water quality (Pötz and Bleuze 2012). The problem of the traditional system is seen in removing the surface water from the site as quickly as possible, without thinking that this might harm our water resources and cause numerous negative impacts such as:

- **quantity issues**—when it is necessary to prevent local flooding and move it away from the place where runoff falls by the use of underground pipe systems
- **increased downstream flood risk** because the river channels are too small to deal with
- **the erosion of riverbedsand deepening of riverbanks** caused by the increased flows (the riverbeds and river banks became unable to receive water that leads to the need to straighten the rivers and place them into concrete channels or bury underground into culverts),
- **destruction of aquatic habitat** (number of aquatic plants and animals in watercourses) because of polluted surface water

- **pollution of water courses** caused by the overflows of combined sewer system (this allows sewage to spill into water course during heavy rain)
- **lowering of ground water table and soil subsidence** caused by the lack of infiltration of water into ground
- **full capacity of pipes** – work in full capacity and are unable to receive additional flow

Figure 2.27 shows the traditional urban drainage systems with and without wastewater treatment plants. On the left side we can see how untreated water (as a bend of raw sewerage and storm runoff) is released to surface waters (rivers, ponds, lakes...), causing environmental degradation, while on the right side we can see the percentage of water that belonged to waste water (sewage water) which is purified through the use of treatment plant.

![Components of an Urban Drainage Catchment](image)

**Fig. 2.26: Traditional urban drainage systems with and without wastewater treatment plants [Source: BGD Project, 2012]**
SUDS can significantly reduce the harms caused by the traditional drainage systems to our water course and improve the built environment by moderating flows and filtering run-off. This was necessary, as we have treated runoff water as a waste for such a long period. Traditional water management by using the elements of the urban water system as isolated services, led to an unbalanced urban ‘metabolism’ (Novotny, 2010). In the traditional approach, little attention was given to water quality and amenities/biodiversity as it is important that the surface water is conveyed away from the cities in a short period of time in order to prevent flooding. This approach is only preventive with poor sanitation. The SUDS philosophy is to mimic the natural drainage of the surface water. This system is designed to make the balance between the benefits obtained from water quality, water quantity and amenities/biodiversity. The overlap of these benefits is known as the SUDS triangle (See Fig. 2.28).

![Fig. 2.27 The traditional approach](Sources:S2usdrain website, http://www.susdrain.org/delivering-suds/using-suds/background/sustainable-drainage.html)

![Fig. 2.28 The SUDS triangle](http://www.susdrain.org/delivering-suds/using-suds/background/sustainable-drainage.html)

SUDS system is more sustainable than the traditional one, which can be seen in the following characteristics:

- reduction of the flood risk in urban areas by controlling runoff volumes and flow rate from hard surface
- creating the condition for the use of runoff at the place where it falls
- water quality improvement through the filtration of runoff
- protection of natural flow regimes in watercourse
- understanding the needs of local community, respecting the environment
- preservation of the habitat of wildlife in urban watercourses
- creating the opportunity for evapotranspiration from vegetation and surface water
- recharge of natural groundwater/aquifer
- improving the place where we live, work and relax

By making the balance between different opportunities and challenges, we create the sustainable development and a better place for living. In order to achieve that, it is necessary to use the integrated

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measures employed in the SUDS Scheme known as the SUDS Management train.¹⁵ These measures taken together enable the control volumes of runoff and reduce the pollution before discharge. The aim is to mimic the natural catchment process. The whole process involves four measures such as prevention, source control, site control and regional control. Under the term prevention we mean the good design of the environment in order to minimise runoff and pollution level. Source control, as the second measure, means that green roofs, soak ways, rain gardens and permeable pavements are used at or very near the source of runoff. This shows that collected runoff might be used again as grey water that reduces the need for the use of drinking water from the system. The third measure called site control mean that in the local area or site we direct water from building roofs and car parks to soak ways or infiltration areas. This is a preventive measure of keeping the runoff in swales in order to create more space in the balancing pond in case of storms. The last measure is the regional control that involves the effective management of runoff from the site or several sites, which results in creating the balancing bonds or wetlands.

SUDS solves the problem of drainage water in a way that it offers monoculture solution by creating the swales and the balancing ponds where runoff would be kept. Water Sensitive Urban Design (WSUD), as the integral part of SUDS has a multifunctional approach, integrating water into urban planning in order to get more benefits from SUDS solution that has only engineering character. Key concepts and principles are the same for both systems. While SUDS was only used in the UK and Ireland, WSUDS is a much more global term, showing that we should bring the water in the city instead of taking water out of the city.¹⁶ WSUD is a land planning and engineering design that supports the management of the whole urban water cycle, incorporating water supply and demand, waste water, rainfall and its runoff, storm water and ground management. By bringing all the elements of water cycles together and integrating them with the built environment through good urban planning, WSUD contributes to the development of local character, environment and community. By addressing the flooding, pollution and water scarcity issues, it tends to improve the quality of live by changing the water from a potential nuisance into a valuable resource and priority in the process of city design. It differs from the term SUDS which tends to refer only to surface water runoff. WSUD might be applied at every scale, from the design of our home to the strategic planning of large cities. Its principles have the following roles in the sustainable urban planning such as¹⁷:

- reduction of water pollution

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¹⁵. See more, PermcCalc website: http://www.permcalc.co.uk/why-suds/sudsmanagement-train/
¹⁶. See more, https://www.theguardian.com/sustainable-business/water-sensitive-design-urban-planning
¹⁷. See more, Water Sensitive Urban Design, https://www.youtube.com/watch?v=b_DTNnOzYTR4
• decrease of flood risk
• security improvement of water supply
• improvement of ecosystem health
• established connection between community and water
• alleviation of the urban heat island effects
• creation of intelligent environment by bringing different disciplines

In order to make WSUD to function properly, it is necessary:
• to control the grey water from sinks in order to be reused to water the gardens or to flush our toilets
• to use permeable surface instead of standard paving in order to relieve the pressure on sewers, reduce pollution and downstream flooding
• to install green roofs in order to reduce runoff, providing urban habitat
• to direct excess roof water to rain garden
• to direct runoff to street trees in order be naturally watered

WSUD is an important component for delivering sustainable development. In the city paving and concrete are dominant, but the runoff can be collected from them as well as the waste water from the building, enabling local supply of recycled water. The areas near streams, rivers and costliness that might be flooded should be designed as strategic open spaces and corridors in order to minimise the flood damage.

With the beginning of 2017, a new way of thinking about stormwater as a potential but not as a problem is developed in China through the concept of the sponge city. The system means that every raindrop must be properly captured, controlled and reused. This newly created system is also supported by the BGD project.

2.3.2. Green Infrastructure (GI)

Green Infrastructure (GI) is a cost-efficient, smart, resilient and multicultural approach that can help to improve the quality of life in the city in a natural way. It can be planned strategically by managing the network of natural and semi-natural features such as green areas (as green components), water, rivers, lakes (as blue components) and other environmental features in urban and rural areas (Ashley, R. Illman, S. and Stephenson, 2015). This shows that green infrastructure is an inseparable part of the blue and water infrastructure and they act in an integrative way as blue-green infrastructure. The main benefits – eco system services provided by this system are:

• better air quality
• clean water
• healthy soil
• food production
• sustainable energy production
• more biodiversity
• climate adaptation,
• stormwater management,
• less heat stress,
• increased quality of life through recreation,
• providing natural shade and shelters in and around the cities.
The above-mentioned environmental, economic and social benefits are the tools for searching for possible natural solutions that reduce our dependence on ‘grey infrastructure’ that is already seen as an expensive solution for building and maintenance. The problem is that grey infrastructure and traditional drainage system store rainwater and stormwater in order to convey them away, outside of the city. In that way, green infrastructure that already exists in the city remains without water during dry periods. Its natural potential is reduced because of the lack of water and the increased level of pollution. Climate changes cause frequent storms that destroy green infrastructure, which is already weakened by the previous and reckless human activities. A part of these activities is the removal of green areas and their replacement with water resistant paving. In that way, the possibility of the absorption of water in the ground is reduced, and its filtration is also prevented. Because of that rainwater and stormwater is mixed, increasing the intensity of flow that carry with itself trash, batteries, heavy metals, and other pollutants from the urban landscape. If we add climate extremes to this, the risk of erosion and flooding is inevitable in urban streams, demining habitat, property and infrastructure. This shows that it is necessary to use the integrated blue and green infrastructure that changes the opportunities in the city in a way that it mimics the natural processes. This means that we have to manage the water resources and green components in a more humane way by improving the biodiversity and the quality of city life. In order to achieve this, it is necessary to recycles and reuse all the water resources (rainwater, grey water, wastewater…) in order to support green infrastructure – the integration of city in nature.

The possible natural and practical solutions defined by EPA (United States Environmental Protection Agency) might be observed from small to large interventions in urban area:\(^{18}\):

- Downspout Disconnection (runoff is diverted into rain barrels, cisterns or permeable areas instead of sewer system)
- Rainwater Harvesting system (collects and stores runoff, saving it to have for later use)
- Rain Gardens (are shallow and vegetated basins that collect and absorb runoff from rooftops, sidewalks and streets)
- Planter Boxes (are urban rain gardens with walls and open or closed bottoms)
- Bioswales (vegetated, mulched and xeriscaped channels placed along streets and parking lots)
- Permeable Pavements (catch water where it falls)
- Green Streets and Alleys (integrate green infrastructure into their design to store, infiltrate and evaporate stormwater)
- Green Parking (is a place where green infrastructure can be installed in order to capture stormwater instead of flowing into sewer system)
- Green Roofs (are covered with vegetation enabling runoff infiltration and evaporation of the stored water).
- Urban Tree Canopy (reduce and slow stormwater by creating cooling shed with their leaves and branches)
- Land Conservation (reduces the risk of stormwater runoff and sewer overflows).

The use of the benefits of blue-green infrastructure and the evaluation of possible practical solutions help to gain new knowledge and experience about urban practice. They are tools for modelling urban design that is seen as an integrative process of searching for sustainable places. It is evident that there is a lack of such sustainable places in the present-day city. These places are unjustifiably neglected and transformed into the passages between two targets instead of treating them as meeting places important

\(^{18}\) See more, EPA, United States Environmental Protection Agency website: https://www.epa.gov/green-infrastructure/what-green-infrastructure
for every community. This infrastructure creates the sustainable places that are stimulating places for people’s gathering. What is missing in this blue-green infrastructure is the interrelationship of these components in the creation of a unique concept of everyday life. In the following section, the new philosophy of the BG urban planning framework that integrated the synergetic effects of blue-green infrastructure will be presented, creating a more humane relationship among people in the city.

2.4. Conclusion - Gaps in the Knowledge

The knowledge gaps recognized in literature review are summarised in Table 2.4. The key point of urban development (human-city-nature relationship) is analysed through the history of urbanisation, urban design concepts and urban design principles. Urbanisation timeline presented in Table 2.4 shows the imbalance in the relationship human-nature-city, where one of these three components is dominant. Imbalanced relationship harmfully impacts the amenities and urban diversity of the city. The main issue is that the urban development has been guided by “good practice” examples, and no environmental quantification has been done. However, due to climate change, microclimate conditions have been altered. As a result of climate change, the environmental condition of city micro units, especially open public spaces are degraded, which has an impact on the amenities and the social aspect of the spaces.

Open public spaces are a subject of discussion among the theory and practice of urban design. From today’s distance, it is questionable how much theory and practice lean towards sustainability, comfort, identity and urban diversity. In her essay ‘Burring the Boundaries: Public Space and Private Life’ published in Everyday Urbanism, a book on Los Angeles, that she coedited, Margaret Crawford discusses the idea of the redefinition of our understanding of spaces, saying that everyday spaces are like everyday life that are invisible in the professional discourse of the city. While designing everyday spaces, an accent is on its micro units (such as social and spatial characteristics) which are ubiquitous but ignored by urban planners, scientists, and underestimated by architects. Thus, it is necessary to design healthy and comfortable spaces for living in 21st century where social and economic development and ecology are well balanced.

Nowadays, open public spaces have a problem with urbanity that is actually defined and measured by the presence of people. This is defined as a social aspect of the use of open public spaces. Besides that, there are also ecological aspects that involve the microclimate comfort as the precondition for the better use of open public spaces. The presence of people from different social and cultural groups in open public spaces is one of the most important components of the regeneration of the cities and neighbourhoods (Jacobs 1961; Hillier and Hanson 1984; Whyte 1988; Carmona et al. 2003; Gehl 2004, 2006, 2011). There are different aspects such as density, accessibility, visual clarity, functional diversity, safety and etc. which are used for quantifying the social performance of open public spaces. The newly created design of open public spaces can improve the sociability and the social communication between users, their activities and ideas (Jacobs 1961; Hillier and Hanson 1984; Gehl 2006). However, from human perspective the amenities of space depend on many other factors. One of the most important factors is the microclimate condition (Nikolopoulou and Steemers 2003; Nikolopoulou and Lykoudis 2006; Chen and Ng 2012) especially today, when urban areas are mostly affected by the effects of climate change and the energy-intensive way of living. The development of urban microclimate significantly depends on the shape, configuration, and surface materialization in open public spaces. It is necessary to know that peoples’ behaviour can be affected by thermal comfort. A significant increase of air temperature in open public spaces, as a direct consequence of climate
change, led to the appearance of the phenomenon of urban heat islands (IPCC 2007; Kuttler 2012). The proof of this lies in the fact that air temperature in Serbia increased by 1.4°C/100 years during the last 55 years (Karadžić and Mijović 2007: 45-55).

This thesis shows the researchers the importance of open public spaces and its micro units that are neglected in theory and practice of city urban design. Creativity and innovation enable the partnership between theory, education and practice (Flyvbjerg, 2001). The most important UN Millennium development goals and the sustainable development strategy of Europe until 2020 emphasise the increase of city development. These innovative strategies look for possible models used to make the balance between the economically sustainable development and the need to return to nature. New instruments, methods and techniques can preserve the identity of open public spaces by the use of BG infrastructure and Eco-system services. All the above-mentioned facts inspire us to do the case studies of selected urban blocks. Every urban block is one important parts of the city. Depending on the historical period of the city, the morphological characteristics of the blocks vary. The changes of the physical properties within a block in the form of the density of the constructions, the number of floors or the relation between natural and built structures are changing the life conditions in them. Spatial access within the block includes two seemingly opposing extremes: the creation (engineering) of the new space in accordance with the predefined values of its attributes (properties), and re-engineering (revitalization) of the existing space. The basic assumption of this study is that these two extremes can be analysed on the basis of a common methodological approach. The confirmation of the applicability of this approach creates the basis for the specification of any design model or tool.

An urban block represents a significant point in the location of the experiment. It is the subject of case studies which have the geometry of ‘urban patterns of basic module’ and ‘basic determinant of urban form’ (Spreiregen, 1965). Morphology and interrelationship plots define the spatial organization of the block, while the internal composition of the block is of great importance for the definition of the common space in it. According to various theorists (Walton, Dravitzi and Donn, 2007; Eren, G. Ş., 1995), an urban block is characterized by the following factors:

- The shape and form of the urban block,
- The size of the urban block,
- The characteristics of the plots and their templates (patterns) in terms of ownership,
- The orientation and topography of the place where it is built,
- The density of the development of the urban block,
- The categorization of land use.

The issues related to block dimensions are crucial for the formation of the urban fabric of the city. Attention should also be paid to the spatial organization of the blocks and connections, public and private spaces and the borders (or their absence) between them. In order to integrate the blocks in the city, it is necessary to use the received knowledge about the integrative design. Landy (2005:13) explains these potential places by saying that: the creative mile presents the place – a group of buildings, a part of the city or the city in general or the whole region which have necessary precondition in terms of ‘hard’ and ‘soft’ infrastructure to generate a flow of information and ideas. According to Landy, this mile is the physical space in which the critical mass of business people, intellectuals, social activists, artists, officials, power mediators or students can participate in cosmopolitan atmosphere.

Thus, we must not to forget that these spaces are fundamental to the inhabitants of the city. Defining Ecosystem services and the principles of Urban practices such as the Sustainable urban drainage system
- SUDS, the water sensitive urban design – the WSUDS and the Green Infrastructure are active contributions to the design of the newly integrated philosophy of the sustainable city of today’s era. This newly created phenomenon is imposing the need to mitigate the climate changes in urban areas that will affect the change of urban practice [infrastructure, vegetation, resource usage, physical structure, etc.].
<table>
<thead>
<tr>
<th>Research periods</th>
<th>human-city</th>
<th>human-nature</th>
<th>nature-city</th>
<th>amenities</th>
<th>urban diversity</th>
<th>Quantifying aspects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prehistoric settlement</td>
<td>strong relationship</td>
<td>dominated by nature</td>
<td>settlement is permeated with nature</td>
<td>What is provided by nature</td>
<td>-</td>
<td>no</td>
</tr>
<tr>
<td>Ancient town</td>
<td>focus on human</td>
<td>nature was inspiration</td>
<td>city by nature</td>
<td>human created the amenities in harmony with nature</td>
<td>zoning</td>
<td>no</td>
</tr>
<tr>
<td>Medieval town – feudal</td>
<td>broken relationship</td>
<td>ignoring nature</td>
<td>the city at the expense of nature</td>
<td>focus is not human amenities</td>
<td>zoning</td>
<td>no</td>
</tr>
<tr>
<td>Industrial city</td>
<td>human was out of focus</td>
<td>nature devastation</td>
<td>city destroyed the nature</td>
<td>function before the amenities</td>
<td>centralized functions</td>
<td>no</td>
</tr>
<tr>
<td>Garden city</td>
<td>brought human back to focus</td>
<td>re-establish relationship with nature</td>
<td>The city was going back to nature</td>
<td>return to the human amenities needs</td>
<td>centralized functions</td>
<td>no</td>
</tr>
<tr>
<td>Master Plan Tel Aviv</td>
<td>integrate human with city</td>
<td>nurtures nature</td>
<td>city increase the nature</td>
<td>amenities increased to higher level</td>
<td>first appearances of diversity</td>
<td>no</td>
</tr>
<tr>
<td>The Ville Contemporaine, Plan Voisin, Cite Radieuse</td>
<td>human as a part of city</td>
<td>intend to establish strong relationship</td>
<td>city in harmony with nature</td>
<td>compromise between amenities and function</td>
<td>zoning</td>
<td>no</td>
</tr>
<tr>
<td>Broadacre City</td>
<td>human as a central figure of the city</td>
<td>strong relationship with nature</td>
<td>city subordinate to nature</td>
<td>amenities at the expense of function</td>
<td>zoning</td>
<td>no</td>
</tr>
<tr>
<td>Urban Diversity</td>
<td>city satisfy human’s needs</td>
<td>remain strong relationship with nature</td>
<td>-</td>
<td>amenities at first</td>
<td>diversity at best</td>
<td>no</td>
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<tr>
<td>Sustainable Urban Drainage System (SUDS)</td>
<td>human is out of focus</td>
<td>use nature for human's needs</td>
<td>nature is used to city needs</td>
<td>amenities must product</td>
<td>yes</td>
<td></td>
</tr>
<tr>
<td>Green Infrastructure (GI)</td>
<td>focus on human</td>
<td>use nature for human's needs</td>
<td>nature is used to city needs</td>
<td>amenities must product</td>
<td>yes</td>
<td></td>
</tr>
<tr>
<td>Water Sensitive Urban Design (WSUD)</td>
<td>focus on human</td>
<td>use nature for human's needs</td>
<td>nature is used to city needs</td>
<td>amenities must product</td>
<td>yes</td>
<td></td>
</tr>
<tr>
<td>BGD Urban Planning Framework</td>
<td>focus on human</td>
<td>harmonize needs of human with nature</td>
<td>Integrate nature back in the city</td>
<td>amenities priority</td>
<td>partial diversity</td>
<td>yes</td>
</tr>
</tbody>
</table>

Table 2.4 Summary of urban design concepts and principles through the history
3. New Proposed Methodology
3.1. BGD Urban Planning Framework

BGD promotes the new paradigm for the effective planning and management of urban environment: maximizing ecosystem services, minimizing the negative environmental impacts and increasing cities’ resilience to climate change, demographic and socio-economic conditions (Maksimović, Stankovic, Liu and Lalić, 2013). Blue Green Solutions enhance the synergy of urban blue [urban water infrastructure] and urban vegetated areas [green assets] by providing multiple benefits to urban ecosystem services and functions. They encompass the options and interventions developed within the WSUD [Water Sensitive Urban Design] concept and go beyond them (See Fig. 3.1).

Blue-Green Infrastructure is the joint framework of water [blue assets] and vegetation [green assets]. The benefits associated with BGI are as follows:

- climate change adaptation and mitigation,
- the reduction of the urban heat island effect,
- better management of storm water and water supply,
- carbon mitigation and improved air quality,
- increased biodiversity,
- water pollution control,
- improvement of public amenities,
- improvement of health and well-being of citizens,
- community engagement,
- landscaping and quality of place, increased land and property values.

The essential concept is the integration of vegetation into the urban framework to provide multiple benefits without the protection of the natural environment. However, to successfully implement BGI solutions, a clear vision and well defined measures for the desired outcomes are necessary. It is essential, when designing the plans, to take into account the needs of the people who are, or will be, the residents in the area. The overall objective/goal should be to provide a better place for living. Urban planners are well aware of the benefits that dwellers gain from vegetation. Vegetation has to have a reliable water supply in order to continue providing those benefits.

To conclude, it is time to stop seeing the benefits brought by vegetation as removed/separate from conventional urban settlements and to rethink the entire urban planning paradigm with these benefits embedded in its core. This approach presents the basics of the vision and the understanding of the available measures and options for planning the new and retrofitting/redesigning the existing cities based on the Blue Green concept. Although the benefits from both “green” and “blue” infrastructure are fairly well understood, the synergies from their integration are less understood and [much] less applied. Now it is good time to rethink all those benefits and incorporate them into consistent innovative urban planning. The thesis introduces the methods by which mutual interactions of urban water infrastructure [blue assets] and urban vegetated areas [green assets] are taken into account in the synergy of spatial planning and the optimized modelling of ecosystems’ performance indicators.
WSUD: Water Sensitive Urban Design [CIRIA, 2013]
BG: Blue Green [Maksimovic, 2013]

Optimal solution for adaptation of urban spaces to CC based on BG interaction with urban ecosystem services

Service Delivery Functions

Fig. 3.1. Development of water management in the cities [Source: BGD Project, 2012]
3.2. Software Analysis – The Validation of New Methodology

Due to the rapid urban growth developing cities are facing problems and have to find a good pattern of development and land use. As these decisions need to be accurate and detailed, in addressing these problems many urban planners are turning to the computer based technologies such as GIS, Geovisualization and simulation 3D and 4D models (Ozkeresteci, 2003). Regarding the simulation tools specialized for the urban microclimate, there are not many options. The reasons for this are mainly due to the fact that most of the applications are designed for the analysis of one building scale and one physical indicator at a time (Vidmar, 2013). As the focus of this thesis is on the environmental design and planning, the thesis uses ENVI-met and LEOARNO software, developed by Michael Burse of the University of Bochum, to simulate the urban microclimate and outdoor comfort. The software analyses the environmental behaviour, taking into accounts the arrangement of anthropogenic and natural structures and elements.

This section addresses two main topics. First, the analysis of the software itself, its possibilities and limitations. Second, the validation of ENVI-met tool with regards to the a) calculation capabilities and b) applicability through the proposed methodology.

3.2.1. ENVI-met software and Leonardo visualisation tool

ENVI-met is a grid-based three-dimensional non-hydrostatic model. The resolution of the model is from 0.5 to 10 metres in space, and in smaller intervals of 10 seconds. By using the fundamental laws of the thermal and fluid dynamics, it analyses the microclimate in longest duration cycles of 48 hours. The available environmental indicators are the wind speed and directions, turbulence, air temperature, humidity, radiative fluxes. In Figure 3.2, can be seen the structure of the data in the software:

![Diagram of ENVI-met data structure](image)

Fig. 3.2 Data structure of the ENVI-met [Source: Ozkeresteci, 2003]

---

15. Leonardo is software solution which reads and illustrate in 2D the ENVI-met results

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Recently, the ENVI-met has been adapted mainly to simulate the surface-plant-air interactions in urban canyons, and to predict the climatic consequences of different urban design options (Bruce, 2010).

The ENVI-met model calculates the meteorological parameters in each point of the grid– receptors [Bruse, 1998]. The validation of the software has been done in different environments, especially for research done concerning the urban morphologies (Peng, 2013).

The main prognostic variables in the atmospheric mode are the wind flow, temperature, humidity and turbulence, while temperature and humidity are given by the combined advection-diffusion equation (See Eq. 3.1):

\[
\frac{\partial \theta}{\partial t} + u_i \frac{\partial \theta}{\partial x_i} = K_h \left( \frac{\partial^2 \theta}{\partial x_i^2} \right) + \frac{1}{c_p \rho} \frac{\partial R_{h,sw}}{\partial z} + Q_h 
\]

(1)

\[
\frac{\partial q}{\partial t} + u_i \frac{\partial q}{\partial x_i} = K_q \left( \frac{\partial^2 q}{\partial x_i^2} \right) + Q_q 
\]

(2)

Equation 3.1: Temperature and humidity equations (ENVI-met 3.0 update model overview Bruse, 2004)

\( \theta \) distribution of the air temperature

\( q \) Specific humidity

\( Q_h \) and \( Q_q \) are used to link heat and vapour exchange

\( \partial R_{h,sw} / \partial z \) is the vertical divergence of long wave radiation

\( \rho \) - air density; \( t \) - time;

Mean Air Flow

The mean air flow is resolved by non-hydrostatic incompressible Navier-Stokes equation, while for the air turbulence ENVI-met uses 1.5 order turbulence closure model, based on Mellor and Yamada (1982; Mellor, 1998)

The basic three-dimensional wind pattern is defined by the non-hydrostatic incompressible Navier-Stokes equations in the Boussinesq- approximated form ((1)-(3)) and the Continuity equation (See Eq. 3.2):

\[
\frac{\partial u}{\partial t} + u_i \frac{\partial u}{\partial x_i} = - \frac{\partial p'}{\partial x} + K_m \left( \frac{\partial u}{\partial x_i^2} \right) + f(v - u_p) - S_u 
\]

(3a)

\[
\frac{\partial v}{\partial t} + u_i \frac{\partial v}{\partial x_i} = - \frac{\partial p'}{\partial y} + K_m \left( \frac{\partial v}{\partial x_i^2} \right) + f(u - v_p) - S_v 
\]

(3b)

\[
\frac{\partial w}{\partial t} + u_i \frac{\partial w}{\partial x_i} = - \frac{\partial p'}{\partial z} + K_m \left( \frac{\partial w}{\partial x_i^2} \right) + g \frac{\theta(z)}{\theta_{ref}(z)} - S_w 
\]

with \( u=(u,v,w), \theta=(\theta_{x,y,z}) \) for \( i=1,2,3 \). (3c)

\[
\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} + \frac{\partial w}{\partial z} = 0 
\]

(4)

Equation 3.2: Navier-Stokes equations [ENVI-met 3.0 update model overview, Michael Burse, 2004]

\( f = (10^8 \text{sec}^{-2}) \) – Coriolis parameter; \( p' \) – the local pressure perturbation; \( \theta \) – the potential temperature at level \( z \) (grid cells of height); \( \theta_{ref} \) – the reference temperature, represents average muscled conditions and is provided by a one-dimensional model running parallel to the main model; \( S_0, S_i, S_w \) – the local source/sink terms, describe the loss of wind speed due to the drag forces at vegetation elements; \( K \) – exchange coefficients for heat and vapor
Turbulence and exchange processes

To simulate the turbulence and the exchange process the 1st order mixing length approach (Blackadar, 1962) and the 1.5 order turbulence model (E-d a 1.5 according to the research of Mellor and Yamada (1982; Mellor, 1982) can both be available in ENVI-met. However, in order to achieve higher accuracy, the 1.5 order turbulence model is adopted with the addition of the local turbulence $\varepsilon$ and its dissipation rate $\varepsilon$ as prognostic variables to the model (See Eq. 3.3):

$$\frac{\partial \theta}{\partial t} + u_i \frac{\partial \theta}{\partial x_i} = K_h \left( \frac{\partial^2 \theta}{\partial x_i^2} \right) + Q_h$$  \hspace{1cm} (5)

$$\frac{\partial q}{\partial t} + u_i \frac{\partial q}{\partial x_i} = K_q \left( \frac{\partial^2 q}{\partial x_i^2} \right) + Q_q$$  \hspace{1cm} (6)

Equation 3.3: Turbulence equations [ENVI-met 3.0 update model overview, Michael Burse, 1999]

These are two internal source terms, which quantify the heat and vapor exchange between the atmosphere and the plant surface. The vegetation model decides the quantities of these two terms.

$$\frac{\partial E}{\partial t} + u_i \frac{\partial E}{\partial x_i} = K_E \left( \frac{\partial^2 E}{\partial x_i^2} \right) + Pr - Th + Q_E - \varepsilon$$  \hspace{1cm} (7)

$$\frac{\partial \varepsilon}{\partial t} + u_i \frac{\partial \varepsilon}{\partial x_i} = K_\varepsilon \left( \frac{\partial^2 \varepsilon}{\partial x_i^2} \right) + C_1 \frac{\varepsilon}{E} Pr - C_3 \frac{\varepsilon}{E} Th + C_2 \frac{\varepsilon^2}{E} + Q_\varepsilon$$  \hspace{1cm} (8)

Equation 3.4: Air turbulence equations [ENVI-met 3.0 update model overview, Michael Burse, 2004]

In Equation 3.4 $E$– local turbulence; $Pr$– the influence of mechanical shearing; $Th$ – dissipation of turbulent energy; $Q_E$ and $Q_\varepsilon$ are local sources for turbulent production and dissipation respectively.

Ground surface and building walls

The energy balance equations are used to calculate the temperature of the ground and wall surfaces. Ground surface temperature $T_0$ can be calculated from:

$$0 = R_{sw,net} + R_{lw,net} - c_p \rho J_h^0 - \rho L \cdot J_v^0 - G$$  \hspace{1cm} (9)

$R_{sw,net}$ and $R_{lw,net}$ are the net radiative energy fluxes; $J_h$ and $J_v$ are the turbulent fluxes of heat and vapour;

When the equation (9) is used to calculate the temperature of the wall surface, $G$ stands for the heat transmission through the walls, which correlates with the insulation of the wall and the difference in temperatures between the indoor and outdoor.

In order to calculate the latent heat flux, the surface humidity $q_0$ is required as well as the surface temperature $T_0$.

The surface humidity $q_0$ is determined by the air humidity $q_a$, the soil moisture content at level $z=-1$ and the saturation value $q^*$ derived from the $\beta$-approach (Deardorff, 1978).

$$q_0 = \beta q_a (T_0) + (1-\beta)q(z=1)$$

$$\beta = \min(1, \eta(z=-1) / \eta_{fc})$$  \hspace{1cm} (10)

$\eta$ - volumetric soil water content in the first soil layer; $\eta_{fc}$ is its value at field capacity; $q_a$ is equal to $q_0$ for wall surfaces, while $q_a$ is equivalent to $q^*$ for water surfaces. The similarity law from Monin and Obhukov (1954) decides the turbulent fluxes of vapor heat and the momentum between the
atmosphere and the surfaces.
3.2.2. Validation of ENVI-met

ENVI-met has been evaluated and validated frequently (Ozkeresteci, I., et al., 2003; Lihua, et.al, 2009; Hedquist, 2010). The simulation results can deviate from the measure values (Fig 3.3), but the deviation is not significant. This is mostly due to the software setting. Up to date, ENVI-met hasn’t had the anthropogenic-generated heat included in the calculations. In other words, the buildings set in the model are considered as high-density cases and share the same building mass. So the anthropogenic heat can be added to the simulation as the background contributed heat (Bruse, 2004).

The validation of the ENVI-met software has been done in different environments, especially for the research concerning urban morphologies. The most applicable validation for this thesis is the validation done by the University of Sheffield, UK (Gill et al., 2013).

![Graph showing temperature variations](image)

Fig. 3.3 Measured averaged temperatures from the 6 central temperature loggers read over 2 days alongside the results from a 2 day simulation from ENVI-met [Gill et al., 2013]

Having taken all the comparative results into account, the ENVI-met model is regarded as an 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 focus of this PhD thesis is to analyse and understand the temperature deviation between different scenario setups, thus the software issue related to the maximum temperature is not an area of interest and does not impact the research results.

One of the aims of this thesis is to include computer based modelling in the concept phase of urban planning. In order to achieve this, during the validation process of several aspects (among which are open source and licence plan, operating system, interface, easy-to-use, and accuracy of the simulations, etc.) and which are related to the possibility to use the software tool by the government and planning bodies without additionally burdening budgets.

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The paper done by Jernej Vidmar (Vidmar, 2013) shows the detailed validation table of the comparison simulation tools which are used for modelling the open public spaces microclimate simulations. Table 3.1 covers most of the elements important for this thesis. Although the conclusion of the above-mentioned paper points out that all tested tools have room for improvement, the ENVI-met (beside archaic user interface) offers the most detailed analysis, and it therefore seems to be the most suitable for the simulation where more elaborate results are needed.

To conclude, ENVI-met successfully calculates the following factors: Albedo (diffuse reflectivity or reflecting power of a surface), vegetation (plant type, stomata resistance, crown density, etc), relative humidity (25-60 % RH – human comfort zone), evaporation, water bodies, material assignment (thermal conductivity), irradiation analysis (radiation process), Air Exchange (wind).

<table>
<thead>
<tr>
<th>ID</th>
<th>APPLICATION FEATURES</th>
<th>PONDER</th>
<th>ENVI-met</th>
<th>Project Vasari</th>
<th>IES VE-Pro</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.1</td>
<td>Incoming solar radiation</td>
<td>10</td>
<td>5  →  50</td>
<td>5  →  50</td>
<td>7  →  70</td>
</tr>
<tr>
<td>5.2</td>
<td>Irradiation analysis</td>
<td>6</td>
<td>3  →  18</td>
<td>0  →  0</td>
<td>0  →  0</td>
</tr>
<tr>
<td>5.3</td>
<td>Air exchange / wind (CFD)</td>
<td>10</td>
<td>8  →  80</td>
<td>8  →  80</td>
<td>9  →  90</td>
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<tr>
<td>5.4</td>
<td>Materials assignment</td>
<td>8</td>
<td>5  →  40</td>
<td>7  →  56</td>
<td>10  →  80</td>
</tr>
<tr>
<td>5.5</td>
<td>Water bodies &amp; evaporation</td>
<td>8</td>
<td>8  →  64</td>
<td>0  →  0</td>
<td>7  →  56</td>
</tr>
<tr>
<td>5.6</td>
<td>Humidity</td>
<td>6</td>
<td>10 →  60</td>
<td>2  →  12</td>
<td>3  →  18</td>
</tr>
<tr>
<td>5.7</td>
<td>Vegetation</td>
<td>6</td>
<td>10 →  60</td>
<td>2  →  12</td>
<td>3  →  18</td>
</tr>
<tr>
<td>5.8</td>
<td>Evapotranspiration</td>
<td>3</td>
<td>0  →  0</td>
<td>0  →  0</td>
<td>0  →  0</td>
</tr>
<tr>
<td>5.9</td>
<td>Acoustics</td>
<td>3</td>
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<td>0  →  0</td>
<td>0  →  0</td>
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<tr>
<td>5.1</td>
<td>Albedo</td>
<td>6</td>
<td>8  →  48</td>
<td>0  →  0</td>
<td>0  →  0</td>
</tr>
<tr>
<td>5.11</td>
<td>Analysis accuracy</td>
<td>8</td>
<td>10 →  80</td>
<td>8  →  64</td>
<td>8  →  64</td>
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<tr>
<td>5.12</td>
<td>3D modeling</td>
<td>8</td>
<td>7  →  56</td>
<td>10  →  80</td>
<td>8  →  64</td>
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<tr>
<td>5.13</td>
<td>Climate data loading</td>
<td>10</td>
<td>10 →  100</td>
<td>8  →  80</td>
<td>10 →  100</td>
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<tr>
<td>5.14</td>
<td>Open format support</td>
<td>6</td>
<td>10 →  60</td>
<td>8  →  48</td>
<td>2  →  12</td>
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<tr>
<td>5.15</td>
<td>Application interoperability</td>
<td>4</td>
<td>6  →  24</td>
<td>7  →  28</td>
<td>6  →  24</td>
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<tr>
<td>5.16</td>
<td>Application programming interface</td>
<td>6</td>
<td>0  →  0</td>
<td>10 →  60</td>
<td>0  →  0</td>
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**FEATURES SUM**

<table>
<thead>
<tr>
<th>ID</th>
<th>APPLICATION USEABILITY</th>
<th>PONDER</th>
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<th>Project Vasari</th>
<th>IES VE-Pro</th>
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<tbody>
<tr>
<td>6.1</td>
<td>Calculation speed</td>
<td>7</td>
<td>6  →  42</td>
<td>10 →  70</td>
<td>4  →  28</td>
</tr>
<tr>
<td>6.2</td>
<td>Visual environment &amp; feedback</td>
<td>8</td>
<td>6  →  48</td>
<td>10 →  80</td>
<td>8  →  64</td>
</tr>
<tr>
<td>6.3</td>
<td>UI simplicity &amp; intuitiveness</td>
<td>6</td>
<td>3  →  18</td>
<td>8  →  48</td>
<td>5  →  30</td>
</tr>
<tr>
<td>6.4</td>
<td>Ease of use &amp; learning curve</td>
<td>6</td>
<td>3  →  18</td>
<td>8  →  48</td>
<td>5  →  30</td>
</tr>
<tr>
<td>6.5</td>
<td>Software documentation</td>
<td>8</td>
<td>7  →  56</td>
<td>10  →  80</td>
<td>6  →  48</td>
</tr>
<tr>
<td>6.6</td>
<td>Supported operating systems</td>
<td>4</td>
<td>4  →  16</td>
<td>4  →  16</td>
<td>4  →  16</td>
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<tr>
<td>6.7</td>
<td>Community &amp; technical support</td>
<td>7</td>
<td>7  →  49</td>
<td>7  →  49</td>
<td>10 →  70</td>
</tr>
<tr>
<td>6.8</td>
<td>License, cost &amp; development activity</td>
<td>5</td>
<td>6  →  30</td>
<td>8  →  40</td>
<td>7  →  35</td>
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**USEABILITY SUM**

<table>
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<th>PONDERED VALUE</th>
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<th>140</th>
<th>122</th>
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<tbody>
<tr>
<td></td>
<td>FINAL RANK</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
</tbody>
</table>

Table 3.1 Evaluation of the simulation tools [Source: Vidmar, 2013, https://docs.google.com/spreadsheets/d/1A2rlx5fT7XDX6CyrOBukb3jTUw7Oqb3YyM-FEU/ahh!/edit#gid=0]
The setup of ENVI-met model is divided into two groups: a) meteorological information, dates and duration of simulations, materials and vegetation properties, sun radiation factors, shades, turbulence factors etc., and b) the information about the morphology of the environment, such as the positions and the height of buildings, the position and type of plants, the distribution of surface materials and soil types, the position of sources and receptors, geographical positions of the locations on earth and so on.

Input data

The configuration file decides the settings for the simulation which is supposed to be run – for example, the date of the simulation and the duration, as well as the basic meteorological information. The area input files basically specify the geometry of the model environment, such as:

- Position and height of the buildings
- Position and type of the plants
- Distribution of the surface materials and soil types
- Position of sources and receptors
- Database links [database of soil, plants, material types]
- Geographical positions of the location on the earth

Output data

ENVI-met generates a significant amount of data for every simulation. Main data files, known as the output files, contain the complete microclimate of an area, including the atmosphere, the surface and the soil information. Output files are stored in a binary format. To read these files, one needs either Xtract [ASCII-unformatted output file] programme or LEONARDO [graphical output]. The data can be exported from the binary output files with Xtract and then written into ASCII files. ASCII files are easily opened with Excel so that the data become readable to non-technical users. LEONARDO is a graphical interface for displaying and analysing numerical data. LEONARDO, support export option to standard JPEG image files [Bruse, 2009].

When the research about open public spaces started, the evaluation of the environmental simulation tools also started. In the beginning it seemed that there are a lot of options. During 2012 the US Department of Energy listed 410 simulation tools for Energy Efficiency.
3.3. Newly Integrated Philosophy of the City – Conclusion

This section covers the perceived relationship between nature, ecosystem services and human well-being from the first human records to the present-day cities. In this relationship, three components (human and his relation to nature and cities) are evaluated. Table 3.2 is the result of the research conducted about urban design concepts and principles throughout the history. It summaries the key elements of each period based on the predefined criteria:

- relationship human-city
- relationship human-nature
- relationship nature-city
- amenity – to recognize if a certain period thought about the human and his environmental comfort in the city
- urban diversity – to recognize if a certain period thought about the human and his social comfort in the city
- quantifying aspects – whether a certain period was based on theory or performance indicators

In order to understand the meaning of the table, the criteria needs to be further explained. Human-city criterion was used to analyse the awareness of the human towards the city, to be more precise, whether the human was focused on the city urban design or not. In the relation human-nature the aim was to analyse the awareness of the human towards nature. In this relationship it was important to see whether the city enabled the human to live in a natural way or not. The relation nature-city shows whether urban settlements were designed in harmony with nature or not, and what kind of natural capacities are used.

In the amenity criterion amenity represents the level of designer’s awareness about comfort when using and experiencing space. The urban diversity criterion refers to the multi-functionality of the city’s district, instead of the multi-functionality of the city as a whole. The last criterion is the quantifying aspect, meaning whether the concept is based purely on theoretical approach or it has a quantifying proof, too.

In Table 3.2, good practices from the literature review of urban development are highlighted in colour. These selected human-nature-city-amenity relationships are serving as the basics for the new integrated philosophy, which can be summarised as follows:

- in the relationship human-city, the human must be focused on city planning i.e. it is necessary to create the city according to its citizens’ needs
- in the relationship human-nature, it is necessary to enable the human in the city to communicate with nature on a daily basis by incorporating the citizens and natural environment
- in the relationship nature-city, the principal aim is to integrate the present-day city with nature by respecting the principles of nature
- amenity is an important element of the sustainable city and it requires the comfort and healthy life of the contemporary human in a natural way
- urban diversity must be brought into the focus of contemporary city life again
- quantifying aspects are not based only on theory but they also have to be applied in practice; this means that it is necessary to act preventively from the beginning, when the strategic decisions are made in the process of urban planning, up to their application in practice.
<table>
<thead>
<tr>
<th>Research periods</th>
<th>human-city</th>
<th>human-nature</th>
<th>nature-city</th>
<th>amenities</th>
<th>urban diversity</th>
<th>Quantifying aspects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prehistoric settlement</td>
<td>strong relationship</td>
<td>dominated by nature</td>
<td>settlement is permeated with nature</td>
<td>What is provided by nature</td>
<td>-</td>
<td>no</td>
</tr>
<tr>
<td>Ancient town</td>
<td>focus on human</td>
<td>nature was inspiration</td>
<td>city by nature</td>
<td>human created the amenities in harmony with nature</td>
<td>zoning</td>
<td>no</td>
</tr>
<tr>
<td>Medieval town – feudal</td>
<td>broken relationship</td>
<td>ignoring nature</td>
<td>the city at the expense of nature</td>
<td>focus is not human amenities</td>
<td>zoning</td>
<td>no</td>
</tr>
<tr>
<td>Industrial city</td>
<td>human was out of focus</td>
<td>nature devastation</td>
<td>city destroyed the nature</td>
<td>function before the amenities</td>
<td>centralized functions</td>
<td>no</td>
</tr>
<tr>
<td>Garden city</td>
<td>brought human back to focus</td>
<td>re-establish relationship with nature</td>
<td>The city was going back to nature</td>
<td>return to the human amenities needs</td>
<td>centralized functions</td>
<td>no</td>
</tr>
<tr>
<td>Master Plan Tel Aviv</td>
<td>integrate human with city</td>
<td>nurtures nature</td>
<td>city increase the nature</td>
<td>amenities increased to higher level</td>
<td>lst appearances of diversity</td>
<td>no</td>
</tr>
<tr>
<td>The Ville Contemporaine, Plan Voisin, Cite Radieuse</td>
<td>human as a part of city</td>
<td>intend to establish strong relationship</td>
<td>city in harmony with nature</td>
<td>compromise between amenities and function</td>
<td>zoning</td>
<td>no</td>
</tr>
<tr>
<td>Broadacre City</td>
<td>human as a central figure of the city</td>
<td>strong relationship with nature</td>
<td>city subordinate to nature</td>
<td>amenities at the expense of function</td>
<td>zoning</td>
<td>no</td>
</tr>
<tr>
<td>Urban Diversity</td>
<td>city satisfy human’s needs</td>
<td>remain strong relationship with nature</td>
<td>-</td>
<td>amenities at first</td>
<td>diversity at best</td>
<td>no</td>
</tr>
<tr>
<td>Sustainable Urban Drainage System (SUDS)</td>
<td>human is out of focus</td>
<td>use nature for human’s needs</td>
<td>nature is used to city needs</td>
<td>amenities muss product</td>
<td>yes</td>
<td></td>
</tr>
<tr>
<td>Green Infrastructure (GI)</td>
<td>focus on human</td>
<td>use nature for human’s needs</td>
<td>nature is used to city needs</td>
<td>amenities muss product</td>
<td>yes</td>
<td></td>
</tr>
<tr>
<td>Water Sensitive Urban Design (WSUD)</td>
<td>focus on human</td>
<td>use nature for human’s needs</td>
<td>nature is used to city needs</td>
<td>amenities muss product</td>
<td>yes</td>
<td></td>
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<tr>
<td>BGD Urban Planning Framework</td>
<td>focus on human</td>
<td>harmonize needs of human with nature</td>
<td>Integrate nature back in the city</td>
<td>amenities priority</td>
<td>partial diversity</td>
<td>yes</td>
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<tr>
<td>New integrated philosophy</td>
<td>Focus on human in city</td>
<td>bring human back to nature</td>
<td>bring city back to nature</td>
<td>amenities priority</td>
<td>introduced in focus again</td>
<td>yes</td>
</tr>
</tbody>
</table>

Table 3.2 Summary of urban design concepts and principles through history
When defining the key components of the new integrated philosophy presented in Table 3.2, it is necessary to define at which stage of urban planning process these components should be implemented. The new integrated philosophy proposes that the key components should be moved from the detailed design stage to the concept stage and tested through computer based environmental simulations. In order to achieve results with the new philosophy and to answer all the key points form Table 3.2, all participants in urban development process should be involved from the beginning – the concept stage. That means that besides urban planners, architects and engineers who are directly involved in the process of city development, it is necessary to involve the scientists from other fields such as philosophers, psychologists, sociologists, anthropologists and other experts (See Fig. 3.4). It is also necessary to engage all the users of open public spaces that are involved in community life.

The new integrated methodology proposed by both Table 3.2 and Fig 3.4 is the subjects of further research. In the following sections through two selected case studies (Block 21, Belgrade and Main Square, Leskovac) and the demo site Imperial College London Campus, this finding or mythology will be tested in practice.

In order to test the first and the second hypotheses, we selected two case studies in a way that they are built in modern period but reconstructed in the last two decades:

- Block 21, Belgrade, Serbia (built in 1960s is an open public space within an open block)
- The Main Square in Leskovac, Serbia (built in 1960s is the main square which is from modern period)

The results and knowledge obtained from testing the above-mentioned polygons are used as the indicators of how Hypotheses and the proposed methodology can be further applicable to Demo Site. Both Case studies would give the indicators of which BG elements are mostly used and which of them have significant impact on the thermal comfort and amenities of space. Moreover, the reconstruction of the open public spaces serves as a test for how a computed based simulation could potenitally improve the urban design process.

4.1 Case Study 1 - Block 21, Belgrade, Serbia

4.1.1. Hypothesis

The residential Block 21, Serbia is an example of the use of urban design methodologies in order to show how the spatial transformation of the space significantly affects its microclimate comfort, illustrating the difference within the residential Block 21, Serbia, before and after the transformation. It was a mono-functional residential block which included new functions such as commercial and administrative and new residential structures before the transformation. The figure-ground ratio changed in favour of ground occupancy so nowadays there is less greenery and more covered pavements. This significantly influences the microclimate comfort of this urban block. Thus, it is necessary to test the Hypothesis to show that modern urban planning without BG methodology is producing spaces with fewer amenities and thermal comfort.

4.1.2. Case Study description

The transformation of the residential Block 21, Serbia that occurred during 1990s and around 2000 influenced the intensity of the use of its open public spaces and significantly changed its character. The original form of Block 21 was a mono-functional residential block with a matrix of slabs and towers placed in large green open public spaces. The layout of the residential buildings within the Block 21 was created in a way that it forms enough green open public spaces for its users and their everyday activities. As the residential function was dominant in the original concept of the Block 21, it was necessary to find the way to create the new urban functions, including commercial and office venues. The idea of the transformation was to keep the original concept of the Block 21 but to add new residential, commercial and office structures that would be built around them and along the main streets. Newly-built structures are significantly distinctive from the existing ones, since building them has the aim to meet the needs of

contemporary users. In that way the figure-ground ratio significantly reduced green open public spaces, which resulted in less greenery and more covered pavement. Despite the ideas of urban planners to keep the original concept of the Block 21 its density radically increased, which also resulted in the change of the values of microclimate comfort. Thus it was necessary to make the comparison between the Block 21 before (Fig. 4.1.a), and after the transformation (Fig. 4.1.b) in order to see the changes related to the size, the function and the accessibility of its open public spaces.

Fig. 4.1.a. Residential block before the recent interpolation of new buildings.
4.1.3. Methodology

Gideon S. Golony's study based on urban design morphology and thermal performance explores the relationship between the spatial configuration and the microclimate comfort of the open public spaces (Golany 1996). This means that the changes of the physical characteristics of open public spaces such as the shape and density of urban structures and surface materialization significantly influence urban microclimate. As for the microclimate comfort, it is important to emphasize that each geographical region has its own specific thermal index so it must be applied to the local climatic conditions and cultural patterns of used space, instead of global application. Thermal comfort depends on various environmental factors, mostly:

- air temperature,
- surface temperature,
- wind speed and direction,
- relative humidity,
- sun radiation, etc.

Thus this section analyses the thermal comfort of the open public spaces in the residential Block 21 in Belgrade, Serbia, as explained by Golony, and then tests it by using the environmental 3D modelling tool called the ENVI-met (Bruse 2010, Bruse and Fleer 1998). The aim of this case study is to show how the changes that occurred in the density of the residential Block 21 and the reduction of the green open public spaces after building new urban structures affect its thermal condition. Two different urban configurations of the same residential block (before and after the transformation) have been tested by the ENVI- Met model for the simulation of airflow, heat and vapour exchange, the exchange of
vegetation and vegetation parameters, as well as the particle dispersion in urban areas. The software key inputs are: site location, initial climatic parameters, soil, plan type, building structure and thermal properties. In order to run the software, the use of two files is required: the configuration files (including the date, the duration and the basic meteorological information of the environment) and the area input file (the morphology of the environment, including the position and the height of the buildings, the position and the types of plants, the distribution of surface material and soil types, the position of sources and receptors, geographical position of the location on earth, and etc.)

Table 4.1 shows the description of the parameters of the ENVI-met model for the open public spaces in the residential Block 21 in Belgrade. The simulation date is 24 July 2013 and it starts from 12PM on 24 July 2013 and the time of initialization is from 6AM on 24 July till 6AM 25 July. This shows that the duration of simulation is 24 hours. The simulation was run at the different time of the day: 10 AM, 12PM, 2PM, 4PM and 6PM. This is a typical summer day in Belgrade with the initial air temperature of 19.8°C. Air temperature and humidity at 0.8m above the ground were extracted from the results. Wind speed at 10m above ground level was 3m/s from the south-easterly direction; relative humidity up to 2m above the ground was 50%; specific humidity at 2.500m was 7g water/kg air±1 and the adjustment factor for solar input was 1. The area input data for the ENVI-met simulation was the 100x90x30 grid; the grid cell size in meters was dx=5, dy=5 and dz=3; the geographic latitude and longitude was 44.8167° N, 20.4667° E.21

<table>
<thead>
<tr>
<th>Model parameter</th>
<th>Model Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Simulation input date</td>
<td>24.07.2013</td>
</tr>
<tr>
<td>Starting time</td>
<td>12PM, on 24 July 2013</td>
</tr>
<tr>
<td>Time for initialization (h)</td>
<td>From 6AM on 24 July till 6AM 25 July</td>
</tr>
<tr>
<td>Simulation Duration (h)</td>
<td>24h</td>
</tr>
<tr>
<td>Initial air temperature (K)(°C)</td>
<td>292.95 K; 19.8°C</td>
</tr>
<tr>
<td>Wind speed 10m above ground (m/s)</td>
<td>3</td>
</tr>
<tr>
<td>Wind direction (North 0, East90)</td>
<td>135 (South East)</td>
</tr>
<tr>
<td>Relative humidity at 2 m (%)</td>
<td>50</td>
</tr>
<tr>
<td>Specific humidity in 2500 m (g water/kg air−1)</td>
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</tr>
<tr>
<td>Cloud cover (low/mid/high)</td>
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</tr>
<tr>
<td>Adjustment factor for solar input</td>
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</tr>
<tr>
<td>Dimensions in grid cell points</td>
<td>100x90x30 grids</td>
</tr>
<tr>
<td>Size of grid cell in meters</td>
<td>dx=5; dy=5; dz=3</td>
</tr>
<tr>
<td>Location</td>
<td>Belgrade 44.8167° N, 20.4667° E</td>
</tr>
</tbody>
</table>

Table 4.1 parameters for ENVI-met model

---

4.1.4. Results and Discussion

Fig 4.2. Representation of the Block 21 before and after interpolation of new buildings as an ENVI-met area model

The comparison of the residential Block 21 before and after the transformation (Fig 4.2) shows the following facts. The built area of the original concept of the residential Block 21 before the transformation was around 54.68%. This percentage was changed and increased to 70.24% after the transformation that occurred during the 1990s and around 2000. The green area of the open public spaces within the original residential Block 21 was 103.172, 54m2, but today the green area is reduced to 67.757, 15m2. Besides the changes of the figure-ground ratio, it is necessary to say that the treetop surfaces of the 40-year-old trees are 4 times bigger and lead to the creation of shade areas within the residential Block 21.
The outputs of the ENVI-met simulation at 10 AM (See Fig. 4.3) obtained after the comparison of the residential Block 21 before and after the transformation show that there is a decrease of air temperature for 1 to 2°C in the central parts of the open public spaces. The reason for that is the increase of the treetop surfaces which create new shade areas. However, there is an increase of air temperature by 1°C along the edges of the residential block at the places where the new structures were built. The areas that are surrounded by high vegetation have much lower air temperature than the areas covered by concrete or asphalt. In those areas that are without vegetation the air temperature is also low because of the shading effect. The areas with high vegetation have 0.5 – 0.6 °C lower air temperature than the areas covered by grass. In the north-western and south-eastern parts of the residential Block before and after the transformation the highest air temperature difference is around 2.5°C.
Fig. 4.4 ENVI-met air temperature simulation at 2 PM before the transformations (top) and after the transformations (bottom).

The outputs of the ENVI-met simulation at 2PM (See Fig. 4.4) obtained from the comparison of the residential Block 21 between the period before and after the transformation show a significant increase of air temperature by more than 2°C in the south-eastern part of the residential Block 21 where the new structures were built. The reason for that lies in the fact that the typical wind in Belgrade is the south-western wind, so these newly-built structures in the south blocked the air circulation and accumulated hot air in the area between the new structures and the Main Street in the south.
Besides the outcomes of ENVI-met simulation at 10 AM and 2 PM obtained by calculating the pure meteorological data of the residential Block 21 before and after the transformation, it was necessary to include the bio-meteorological model in ENVI-met simulation to predict the thermal comfort due to the complexity of the interventions in the Block 21. The predicted mean vote (PMV), known as the best Biomet model, is illustrated in Fig. 4.5. The function of this model is to enable urban planners to make the balance between the energy balance of the human body and the feeling of personal comfort. According to the ASHRAE (American Society of Heating, Refrigerating and Air-Conditioning Engineers) thermal sensation scale (Standard 55) where +3 represents hot, +2 warm, +1 slightly warm, 0 neutral, -1 slightly cool, -2 cool and -3 cold, the PMV index shows how a large group of people react to the changes of the thermal comfort. The PMV index is expressed as \[ \text{PMV} = (0.303e^{-0.036M^{0.021}}) L, \] where \( M \) stands for metabolic rate and \( L \) for thermal load, showing the difference between the internal heat production and the heat loss in the actual environment (Ostergaard et al. 1974).

Fig. 4.5. ENVI-met PMV simulation at 2 PM before the transformations (top) and after the transformations (bottom)

The PMV index in Block 21 shows that the level of comfort goes beyond +3 (hot) and its average is between +2.9 and +4. PMV value increased by more than +3.5 because of the construction of new buildings in the Block 21.
4.2 Case Study 2 - Leskovac, Serbia\textsuperscript{22}

4.2.1 Hypothesis

In this Case Study 2, the Hypothesis is tested in a way that BG methodology is involved directly in the process of urban planning with the aim to get the final open public space solutions with better UHI indicators by the use of computer model based on ESS. This means that microclimate indicators need to be involved in the process of urban planning objectives from the start - Project Description and Concept Design Phase.

In order to achieve this in Case Study 2, it is necessary to establish the cooperation project stakeholders - Leskovac City Council. The local government announced a public competition for the reconstruction of its main square in Leskovac called ‘The open, public, preliminary competition for urban design of the Central Zone of Leskovac’ on 8\textsuperscript{th} July 2013, as there was a need to reconstruct the main square in Leskovac (Fig 4.6). The unplanned interventions and a great area of parking space which was not adequately maintained significantly influenced the quality and character of the square in the last decade. The microclimate comfort, which is the subject of this thesis, was not included in the competition objectives\textsuperscript{23}, even though we can see by analysing the location of the city square that there are extremes in terms of thermal conditions during the summer time. The consequence of this was that the competition jury was not completely satisfied with any of the proposed solutions, so instead of the first prize, there were two first special mentions (proposal no. 15498 and no. 10194). The focus of the research in this part of the thesis is that we firstly test the existing layout of the square and the two above – mentioned competition proposals (no. 15498 and no. 10194) by ENVI-met 3.1 Beta 5 model with the aim to create a solution scenario that will improve the microclimate comfort of the main square in Leskovac. This will be further explained in the following section.

\begin{center}
\textbf{Fig.4.6: Present state of the competition territory. Source: City of Leskovac [Source: http://www.gradleskovac.org/]}
\end{center}

\textsuperscript{22} Djukić, A., Vukmirović, M., Stanković, S. 'Principles of climate sensitive urban design analysis in identification of suitable urban design proposal. Case Study: Central Zone of Leskovac competition' in Energy and Buildings Vol. 115, 23-35. [Online] ELSEVIER, Available at https://doi.org/10.1016/j.enbuild.2015.03.057

\textsuperscript{23} The competition objectives are as follows: update the public square, give an advantage to pedestrians than vehicles by building interconnect routes, define hard surfaces and develop the landscape design, propose an urban furniture and re-arrange existing parking space.
4.2.2 Case study description

It is evident that the main square in Leskovac does not provide a sufficient level of microclimatic comfort because of high temperature above a large area of pavement and parking area and the consequences of this are seen in the lack of users. In order to alleviate high temperatures on the main square in Leskovac and prevent the creation the Urban Heat Island (UHI) (Jones, Phino, Tweed, 2009) as a result of the ever-present climate change, it was necessary to make the square more liveable and vital (Hass, 1993; Gehl, 2004; Gehl 2006). In that way the number of users and their activities on the square will be significantly increased (Nikolopolous, Lykoudis, 2006; Stathopoulos, Wu, Zacharias, 2004). In this case, the microclimatic comfort is conditioned by the appropriate urban design concept which was selected by the competition and the morphology of urban environment. Instead of creating a new main square in Leskovac, a better solution is to do the retrofiting of the existing square by using the best rated competition proposals. In this section, the first two special proposals selected by the competition jury (no. 15498 and no. 10194) for Leskovac square will be tested and compared to the existing situation.

![Fig. 4.7: The subject of the competition for urban design of the Central zone of Leskovac.](image)

The boundaries of the competition for the main square in Leskovac are defined by the Veternica River in the west, Liberation Boulevard (Bulevar Oslabodjenja) in the north, Kosta Stamenković St. in the east, and Stojan Ljubić St. in the south (Fig. 4.7). The diagonal street (Svetozar Marković) had two functions in the past: to connect the banks of the Veternica River with the main city square and Belgrade department store and so divide the central zone of the city into two parts. In 1983, the part of Svetozar Marković St. that led through the central zone was converted into a pedestrian zone (Fig 4.8). The City Park occupies the central position of the main square. In the City Park there is a monument dedicated to the Liberators of the First World War (in the south-west) and the monuments dedicated to Kosta Stamenković and Toma Zdravković (in the north), around which the citizens of Leskovac gather. All the buildings that surround the competition area were mostly built in modern style of the 1960s. These buildings are situated in the City Park in the following way: along the Veternica River in the west there is an eight storey residential and commercial building and a two-storey commercial office building (Economic Court); along the Liberation Boulevard from the northwest to the northeast there is a five-storey Belgrade Hotel, a two-storey business centre and a three-storey Belgrade department store; along Kosta Stamenković St. from the northeast to the southeast, there is a three-storey business centre, a two-storey administrative building, a two-storey residential building and a three-storey residential and commercial building; along Stojan Ljubić St. from the southwest to the southeast, there is an 8-storey residential and commercial building (called
South Block) with an annex which has a characteristic of a commercial office building and a six-storey Courthouse. Except the quay alongside the Veternica River which is in a quite good condition, the pavement and the parking area are in poor condition. These are the characteristics of the present state of the main square in Leskovac, so from this we can see that it was necessary to act urgently. The solution for this was seen in the announcement of the competition. The aim of the competition was to make the main square in Leskovac attractive, safe and pleasant, which would significantly increase its value and vitality. The competition tasks were covered:

- improving the open public spaces within competition area;
- integrating the pedestrian routes, where the advantage will be given to pedestrians rather than car traffic;
- reducing the pavement and parking area;
- improving the concept of green areas;
- proposing the urban furnishing and equipment; and
- reconstructing the parking area.

The significance of the two best ranked competition proposals (no. 15498 and no. 10194) will be described in the following way.

![Existing land use map](http://www.gradleskovac.org/)

Competition proposal no. 15498 (Fig. 4.9) shows the successful connection of old and new urban forms and structures at the ground level. We can observe the three main areas such as the public square, the City Park and the plateau based on that concept. They are integrated by the diagonal pedestrian route. The proposal is flexible as it offers the possibility for the users to move smoothly from one area to another. What can be concluded from this competition proposal is that the ratio between the hard surface and the green area is questionable. The users’ movement
is directed in an unnatural way by following concentrated circles, lines and de-level segments. It is evident from the competition proposal that the microclimate comfort, which significantly influences the vitality and everyday attendance of the place, was not analysed.

![Image](image_url)

Fig. 4.9: Competition proposal no. 15498 [Source: Competition Material, City of Leskovac]

Competition proposal no. 10194 (Fig 4.10) shows that the focus is on the reconstruction and the revitalisation of the central zone of Leskovac (Public Square+ City Park). The diagonal pedestrian route is the dominant element which connects the green areas with the public square located in the northeast. The ratio between the old and the new forms and structures is questionable. This proposal enables access to all users – the integration of the users into the space. The underground garage provides the possibility to eliminate the parking area from the ground level and convert it into a green area. The phenomenon of water that is proposed along the dominant diagonal pedestrian route will have a potential to create a microclimate comfort but unfortunately it looks more like a design element which is questionable in the open public spaces. It should have been formed more thoughtfully. Hard surface is dominant in the concept, with strict elements and structures which are the opposite of free green areas. The consequence of this is the lack of integrity between the built and the green areas, which results in creating unpleasant space for the users.
4.2.3 Methodology

In this section, the research is divided into four case studies:

- testing the existing state of the main square in Leskovac,
- testing the competition proposal no. 15498,
- testing the competition proposal no. 10194,
- developing a new solution scenario.

This requires the need to conduct a two-phase research. In the first phase the two best ranked proposals and the existing state of the main square were presented and examined in detail by the ENVI-met3.1 Beta 5 model tool. On the basis of these results, the second phase included the development of the solution scenario that was also tested by using the same methodology and tool. The parameters that define the setup of ENVI-met model are divided into two groups. The first group involves the following parameters: meteorological values taken from the Republic Hydro-meteorological Service of Serbia\(^2\); simulation date, time and duration, material and vegetation types, sun radiation factors, shades, air flow and etc. (See Table 4.2).

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Table 4.2 Model configuration input data for the ENV1-met simulation.

The second group of the parameters includes: geographical location on the Earth, the distribution of the surface material and soil type, the morphological structure of the environment with the focus on the position and the height of the surrounding building, as well as the positions and types of plants, etc.

The ENV1-met is based on grid pixels or cells which produce temperature maps in more detailed resolution\(^1\). The ENV1-met model is designed as a rectangular area with cells extending in \(x\), \(y\) and \(z\) directions. The competition area for the main square in Leskovac has the following dimensions 375mx325mx50m and is shown in the ENV1-met model by 150x130x30 cell grid with the cell dimension \(dx=2.5; dy=2.5; dz=3\) (see Table 4.3).

Table 4.3: Model area input data for the ENV1-met simulation.

The starting model constructed in ENV1-met is the existing state of the main square in Leskovac (see Fig. 4.8). This serves as a reference point on the basis of which we can see if the competition proposed solutions (see Fig. 4.11) would improve or deteriorate thermal performance and human experience. In this case, the thermal performance is the only parameters that was analysed in order to see the changes of the microclimate comfort. This was done in the following way: five ‘receptors’ (data-extraction points in ENV1-met grid) were set in the areas in which the existing state was significantly changed (see Fig. 4.12). The same methodology will be used when we test the solution which was created based on the results of the evolution of the existing state and the two best ranked competition solutions.

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Fig. 4.1: a) Area model – existing state and b) Area model with spatial allocation of points called receptors in which the temperature measures are extracted.
4.2.4 Results and Discussion

The simulation of the existing state of the main square in Leskovac in term of thermal analysis shows the following results (see Fig. 4.13) at different times of the day (10 AM, 12 AM, 2 PM and 4 PM). When analysing these results, as expected, the areas with intense vegetation have different microclimate conditions, in comparison to the areas where asphalt and concrete are dominant. Air temperature varies to the maximum of 3°C at the boundary between vegetated and non-vegetated area, while the temperature between high vegetation area and ground vegetation area [grass, bush...] is much lower - around 0.5-0.6°C. As we can see from the thermal maps, the parking area in front of Belgrade department store (in the northeast) and the business centre increases the air temperature around these buildings and its maximum is seen at the crossroads [between Liberation Boulevard and Kosta Stamenković St.] that is located in their proximity. On the thermal map recorded at 2 PM we can see the temperature maximum, so this period of the day will be used to analyse and compare the best ranked competition proposals.
The simulation results of the competition proposal no. 10194 show that the average increase of temperature was about 0.33 °C in the central zone of Leskovac. The largest deviations in the thermal performance were noticed in the area where the vegetation density is reduced [temperature increased] and the parking area next to Belgrade department store and business centre [temperature decreased]. The detailed comparative analyses of the results are presented in Figure 4.9. As expected, the area that did not suffer a significant urban change has not shown any significant deviations of thermal performance. The improvements were made in the north-eastern part of the tested area, with the reduction of 0.34 °C. However, the new pavement area that was proposed next to the crossroads between Stojan Ljubić St. and Svetozar Marković St. increases the air temperature by 0.41°C. The new organisation of the central zone of Leskovac did not significantly affect the rest of the main square.
The simulation results of the competition proposal no. 15498 show that the changed of the surface materialization in front of Beograd department store and business centre influenced the temperature drop by 0.32 °C. The similar situation occurred on the western edge of the site, where the transformation of parking area into green space also reduced the temperature by 0.24-0.47 °C. However, the increase of temperature was recorded on the northern and southern side of the square due to the lack of vegetation, with a maximum value of 0.51 °C. (See Fig. 4.14b).

After the analyses of the thermal maps of the two best ranked competition proposals and the existing state of the central zone of Leskovac, the next step was to propose a new solution, creating the scenario which would use the positive experience of the previous analysis (See Fig 4.16). The proposed solution scenario kept the concept of the diagonal pedestrian lane and the existing greenery in the City Park. New vegetation was designed in the north-western part and ‘water mirror’ was proposed beside the main lane.
The largest part of the existing city square (in the north-east) that had been paved with asphalt and concrete was converted into a green area. It was proposed that the smaller part of this area be paved with cool pavement technologies\(^{26}\) and enriched with splash fountains. A large marquee was set up in the south-east of the newly formed city square. The parking area in front of Belgrade Hotel was retained in term of capacity, but its materialisation and urban furniture were changed.

The additional analysis of the newly proposed solution scenario was done in ENVI-met (See Fig 4.17). Due to the reorganization of the public space and the use of the specific surface materialization with higher reflective index, lower temperatures were recorded across the site.

\(^{26}\) Cool pavements include a range of established and emerging technologies that communities are exploring as part of their heat island reduction efforts. The term currently refers to paving materials that reflect more solar energy, enhance water evaporation, or have been otherwise modified to remain cooler than conventional pavements.
Table 4.4 shows the comparison of temperatures between the existing and the final solution scenarios at different time of the day (10 AM, 12 PM, 2 PM and 4 PM) at certain points in the central zone of Leskovac (R1, R2, R3, R4 and R5). From the table we can see that on average the temperatures are lower - from 0.3 to almost 1.5°C (R5 at 12 PM). It is important to mention that the temperatures in R3 have been recorded to be slightly lower (between 0.1-0.3 °C) despite the fact that is located outside the competition area. The reason for that was to show that the changes of the surrounding areas influence their border areas. There is a slight difference between different simulations done by the ENVI-met, but the deviations in R5 are imperceptible (0.01-0.05 °C). All the above-mentioned facts show that the solution scenario has better microclimate comfort than the existing state. The results will be illustrated by the following graphs.
The graphs show the temperature plot at control points (receptors) for the existing solution, the two best ranked competition proposals and the solution scenario. In this way it is possible to have an overview of all the solution. Each receptor has its own position within competition area:

- R1 was placed on the dominant pedestrian lane that leads through the city park
- R2 was set on the square in front of Belgrade department store
- R5 was located in front of the business centre.

There are other two receptors that are set outside competition area in the border zone:

- R3 was placed in the Liberation Blvd.
- R4 was placed on the crossroads between Liberation Blvd. and Kosta Stamenković St.

These identified receptors will be further explained throughout the one day performance (24.07.2014) at the different time of the day (10AM, 12PM, 2PM and 4PM).

The difference in air temperature between the vegetated areas (R1) and the non-vegetated ones (R2, R3, R4 and R5) at 10 AM is evident. The existing state shows a higher temperature in R2 and R5, in comparison with other solution where the change of surface materialization and the dislocation of the parking occurred. The temperature of all the solutions was almost identical at control points R3 and R4 (See Graph 4.1). As we can see from the graph, the lowest temperature at all control points is related to the solution scenario.

![Graph 4.1 Leskovac - temperature plot at control points (receptors) at 10 AM, 24.07.2014 (Y-axes Temperature values in Celsius)](image1)

The temperatures values at 12 PM and 2 PM (See Graph 4.2, 4.2 and 4.4) are similar to the previous graph that shows the temperature at 10 AM. A significant difference in the air temperature between the solution scenario and the other solutions is evident at the receptors (R2 and R5). This difference is created because of the different materialisation (instead of asphalt area there is pavement, wood and grass area).

![Graph 4.2 Leskovac - temperature plot at control points (receptors) at 12 PM, 24.07.2014 (Y-axes Temperature values in Celsius)](image2)
Graph 4.3 Leskovac - temperature plot at control points (receptors) at 2 PM, 24.07.2014 (Y-axes Temperature values in Celsius)

Graph 4.4 Leskovac - temperature plot at control points (receptors) at 4PM 24.07.2014 (Y-axes Temperature values in Celsius)

At the end of the day the competition proposal scenarios (no. 10194 and no. 15498) have slightly lower air temperature than the existing state, but the solution scenario has a significantly lower temperature at R1, R2, R3 and R5 (except R4) than other solutions because of the change of materialisation and urban organisation.

The temperature difference on the vertical plane through the control points (R5 and R2) will be shown in the following graphs. The comparison between the following states will be analysed:

- the existing state and the competition proposal no. 10194;
- the existing state and the competition proposal no. 15498; and
- the existing state and the newly created solution scenario.

A minor improvement in cooling effect (from 0.09 to 0.5°C) can be seen in both competition proposals, while the vertical profile of the solution scenario has major improvements in the cooling effect than the existing state, reaching 1.3°C (between 0.2 and 1.3°C). The reason for this can be seen in the change of the materialisation and the additional vegetation.
Fig. 4.18 Temperature difference in vertical section plane through R2 and R5: a) between the existing state and proposal 10194; b) between the existing state and proposal 15498; c) between the existing state and final proposed solution.

The following graphs will show the temperature difference on the vertical plane through the control point (R1) (See Fig 4.18 and 4.19). The comparison between the following states will also be analysed:

- the existing state and the competition proposal no. 10194;
- the existing state and the competition proposal no. 15498; and
- the existing state and the newly created solution scenario.

As we can see from the graphs, there was no change as the pavement and the vegetation area in this section stayed relatively the same.
Fig. 4.19 Temperature difference in vertical section plane through R1: a) between the existing state and proposal 10194; b) between the existing state and proposal 15498; c) between the existing state and the final proposed solution;

4.3 Key Conclusions

Golany’s theory based on principles that urban geometry mainly grid network of streets - improves the air circulating to the innermost part of the urban areas by orientating urban canopies along the dominant wind directions. This theory was tested in Case study 1 - Block 21 and used as the guidelines in Case Study 2 – Main Square Leskovac.

Case study 1 confirms the part of Golany’s theory that wind speed in areas with high density and high-rise buildings is slower than in other areas, and also proved that the size and density of cities affect temperature levels within the city. The results of the ENVI-met simulations of the Block 21 before and after the transformation confirmed Golany’s theory that the changes of urban morphology have a negative impact on the urban environment and thermal comfort. This can be seen through blocking the wind temperature flux and building new structures which resulted in the increase of the air temperature by 2.4 °C within the open public spaces of the Block 21. All of the above-mentioned led to the degradation of the space amenities - the PMV value increased from neutral-slightly warmer (1.3 points) to the hot conditions (3+ points). This case study shows that urban planners should pay more attention to the configuration of urban density in order to fulfil the social, functional and microclimate requirements. All the above-mentioned facts should be taken into account in the context of contemporary urban design as proposed in the BG methodology.
Case Study 2 tests the newly proposed BG methodology on the central zone of Leskovac. The knowledge and results obtained from Case Study 1 about the importance of ESS indicators should be a part of urban planning specification.

As showed in Case Study 2, we have analysed the thermal comfort of the two best ranked competition proposals (no. 10194 and no. 15498), and compared them with the existing states. The results obtained by the ENVI-met show that the competition proposals did not improve the microclimate comfort in comparison to the existing state. This means that the climatic consideration was not involved in the competition criteria for the retrofitting of the main square in Leskovac. By following BG methodology approach, analysing ESS and implementing BG elements, a new solution scenario where the microclimate comfort would be improved was created. As we can see, the aspects of climate sensitivity should be clearly defined at the beginning of the preparation of competition documentation. This involves the temperature data for the existing site, as well as the comparative simulation of the temperature levels in order to efficiently reduce overheating in the composite site.

Key findings of these case studies can be summarized as follows:

- Ongoing urban methodology does not include ESS as parameters, so this approach should be changed.

- The newly proposed methodology in this PhD thesis suggests that microclimate comfort should be involved in the early stages of urban planning – Project Definition and Concept Design - in order to become an important criterion for the retrofitting of open public spaces in the future.

- Integrated Blue Green Elements have a positive effect on the thermal comfort of open public spaces and increase the use of those spaces.

- As presented in the both case studies, the computer based models were necessary to design and test the ESS performance indicators.

- From this it can be seen that the ENVI-met, as the only three dimensional software, fulfils all the criteria related to simulating and quantifying urban heat island effects. The characteristic of this software is analysing the influence of the vegetation on outdoor air temperature. In this way, the situation when a prize-winning competition proposal does not fulfil the microclimate criteria will be avoided.
5. Demo Site

The outcomes of the previous two case studies (Block 21, Belgrade and Leskovac), explained in the previous chapter enable us to gain new knowledge and experience that will be used and applied to the demo site (Imperial College South Kensington Campus). The good practice noticed in the case studies is applied in open public spaces within a public domain - Imperial College South Kensington Campus - to find the correlation between BGD elements and urban design practice. In that way we analyse the environmental impacts of urban regeneration. The urban geometry of the Campus was created exactly as it was built, and it was not changed. It plays an important role in the microclimate. Due to the high density of the buildings at Imperial College Campus (ICL), it was decided that there would not be any changes of its urban geometry. Thus some interventions were necessary on the surfaces on the ground and on the roofs of the buildings according to Blue Green Dream Principles which significantly influence the microclimate comfort of open public spaces. At the demo site the analysis of microclimate was performed in three scenarios:

- Scenario 1 - Existing ICL site
- Scenario 2 - Ideal disposition of BGD measures
- Scenario 3 - Optimal disposition of BGD measures

Scenario 1 analyses the microclimate comfort of the existing state of Imperial College London Campus (i.e. open public spaces within a public domain). The present situation of the campus was analysed and based on this analysis we created the model that corresponds to the real life situation. The purpose of this analysis is to determine the existing situation of urban design and to set the point of reference for all other simulation scenarios.

Scenario 2 was designed to implement the maximum amount of BGD elements on the site, regardless of the functional or science-practice rules. For example, every roof was treated as a green roof, no matter if there were technical and economic possibilities for that or not. The aim of this analysis is to have the best case scenario results. The simulations for the first two scenarios are straightforward and will serve as a point of reference for the proposed BGD scenario.

Scenario 3 is actually a final BGD proposed solution, developed and designed with help of Adaptation Support Tool [AST]27. AST is the software tool designed by the Deltares, the industrial partner of the Blue Green Dream Project. Its purpose is to suggest the list of BGD adaptation elements based on the properties of the adaptation target.

The aim of the computer-based simulations is to verify the proposed methodology [new integrated approach]. The objective of this integrated approach is to create the solution that solves the main problems, but does not harm other indicators of urban design. The main principle of the integrated approach will be analysed at the demo site through three Ecosystem Services: Water Balance, Urban Micro Climate and Predicted Mean Vote28 [PMV]. General conclusions will be obtained and the main principles will be defined from the specific results, thus the future researches can implement all other ESSs in the same manner.

27. Adaptation Support Tool is developed at Deltares, Netherland as part of the BGD Project, link: http://climateapp.org/
28. PMV was originally developed for steady-state indoor situations, but by extending the energy flux related parts of the model with solar and long wave radiation and allowing wind speeds above an indoor room situation, PMV can also be applied with limits to outdoor situations (see e.g. German VDI 3787 Part 2, 2008). Normally, the PMV scale is defined between -4 (very cold) and +4 (very hot) where 0 is the thermal neutral (comfort) value. (See more, http://www.ienvi-met.info/doku.php?id=app:biomet_pmv)
5.1. Imperial College London – Open Public Spaces within a Public Domain

Imperial College South Kensington campus (See Fig. 5.1) is based in London, the capital of Great Britain. Geographical location is 51°30'26"N, 00°07'39"W. London has a characteristic climate with warm summers and cold and humid winters. The precipitation is modest throughout the year. Imperial College Campus is densely built and it is mostly edged by high vegetation along the streets. The Campus has the characteristics of a closed block where all the structures differ by height, form, material, etc. The structures are positioned in a way that they create closed public spaces that are usually covered by hard surface into which the air hardly penetrates, creating the phenomenon of Urban Heat Island.

![Fig. 5.1 ICL Panoramic view](source: Imperial College London Gallery)
5.3.1 Methodology

The methodological approach applied to a demo site (Imperial College Campus) was created in a way that it analyses and understands the existing water availability pattern, primarily the soil moisture and rain events. The data was provided by the weather station at Imperial College London South Kensington Campus [BGD PhD research – Green roof full-size experiment conducted by Miss Xi Liu, plus the weather data of London in the last 3 years]. Both data sets were compared and processed in order to form and set up the base point for the environmental analysis of open public spaces within the Campus. The analysed data was used to create the comparison between the rain events and the temperature values in order to recognize the availability of water for BG (blue and green) measures. In order to avoid any ‘silo’ solutions, when designing BG (blue and green) solutions, water availability on the site will be calculated [data from the local weather station] and interlinked in a sequenced manner, and the obtained weather results will be used as input parameters for the Urban Heat Island simulations. The Urban Heat Island simulation tool (ENVI-met) can provide the evaporation rate at the site which can be translated into the water consumption of BG (blue and green) elements. The objective is to understand the water balance and determine if there is enough water for BG solutions to provide the full functionality [evaporative cooling] at all times. Water balance differs by the application of different vegetation spaces. This helps us to understand the direct correlation between water and vegetation, as well as water availability and the Urban Heat Island. The aim is to understand the potential of the open public spaces and maximize the reduction of air and surface temperature in urban areas.

Before BGD concept for ICL South Kensington Campus was designed and tested, the current urban design issues and BGD methodology were analysed on the existing projects (Elephant and Castle Project, etc.). The phenomenon of urban creep\(^{29}\) was recognized by BGD Project as one of urban elements leading to the Urban Heat Island effect.

In microclimate simulations the main objective is to analyse the reduction of the Urban Heat Island effect by implementing BG solutions. Besides this, the Predicted Mean Vote [PMV] will be calculated to analyse the human thermal comfort in the outdoor environment. The output results from this model are air temperature, humidity, wind speed and PMV.

The methodological approach explains the way in which the three scenarios were created in order to perform the integrated impact analysis of urban design on urban microclimate.

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29. In Blue Green Dream Project, Urban Creep represents the loss of permeable (green) surfaces within urban areas.
5.3.2 Definition of Input Data for Scenarios

In order to understand and quantify the correlation between green elements and air temperature, it was necessary to build a computer based model. For this purpose, the ENVI-met solution was chosen. The BGD measures which are analysed in ENVI-met were derived from the Adaptation Support Tool knowledge database (part of the Blue Green Dream Project).

5.3.2.1 BGD Measure Selections

As a research follower in BGD project, I was a part of the team which developed a web-based tool for the selection of the best BGD measures for the specific area and the specific adaptation target [Deltares]. The AST tool is engine based on the literature review which provides the insight into the feasible BGD measures, ranking them, depending on the input parameters - project needs. The tool works based on several input settings. Bellow you can see the list of the settings and the values used for the Demo Site:

- Adaptation target – Heat [mitigation of the URBAN HEAT ISLAND]
- Land use – City Centre
- Dominant soil type – Clay
- Surface level and slope – Flat Area on low ground
- Scale - Neighbourhood
- Project type – Retrofitting [Improving the existing situation]

By using the AST, the following list of BGD measures was selected to be tested for Imperial College Campus:

1. Change of surface materialisation [vegetated surfaces - reduction of paved surfaces, use of cool paving materials]
2. Additional greenery in the streetscape [trees and shrubbery]
3. Green roofs and green facades
4. Cooling with water elements [swales or fountains]
5. Retention/detention ponds
6. Different surface types/materials [concrete, asphalt, cool materials]
7. Improved soil infiltration capacity

In the next part of the chapter, the detailed explanation of the simulation setup and results will be analysed.

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30. AST, Deltares (https://www.deltares.nl/en/software/adaptation-support-tool-ast/)
31. Data obtained from the UK Soil Observatory http://www.ukso.org
5.3.2.2 Simulation Input Parameters

ENVI-met microclimate simulations tool requires some specific input information and setting to produce the calculations for a specific site (explained in Chapter 3). In this chapter, the origin and the values of the data used for ICL Campus simulations is elaborated.

5.3.2.2.1 Weather Data

The simulations were conducted based on the data records from 2015. After analysing the Met Office (UK Meteorological office) data from 2013 to 2015, the average temperature of London was from 4.3°C in January [coldest month] to 25.5 °C in July [warmest month], respectively (Met Office, 2016). The average relative humidity was 85% in January and 70% in July. This data was compared with the obtained weather data from BGD (blue, green dream) weather station and used for the microclimate simulations of the Urban Heat Island. The weather data obtained from BGD weather station based at East Side Building, Imperial College South Kensington Campus showed similar results [weather station is a part of BGD PhD research program - The Blue-Green roof ful-size experiment conducted by Miss Xi Liu]. The detailed weather data from the local weather station [temperature, air humidity and rainfall] will serve as the input data for the computer simulations in order to mimic the exact weather conditions. One specific day, 26th July was selected for the Urban Heat Island simulations as it is the day with the highest temperature value in the season (See Graph 5.1).

![Average Temperature Graph](image)

Graph 5.1 Temperature plot in the demo site [Results obtained from BGD weather station at the site]
5.3.2.2 Water Availability

As vegetation requires water to perform the evaporation function, the water availability analysis was performed to evaluate the feasibility at the demo site. The data from the local BGD weather station was analysed in order to establish if the rain events are sufficient to support BG measures.

Graph 5.2 Water precipitation during the 2014 and 2015 [Results obtained from BGD weather station at the site]

On Graph 5.2 can be seen the constant precipitation trend during the year, with relatively short and low intensity. The accumulated amount of rain water during the period from June 2014 till December 2015 is presented on Graph 5.3.

Graph 5.3 Accumulative preview of the rain water availability [Results obtained from BGD weather station at the site]
As presented on graph 5.3, the total accumulated amount is 895.6 mm, where the total rainfall in 2015 was 473.4mm (disparity of 422.2mm). The water analysis was performed to analyse water availability for the Urban Heat Island reduction measures. The hottest months during last three years, for which the microclimate simulations were performed, were analysed.

![Precipitation in July 2015](image)

Graph 5.4 Accumulative preview of the rain water availability in July 2015 [Results obtained from BGD weather station at the site]

The obtained results and the data from the parametric analysis were used as the soil moisture indicator in the ENVI-met setup. This determines how vegetation can provide the impact on the local microclimate by evaporative cooling. On Graph 5.4 it can be noticed that the total rainfall amount in July 2015 was only 59.8mm. Having compared it to the same period in 2014, the total amount is even smaller (See Graph 5.5).

![Comparison of rainfall between July 2014 and July 2015](image)

Graph 5.5 Comparison of rainfall between July 2014 and July 2015 [Results obtained from the BGD weather station at the site]

Metadata recorded by the BGD weather station shows long dry periods during the hot summer months. For example, there were 20 [64.51%] dry days in July 2015, and 21 [67.74%] in the same period during 2014.
This is a clear indicator that the rainfall water harvesting is not sufficient enough to support the vegetation and its function of evaporative cooling. Other methods or additional water supply are needed. The literature review and the AST results show that the most common measures for supplying additional water supply are rainwater harvesting and grey water recycling. **Rain water harvesting** can be done directly from all impervious areas and roofs. To use this harvested water it is necessary to have the collection reservoirs. Reservoir volume is determined by balancing the cumulative inflow (surface runoff or green roof overflow) and the need for potential evaporation. However, the biggest need for these services are during hot summer months when in most climate conditions rainfall is at its minimum. In that case we can rely on some other non-conventional water resources such as the **recycling of grey water** (or at least hand washing sink water). This type of water is available in all types of settlements (residential, commercial, public, tourist/recreational).

As water availability analysis is done regardless of the potential and the impact of rainwater harvesting or the grey water recycling, the potentials of such solutions were analysed in the microclimate simulations. In the ENVI-met tool, the soil moisture parameter was adjusted to simulate different scenarios. Besides the different layouts and the combination of BG measures, each of the above mentioned Imperial College scenarios has different soil moisture parameters:

1. 0% in top soil layer [first 50cm]- To simulate the situation where there is no water available for evaporative cooling
2. 50% in top soil layer [first 50cm]- to simulate situation if the vegetation is supported with the sufficient amount of water for evaporative cooling
3. 100% in top soil layer [first 50cm] – to simulate situation if the vegetation is fully supported with water for evaporative cooling

### 5.3.2.3 Position and Type of the Plants

The positioning of the plants was determined by the urban structure and the availability of the space. However, the types of vegetation were selected based on the research called Valuing London’s urban forest (Roger et al., 2015). In the research the record of 126 species is stated, of which the most common are sycamore (Acer Pseudoplatanus), English oak (Quercus robur) and Silver birch (Betula pendula) (See Fig 5.2).
Hence, these four most common species are used for vegetation in the microclimate simulations later in this chapter. Plant parameters used in ENVI-met are presented in the table below.

<table>
<thead>
<tr>
<th>Latin name</th>
<th>Common name</th>
<th>Height (m)</th>
<th>Width (m)</th>
<th>Depth of Root (m)</th>
<th>Diameter Root (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acer Pseudoplatanus</td>
<td>Maple</td>
<td>15</td>
<td>11</td>
<td>3.5</td>
<td>12.5</td>
</tr>
<tr>
<td>Betula Pendula</td>
<td>Silver Birch</td>
<td>6</td>
<td>7</td>
<td>1.4</td>
<td>10</td>
</tr>
<tr>
<td>Platanus Acerifolia</td>
<td>London/Hybrid Plane</td>
<td>20</td>
<td>15</td>
<td>1.5</td>
<td>10</td>
</tr>
<tr>
<td>Quercus Robur</td>
<td>English Oak</td>
<td>25</td>
<td>15</td>
<td>15</td>
<td>25</td>
</tr>
</tbody>
</table>

Table 5.1 Parameters for tree used in the microclimate simulations
5.3.2.4  Configuration File Parameters

Concerning all the above-mentioned parameters, the computer based models were developed. The configuration file setup for all the models in this chapter are the same, and they are presented in the tables below (See Table 5.2-5.5). The only difference is in the spatial layout of the buildings and the materialization of the space [implementation of BG infrastructure].

<table>
<thead>
<tr>
<th>Model parameter</th>
<th>Model Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Simulation date</td>
<td>25.07.2015</td>
</tr>
<tr>
<td>Starting time</td>
<td>6am, on 24 July 2013</td>
</tr>
<tr>
<td>Time for initialization [h]</td>
<td>From 6am on 24 July 2015 till 6am 26 July 2015</td>
</tr>
<tr>
<td>Simulation Duration [h]</td>
<td>48h</td>
</tr>
<tr>
<td>Initial air temperature [K][°C]</td>
<td>Calculated by software*</td>
</tr>
<tr>
<td>Wind speed 10m above ground [m/s]</td>
<td>3</td>
</tr>
<tr>
<td>Wind direction [North, East, West]</td>
<td>225 [South West]</td>
</tr>
<tr>
<td>Relative humidity at 2 m [%]</td>
<td>50</td>
</tr>
<tr>
<td>Specific humidity in 2500 m [g water/kg air−1]</td>
<td>7</td>
</tr>
<tr>
<td>Cloud cover [low/mid/high]</td>
<td>0/0/0</td>
</tr>
<tr>
<td>Adjustment factor for solar input</td>
<td>1</td>
</tr>
</tbody>
</table>

*air temperature data from weather station is used, thus software calculate the initial air temperature accordingly.

Table 5.2 Model configuration input data for the ENVI-met simulation.

<table>
<thead>
<tr>
<th>Imperial Campus Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dimensions in grid cells</td>
</tr>
<tr>
<td>Size of grid cell in meters</td>
</tr>
<tr>
<td>Location</td>
</tr>
</tbody>
</table>

Table 5.3 Model area input data for the ENVI-met simulation

<table>
<thead>
<tr>
<th>Inside Temperature [K]</th>
<th>Default values</th>
<th>Albedo-changed model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kerne temperature</td>
<td>293 [19.85°C]</td>
<td>293 [19.85°C]</td>
</tr>
<tr>
<td>Heat transmission walls [W/m²K]</td>
<td>1.940</td>
<td>1.940</td>
</tr>
<tr>
<td>Heat transmission roofs [W/m²K]</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>Albedo wall</td>
<td>0.2</td>
<td>0.5</td>
</tr>
<tr>
<td>Albedo roof</td>
<td>0.3</td>
<td>1.0</td>
</tr>
</tbody>
</table>

Table 5.4 Building properties

<table>
<thead>
<tr>
<th>Temperature [K]</th>
<th>Soil moisture [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upper layer</td>
<td>293 [19.85°C]</td>
</tr>
<tr>
<td>Middle layer</td>
<td>295 [21.85°C]</td>
</tr>
<tr>
<td>Deep layer</td>
<td>293 [19.85°C]</td>
</tr>
</tbody>
</table>

*as explained above, the upper layer differs between different scenarios.

Table 5.5 Soil Properties
<table>
<thead>
<tr>
<th>Name</th>
<th>DO</th>
<th>L1</th>
<th>XX</th>
<th>Tb</th>
</tr>
</thead>
<tbody>
<tr>
<td>TY</td>
<td>01</td>
<td>01</td>
<td>03</td>
<td>01</td>
</tr>
<tr>
<td>rs_min</td>
<td>400</td>
<td>400</td>
<td>200</td>
<td>400</td>
</tr>
<tr>
<td>a_f</td>
<td>0.2</td>
<td>0.2</td>
<td>0.2</td>
<td>0.2</td>
</tr>
<tr>
<td>HH_HH</td>
<td>20</td>
<td>15</td>
<td>0.63</td>
<td>16</td>
</tr>
<tr>
<td>TT_TT</td>
<td>2.0</td>
<td>2.0</td>
<td>2.0</td>
<td>2.0</td>
</tr>
<tr>
<td>LAD1-LAD10</td>
<td>0.110 0.140 0.180 0.270</td>
<td>0.040 0.060 0.070 0.110</td>
<td>0.300 0.300 0.300 2.000</td>
<td>2.000 2.180</td>
</tr>
<tr>
<td></td>
<td>0.330 0.370 0.360 0.330</td>
<td>0.130 0.150 0.140 0.130</td>
<td>0.300 0.300 0.300 2.180</td>
<td>2.180 2.180</td>
</tr>
<tr>
<td></td>
<td>0.250 0.000</td>
<td>0.100 0.000</td>
<td>0.300 0.300 0.300 1.720</td>
<td>2.180 1.720</td>
</tr>
<tr>
<td></td>
<td>0.300</td>
<td>0.300</td>
<td>0.300</td>
<td>0.000</td>
</tr>
<tr>
<td>RAD</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
</tr>
<tr>
<td>Description</td>
<td>Tree, dense, no distinct crown layer</td>
<td>Tree, light 15 m</td>
<td>Grass, 50 cm average density</td>
<td>Tree, 15 m very density</td>
</tr>
</tbody>
</table>

Table 5.6 Plants Properties

Due to the complexity of the topic, it is important to mention that the microclimate simulations were performed with certain assumptions and restraints. The microclimate calculations were performed with the setup that the air temperature of all buildings at the demo site was the same – it was 23°C. Furthermore, no additional anthropogenic heat sources were calculated at the sites. This is one of the limitations of the performed simulation, as these heat sources largely influence the microclimate of the site. However, due to the fact that the goal of the thesis is not to predict the exact microclimate state but to determine the difference between different scenarios, the assumption was that if no anthropogenic heat is calculated, it will not influence the simulation results significantly. The cloud coverage was also excluded as the factor of the simulation. The Cloud Coverage parameters for low, medium and high clouds are set to 0 in all the simulations. The model itself has the nesting grid\(^3\) which represents the edges of the models that serves as a buffer to the temperature calculation. Thus, no additional protection layer of the model was needed to be developed.

### 5.3.2.2.5 Disposition of BGD Measures in Scenarios

The environmental parameters of the scenarios are explained in the previous sections. In this section the area model and the layout of each scenario are explained. The models will be explained related to the disposition of BG measures [urban geometry, vegetation, materialisation and water elements]. In the following three scenarios the urban geometry was recorder from the existing state, and did not vary from the scenarios. All models were built based on the survey done at Imperial College Campus (see Fig 5.3).

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32. The nesting grid is improve reliability of the calculation in core areas (see more, http://www.envi-met.org/doku.php?id=kb:nesting)
Fig. 5.3 Architecture drawings of survey ICL campus

Fig. 5.4 Map of the ICL campus - demo site section [Source: https://map.google.com]
Scenario 1 - representation of existing ICL campus layout

In Figures 5.5 and 5.6 the ENVI-met area model for the existing state is presented. The green infrastructure was recorded at the campus and translated to the model (See Fig 5.5). The surface materialisation was translated and the soil type was built to match the real world (See Fig 5.6).
Scenario 2 – Ideal Disposition of BGD Measures

Fig. 5.7 The area model of the ideal disposition of BGD measures

Fig. 5.8 100% surface type model
AST selected BGD adaptation measures have been applied in the second scenario in the following manner:

**Increased vegetation**

In the area of Imperial College, Exhibition and Prince Consort Road, the new three lines (London Plane) have been planted to cover the pedestrian communication with shade all the way and to reduce the air temperature. Also, in Queen’s Lawn and Imperial Union lawn new trees have been planted. In this part, the combination of the London Plane and the English Oak is used.

**Change of the surface materialisation**

At demo site, on Exhibition and Prince Consort Road the surface materialisation is changed from asphalt to cool paving (ENVI-met material Light Concrete with higher albedo and lower thermal capacity). These measures were introduced to reduce the air temperature due to direct radiation.

One part of the pedestrian walkways has been changed from concrete slabs to materials with better thermal and infiltration characteristics (See Fig 5.6). In this case, crushed brick was used. The remaining pedestrian walk was removed and replaced with natural grass.

**Introduction of green roofs on all rooftops**

Although there is no technical possibility to install green roofs on the campus (except on several buildings), in this scenario all roofs have been treated in the simulation tool as green to support the URBAN HEAT ISLAND effect reduction.

**Introduction of the water elements**

The literature review of the detailed Computational fluid dynamics (CFD) models which calculate heat, mass and momentum transfer between surface - water droplets - air (Emmanuel, et. Al, 2007), shows that water has a positive effect on air temperature. Water fountains have a cooling effect between 1°C and 4°C. With regard to that, water elements were introduced on the Queen’s lawn next to the Queen’s Tower, and in front of the Mechanical Engineering Building.
The solution follows the good practice of the change in surface materialisation (see Fig 5.9) and the introduction of new green elements (See Fig 5.10), although small restrictions were made due to the feasibility of the practice. The applied BGD measures are described below (compared to the measured from scenario 2).
Increased vegetation

The vegetation at Imperial College and on Exhibition and Prince Consort Road was preserved. However, the vegetation was removed from the Queen’s Lawn and Tower, due to the organisational purposes of the places.

Change of the surface materialisation

At Imperial College and on Exhibition and Prince Consort Road the surface materialisation kept the cool paving, but the pedestrian walkways were changed into concrete slabs due to the functional need of the college.

Introduction of green roofs an all rooftops

A green roof remained only at the East Side Building. On other rooftops there is no structural capacity for the installation or no space due to the ventilation installations and the equipment.

Introduction of water elements

Water elements were kept on the Queen’s lawn next to the Queen’s Tower and in front of the Mechanical Engineering Building.
5.3.3 Results

This section describes the results obtained from the simulations on Demo site. In these ENVI-met simulations, the emphasis has been put on investigating the relation of blue and green interaction, and its impacts on microclimate. Throughout the scenarios, the quantification of vegetation thermal performance was simulated, taking into account different water availability levels. The results of the computer based simulation of microclimate conditions were consolidated and the effects of BGD solutions were elaborated through human comfort indicator (PMV), which is a combination of several microclimate factors (air and surface temperature, wind speed/direction, direct/indirect radiation, humidity). Although in certain scenarios the air temperatures do not differ significantly, the combination of all microclimate factors can present an improvement in human comfort in open public spaces.

In all scenarios, the microclimate conditions were controlled at four different points of time during the day to have a clear indication of UHI effect. These times were 10.00, 12.00, 14.00, and 16.00. The scope of the analysis is the area between the Imperial College Rd, Exhibition Rd and the Prince Consort Rd. The outside buildings were developed to shield the model and served as a buffer of the model.

5.3.3.1 Scenario 1 - Representation of Existing ICL Campus Layout

![Diagram showing air temperature at different times]

Fig 5.11 Existing state solution at the soil saturation at 0% - air temperature analysis

Air temperature results are presented in Fig. 5.11. As it can be seen from the Figure, air temperatures are lower over the areas covered by vegetation, in comparison to the ones without vegetation. The
temperatures are lower in the morning, where max temperature is 26.3 degrees, and rising to the max temperature of 34.5 degrees at 16.00. The area of the Imperial College Road with tree line [in front of the Skampton building] has lower temperature by 0.43 degrees, compared to the same road without the trees in front of the Imperial College Central Library.

![Image](image.jpg)

10.00

12.00

14.00

16.00

Fig 5.12 Existing state solution at the soil saturation at 0% - PMV analysis

Hence, human comfort, presented in Fig. 5.12 shows that the same areas are less pleasant to be at during the same period of time. Human comfort, presented by the PMV value, indicates that the Exhibition Rd and Prince Consort Road are significantly more unpleasant to be at (between 2.55 and 3.40), compared to the Imperial College Road, where maximal PMV value does not cross 2.66. At this scenario setup the Queen’s Tower and Princes Garden have the average PMV value of 2.5.
In Figure 5.13 the same scenario was analysed again, but the setup of the soil moisture was changed from 0% to 50%. The aim was to validate the influence of water availability on the UHI reduction. As can be seen in the Figure, general temperature reduction was noticed throughout the site. At 10.00 and 12.00, no significant differences were noticed compared to 0% soil saturation, between 0.1 and 0.3 degrees. At 14.00 and 16.00 results slightly bigger difference were recorded, 0.4 and 0.56 degrees. Once again, the vegetated areas had the biggest drop in the air temperature. These results proved the theory that water availability has an impact on the Urban Heat Island reduction. The same pattern was recorded in the analysis of the PMV values (See Fig. 5.13). The PMV values were rising from 0.83 at 10.00 to 2.2 at 16.00. The open public spaces of the demo site are slightly warmer, where the only exception is the Imperial College Road with PMV value of 2.43 at 16.00. A significant reduction of the PMV value was also recorded at the Queens lawn, where, compared to 4.49 in the setup with 0% soil moisture, in the version with 50% soil moisture, the value dropped slightly under 4 [3.98] at 16.00. These results were the direct influence only of water availability as the only difference from the previous version was the soil moisture percentage.
Fig 5.14 Existing state solution at the soil saturation at 50% - PMV analysis

Fig 5.15 Existing state solution at the soil saturation at 100% air temperature analysis
Fig 5.16 Existing state solution at the soil saturation at 100% - PMV analysis

The PMV values presented in Fig. 5.16 showed that human comfort improved from 0.28 to 0.72 points. Even in the morning, the PMV was 0.8 [almost natural], compared to the same time in other setups, 1.02 with 50% soil moisture and 1.29 with 0% of soil moisture setup. As expected, the biggest improvement was recorded in the vegetated areas on Imperial College Road and the Princess Garden where the PMV value was around 2.

Thus, in this section, the direct correlation between the blue and green elements was recognised and quantified. On the demo site the temperature reduced on average by 0.53 degrees [difference is related to 0% and 100% soil moisture setup] just by providing a sufficient amount of water to the vegetation at all the times.

From these three setups of the existing scenario, the areas with unpleasant microclimate conditions for humans on the demo site were recognised and these areas will be treated in the third scenario. However, before the third scenario was developed, the ideal (full potential impact) case scenario of the disposition of BGD elements in order to reduce Urban Heat Island effect was analysed. In the next section the Ideal disposition of the BGD measures will be analysed to research the impact of BG solutions.
5.3.3.2 Scenario 2 – Ideal Disposition of BGD Measures

Fig. 5.17 Ideal disposition of BGD measures at the soil saturation at 0% air temperature analysis

As the problematic areas of open public spaces on the demo site were identified, the application of BG solutions was suggested. In this section, the integration of all the Urban Heat Island reduction measures suggested by AST was done. In this scenario the aim is to find the third scenario, which has the biggest impact on the Urban Heat Island effect, regardless of the feasibility.

The Urban Heat Island reduction measure implemented in this scenario yielded results (See Fig. 5.17). The average lower air temperature was recorded in this scenario, even in comparison to the scenario 1 with the setup of the 100% soil moisture. The air temperature in the scenario 1 was 32.67 degrees, whereas at the same period Scenario 2, with the 0% soil moisture setup, had 32.55 degrees air temperature. Although the BG infrastructure has a positive impact on the comfort of the open public spaces, the change in the surface materialisation provided some results as well. In the inner block of the demo site [Ayrton Rd and Callendar Rd], the change of surface materialisation reduced the temperature by 0.23 degrees.
This scenario showed the lower PMV values in general (Fig. 5.18). The difference between the values presents the improvement in the comfort of the open public spaces as well. The reduction of the values at 10.00 were not significant, however, at 16.00 these differences were around 0.3, compared to the existing scenario. Newly created Scenario 2 shows how the problems identified in the existing scenario were solved. By the introduction of the selected BG measures (See Section 5.3.2.1.) at the problematic areas on the demo site [Exhibition Rd, a part of the Imperial College Rd, Prince Convert Rd], a great improvement was observed. This improvement was seen through the creation of the open public spaces connected with corridors which have approximately equal values of comfort. The results presented in Fig. 5.18 were calculated with the 0% soil moisture setup, thus the reduction in values was not significant.

When the setups of 50% (See Fig. 5.19) and 100% (See Fig.5.20) soil moisture were analysed, much higher reductions of air temperature were recognized. For example, at 10 AM air temperatures were 25.2, 24.8 and 24.4 degrees in the setups of 0%, 50% and 100% soil moisture respectively. The GI supported by water has the stronger influence on the Urban Heat Island reduction.
Fig 5.19 Ideal disposition of BGD measures at the soil saturation at 50% air temperature analysis

Fig 5.20 Ideal disposition of BGD measures at the soil saturation at 100% air temperature analysis
In Fig. 5.21 the PMV values of the scenario setup are much better compared to the existing situation. At 16.00 the reduction of the values was 10.54%, compared to the scenario with the same setup. The green infrastructure is improving human comfort in space. The results for 16.00 are on the border between 1.75 and 2.09, with a positive improvement compared to the existing scenario results with the peak of 2.47.

All positive experiences from this scenario will be considered when proposing scenario 3, according to the feasibility and the technical possibility of the BG measure implementation.
Scenario 3 - Proposed Optimal Disposition of BGD Measures

![Images showing temperature distribution at different times](image)

Fig 5.22 Optimal disposition of BGD measures at the soil saturation at 0% air temperature analysis

After the evaluation of the results from the first scenario and the testing of the parameters of the BGD measures in the second scenario, the third scenario was developed. The recognised good practices in the second scenario applicable on the demo site were used in order to improve the overall human comfort in open public spaces (See section 4.2.4). The results of the third scenario are presented in Fig. 5.22. At first sight, it can be noticed that the temperature is slightly higher than the temperature in scenario 2 [by 0.28 degrees], but lower compared to scenario 1 by 0.31 degrees. Since the goal of the third scenario is to offer a better urban design of the campus, the comparison between the first and third scenario will be made in this section.
Fig 5.23 Optimal disposition of BGD measures at the soil saturation at 0% - PMV analysis

The PMV values have the same pattern as the air temperature in the third scenario. In Fig. 5.23 it can be seen that the values were close to comfortable - 0.83 points at 10.00. As the day progresses, the heat is accumulated in the model, the microclimate is getting warmer, which ends with the maximum value of 3.18 points at the intersection of the Prince Consort Rd and Queen’s Gate where no BG solutions were introduced. At the same time, the intersection of the Imperial College Rd and Exhibition Rd shows the reduction of PMV value by 0.52 points. As the surface materialisation of both intersections is the same, the difference in comfort value can be associated with the BG infrastructure – shading effect.
Fig 5.24 Optimal disposition of BGD measures at the soil saturation at 50% air temperature analysis

Fig 5.25 Optimal disposition of BGD measures at the soil saturation at 50% - PMV analysis

With the increase of the water availability parameters in the model, the pattern of air temperatures varies between different setups of the third scenario (See Fig. 5.24 and 5.26). In the areas rich in
vegetation, the trend of temperature reduction is constant from the setup of 0% to 100% soil moisture. In Fig 5.25 it is obvious that human comfort follows the same trend. In the morning, at 10.00, the PMV values are 1.02 points and 0.83 points in the version of 50% and 100% soil moisture setup, respectively.

Finally, the BG measures implemented in the scenario 3 - setup with the 100% soil saturation - have shown promising results. The air temperatures were reduced by 0.2-1.16 degrees, depending on the area of the ICL campus. The highest reduction was recorded on the Imperial College Road, Exhibition Rd, and Queen’s Lawn. Hence, in the same area, the PMV values were reduced and in an acceptable range up to 2.4 points.
5.3.4 Discussion and Conclusion

After analysing the results of the microclimate simulations from all the above-mentioned scenarios and soil moisture variation, it was noticed that the highest temperatures during the day were recorded at 16:00, mostly due to the accumulation of the temperature in the city – Urban Heat Island effect. Hence, in this section all the results are the comparison of that specific period in time. In order to track the comparison of the results more easily, control points (the receptors) were introduced in the model. Receptors are the manually placed space markets in ENVI-met grid, and serve as the easy result extraction tool of the simulation results (across multiple scenarios), always at the same point in space (x,y,z coordinates). On the Demo site the receptors were placed as shown in Fig 5.28 and the results from these receptors are presented in this section.
The aim of the control points is to quantify the effects of the changes in the design of open public spaces at Imperial College London scenarios. Receptor R1 was positioned at Queen’s Lawn, where new water elements were introduced. R2, R4, R5 and R6 were positioned at Exhibition Rd, Princes Gardens, ICL Union Garden and Prince Consort Rd respectively, where a new tree line was introduced in addition to the change of the surface pavement. R3 was positioned in green areas, thus they will serve as a control point of the modes, as major differences in the results should not be present in these control points.

<table>
<thead>
<tr>
<th>Scenario</th>
<th>S1</th>
<th>S1</th>
<th>S1</th>
<th>S2</th>
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<th>S2</th>
<th>S3</th>
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Table 5.7 Temperature recordings from the receptors in all scenarios at 16:00
In the previous section it was established that water availability plays a significant role in temperature reduction in open public spaces. From Table 5.7 we can see that on average the simulated temperatures are lower from 0.5 to 1.5 degrees. Moreover, the temperature value in R3 remained the same (Graph 5.6) in all scenarios which verify the model, thus R3 will be removed from further analysis.

![Graph 5.6 Comparison of receptors temperatures between scenarios](image)

On Graph 5.7 it can be noticed that both the second scenario and the third scenario have lower temperatures than the existing one. The difference between the first and the second scenario in this case is from 0.64 [R5] to 1.16 degrees [R1]. The third solution has a slightly lower difference and it is between 0.31°C and 0.61°C. The biggest differences are in R1 and R6, where new greenery was introduced. As this is the case of 0% of the soil moisture, this difference is caused mainly by shading.

![Graph 5.7 Comparison of receptors - soil moisture was set to 0%](image)
Graph 5.8 Comparison of receptors - soil moisture was set to 50%

On Graph 5.8, where the model was set with the 50% soil moisture, the first noticed difference is that the temperature is generally lower in every model by 1°C due to the evapotranspiration of the vegetation. The second and third scenarios have maintained the trend of lower temperatures. The highest deviation from the existing solution was in R4, where S2 and S3 had a drop in temperature of 0.73 °C and 0.56°C, respectively.

Graph 5.9 Comparison of receptors - soil moisture was set to 100%

With the assumption that water availability for vegetation is 100%, we can see a significant improvement in the thermal performance in the third scenario. The areas around R1 and R6 have the same design in S2 and S3. Thus the air temperature did not change for both scenarios (Graph 5.9). On average, the temperature is lower by 0.68 °C.
Besides the air temperature reduction, the target of the simulation was to quantify the impacts that BGD solutions have on the microclimate of open public spaces. Human thermal comfort is quantified with PMV value and the results are presented in Table 5.8 and on Graph 5.10.

<table>
<thead>
<tr>
<th>Scenario</th>
<th>S1</th>
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<th>S1</th>
<th>S3</th>
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<td>50%</td>
<td>100%</td>
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<td>50%</td>
<td>100%</td>
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<td>4.38</td>
<td>4.10</td>
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<td>2.64</td>
<td>2.53</td>
<td>2.21</td>
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<td>4.18</td>
<td>4.07</td>
<td>3.80</td>
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<tr>
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<td>4.15</td>
<td>4.02</td>
<td>2.51</td>
<td>2.50</td>
<td>2.06</td>
</tr>
<tr>
<td>R5</td>
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<td>3.80</td>
<td>4.11</td>
<td>3.89</td>
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</tr>
<tr>
<td>R6</td>
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<td>4.29</td>
<td>4.15</td>
<td>2.84</td>
<td>2.26</td>
<td>2.22</td>
</tr>
</tbody>
</table>

Table 5.8: PMV recordings from receptors in all scenarios at 16:00

The PMV values are compared between the first scenario (existing state) and the third scenario (optimal disposition of BGD measures) as the final control factor of the new proposed methodology.

Graph 5.10: PMV values in receptors comparison of across all scenarios

At first glance it can be seen from the results that human thermal comfort at all controlled points (all receptors) was improved. The values of receptor 3 are almost the same for both scenarios as expected as this was the control of the simulation. The irrelevant deviation of 0.2-0.5 points can be explained by the change in wind speed and indirect radiation as result of measures nearby.
With receptors R1 and R5, slight improvements in comparison with the first scenario are obtained, due to the low amount of BGD measures applied. The slightly larger improvement, however, is in R1 area (0.14 points) due to the new applied shallow water body. The significant improvements are quantified at the R2, R4, and R6. The reason for such trend is the largest implementation of the BGD measures in these areas. Thus the improvements are continuing from 0% soil moisture to 100% soil moisture scenario. The improvements are larger than 2 points in some cases. However, the significance of the impact is in the fact that the microclimate condition changed from (>3 hot) to “warm” and “slight ward condition”33 (close to 2.0).

These results show that the small changes of thinking about the open public spaces and the use of the BGD (blue green dream) principles can improve their microclimate and human comfort. Besides that, these will trigger other side effects like water management systems, energy efficiency of the building, air quality, biodiversity, socialisation, etc.

The impact of the BGD measures was not shown in its full potential as the simulations have certain assumptions and restrictions. The next chapter is going to cover those and make suggestions for further work.

33. Expression from ANSI/ASHREA Standard 55 scale.
6. Summary and Conclusion

This chapter summarises the main findings and the final proposed steps for the paradigm shift in urban design. This chapter is made of the following:

- The summary of the thesis - made of the evidence-based on bullet point conclusions for each chapter.
- The contribution of knowledge - illustrates the new knowledge in an area of urban design.
- The recommendation for further work - addresses the limitations of the new proposed methodology and suggests further research potentials.
- Implications and Conclusions – present the possible application of the thesis results in practice related to the improvement of urban design of open public spaces.

6.1. Summary of Thesis

Chapter 1

- The current state of modern cities, their inability to cope with climate changes and its extremes is recognised as a research problem. The reason for city dehumanisation lays in the fact that urban practice is mostly driven only by economy without considering social, ecological and cultural aspects.
- Based on the preliminary theoretical research, three research hypotheses are set:
  - First hypothesis: Oriented urban design supported by blue and green infrastructure can facilitate a city’s adaptation to climate change and improve the amenities of open public spaces.
  - Second hypothesis: The new proposed methodology which includes ESS indicators in the earliest stages of urban planning will improve the process of urban design.
  - Third hypothesis: Urban design can be improved by the constant cross-checking and quantification of the ESS indicators and by the use of computer based models during the process of designing open public spaces.
- The Principal Objective is derived from the above-mentioned hypotheses: to recognize and quantify the interactions of the BG elements and urban design [at the neighbourhood level] and analyse their influence on other ESS in order to maximize human comfort in urban space.
- The Principal objective is accomplished by following actions:
  - Critical analysis of the current sustainable urban design and the development of cities resistant to global climate change;
  - Review of the current state of ecosystem services in urban design practices;
  - Analysing and validating the potential of the BG solutions via both quantitative and qualitative indicators;
  - Evaluation of an integrated approach through the verification of the environmental, economic and social aspects of urban design;
  - Reviewing methodologies used in urban design modelling related to ESS analysis;
Performing computer modelling and simulation of the selected ESS to confirm and quantify the positive effects of the proposed ESS based design methodology;
Optimization of the obtained results by using the comparison methods;
Deriving guidelines for architects and spatial planners from the applied methodology.
Analysing the limitations and potential application of the BGD philosophy

Chapter 2

- More than 50% of the world’s population lives in cities. By 2030, 47% of the world population will be living in the areas of high water stress. This implies that the current state of contemporary cities is not durable and persistent, requiring significant changes in city development.

- Human-city-nature relationship is recognised as crucial for city development and it is analysed through different research periods, ranging from Historical Review of Urbanization, Urban Design Concepts to Urban Design Principles.

- The historical review of urbanization defined as the research period shows how human acquisition of knowledge to overcome nature led to the degradation of the human-city-nature relationship, including the destruction of nature and the decrease of human amenities. However, during this period, no significant consequences of human actions to the nature have been observed due to the relatively small size of city footprints.

- In the period after the industrial revolution, the development of cities increased rapidly, creating urban design concepts with the aim to make a balance between human, city and nature. The improvements made by these urban design concepts merely slowed down the degradation of the human-city-nature relationship but did not stop it.

- In the 21st century the consequences of climate change have influenced decision making in a way that urban concepts have been replaced by the development of urban design principles. In order to solve the problems caused by climate change (such as extensive floods and droughts, air pollution, noise, temperature, and etc.), urban design principles have introduced computer based modelling of ESS in practise.

- Ecosystem Services present conditions and processes by which nature sustains and fulfils human life. Millennium Assessment 2015 has categorised ESS and its indicators which have been accepted by TEEB and UKEA.

- The issue related to urban design principles is seen in the fact that they treated each ESS and its indicators as a silo solution. This creates the need for the creation of an integrated approach in urban design process, which considers all the key aspects of urbanisation as well as quantifying the performance indicators of ESS.
Chapter 3

- Blue Green Dream project framework is a foundation of the new proposed methodology in which ecosystem services and their interactions are used as the starting points for the further simulation, analysis, testing, modelling and making experiments related to urban practice principles.

- In order to stimulate ESS in urban design practise, the analysis of the environmental simulation tools was done and ENVI-met, which is a suitable tool for the thesis methodology, was selected.

- ENVI-met was selected for the following reasons: open source, Windows based and the capabilities of the successful calculation of: Albedo (diffuse reflectivity or reflecting power of a surface), vegetation (plant type, stomata resistance, crown density, etc.), relative humidity (25-60 % RH - human comfort zone), evaporation, water bodies, material assignment (thermal conductivity), irradiation analysis (radiation process), Air Exchange (wind).

- New proposed methodology is based on the following key aspects:
  - Human-city: Focus is on human
  - Human-nature: Bring back human to nature
  - Nature-city: Bring city back to nature
  - Amenities as priority
  - Quantification: ESS has to be quantified

- In order to achieve results with the new proposed methodology and to answer all the above-mentioned key aspects, all the participants (including urban planners, architects and engineers) and scientists from other fields such as philopsphers, psychologists, sociologists, anthropologists and other experts should be involved from the beginning - concept stage.

- The new proposed methodology was tested on two selected case studies (Block 21, Belgrade and Main Square, Leskovac) and demo site Imperial College London Campus.

Chapter 4

- In order to test the first and the second hyphotesis, two case studies were selected due to the fact that they were built in modern period but reconstructed in the last two decades (Block 21 and Main Square in Leskovac)

- Block 21 was selected as it has the characteristics of a mono-functional residential block which was transformed in the period from 1990s to 2000s. The transformation has a negative impact on urban geometry, occupancy rate and nature-city relation (nature degradation). This case study is used as a good example to show how degradation of key aspects during the block transformation impacts the open public space amenities. The simulation of the ESS (UHI, amenities (PMV)) was done before and after the transformation. The results of the simulations show that the BG elements (or the absence of them) have a significant impact on both UHI and amenities (PMV). On average, the air temperature in the simulations was lower before the transformation (reduction between 0.5 -2.5°C). The amenities of space follow the same pattern and their factor value was lower before the transformation as well (around 20% or difference of
1.16 to 2 points). The first hypothesis that BG elements can improve the amenities and the thermal comfort of the space and increase its adaptation to climate changes has therefore been proved through the case study Blok 21.

- Main Square Leskovac was selected as it has the characteristics of open public spaces for which the reconstruction was announced. The proposed methodology was tested in order to understand how the integration of ESS in the concept design of open public spaces would impact the microclimate conditions. With the agreement with Municipality of Leskovac, the public call was announced without the ESS requirements. Two best-ranked scenarios were selected for the case study. Both were tested by computer based simulations and both failed in improving the microclimate solutions (UHI and PMV). The third scenario was developed by following the key aspects of new methodology, which at the end resulted in the improvement of the amenities at open public spaces by 20%. The second hypothesis, that implementation of ESS modelling in earlier stages of urban development process can improve the urban design, has been proved by the case study Leskovac.

Chapter 5

- The knowledge and experience obtained from the case studies were applied on the demo site. The demo the site was created in order to apply the new proposed methodology and test the full process from the selection of BGD measures, the design reconstruction scenarios, the computer based modelling to the proposition of the new final solution at the end. In order to achieve this, the following steps have been taken: a) selection of BGD measures, b) interaction of ESS, c) design of scenarios and d) simulation of ESS by using ENVI-met

- In order to select the BGD measures which will be applied on the demo site, the AST tool (developed as a part of the BGD Project) has been used. The following measures have been selected:
  - Change of the surface materialisation [vegetated surfaces - reduction of the paved surfaces, use of cool paving materials]
  - Additional greenery in the streetscape [trees and shrubbery]
  - Green roofs and green facades
  - Cooling with water elements [swales or fountains]
  - Retention/detention ponds
  - Different surface types/materials [concrete, asphalt, cool materials]
  - Improved soil infiltration capacity

- ESS indicator interactions require the analyses of the relation between water supply and greenery performance. Water supply levels were introduced in the ENVI-met simulations as soil moisture levels (which have direct correlation with evaporation). The results of the water availability analysis (obtained by weather station from ICL campus (part of BGD project)) show that rain water levels are low during the period of droughts (especially during the hottest days in year). In the concept design stage of BGD scenario, in which water analysis is included it is noted that all BGD measures have to be planned with additional water supply as the standard rain water harvesting system will not be sufficient.
• The reconstruction process of demo site scope was divided into three sections: 1) simulation of the existing state – base point, 2) implementation of the BG measure in an ideal case (regardless of function, roof capabilities, etc.) and 3) Optimal BGD solution, which is the final proposal.

• The focus of the final proposed solution was to improve the microclimate conditions of the area and allow the more pleasant usage of the space. Although air temperatures were not reduced by large margins (from 0.2 to 2 degrees), the simulation has shown the PMV factor has improved by up to 25% in certain areas (like Imperial College Road), which is a shift from the unpleasant to the pleasant space to be in.

• The interpolation of new proposed methodology (form selection of ESS to its simulations) in urban design practice form the concept stage which has significantly improved urban design of open public spaces.
6.2. Summary of Contribution to Knowledge

This dissertation is an active contribution to science and practice in the research of open public spaces at neighbourhood levels. The contribution to knowledge is seen in the new proposed methodology where the key aspects of urban development (human-nature-city relationship) are defined and established as its foundation. The key aspects are further elaborated though urban design factors that differ from case to case, depending on project requirements. Next step is to select ESS and its indicators which fulfil the project requirements. The computer based simulations of the selected ESS, especially their interactions, provide the creation of the new integrated approach (Fig 6.1). It ensures open public space improvements and the adaptation to climate change that is the principal aim of the thesis.

The new proposed methodology approach in urban design practise was validated on the demo site, in the following steps (Fig 6.1):

- Based on the established key aspects of urban development, urban development factors were selected and the project requirements were defined:
  - Environmental Factor: improve the microclimate condition of the open public spaces of the demo site
  - Social Factor: increase the amenities of space (human comfort)
- ESS indicators selected: in order to achieve water balance and UHI effect
- Computer based simulation: air temperature, surface temperature, humidity, wind speed and direction, PMV, direct/indirect radiation
- Introduction of the ecosystem services: analysing the impact of water availability on the thermal performance of the vegetation and its indicators in the integrated manner, and
- Use computer based models simulation in the stage of the concept design, where the three scenarios (existing state, ideal disposition of BGD measures and optimal disposition of BGD measures) have been simulated in several versions to find optimal scenario.
- In the end, the final proposed solution showed the improvement of the human thermal comfort (PMV) factor by 25%.

In this thesis, two urban design factors are used to test the interaction of the ES services and their indicators which proved the validity of the new proposed methodology. For further work, the inclusion of other urban design factors, as well as other ESS indicators (illustrated in Fig 6.2), is recommended.
Figure 6.1 Illustration of the proposed steps of the new methodology which is tested on demo site (environmental and social factors)
6.3. Recommendation for Further Work

Recommendations for further work refer to following aspects (Fig 6.2):

- Limitations of the input factors in ENVI-met
- Scope of ESS interactions simulations
- Scope of Urban Design Factors

The ENVI-met software is a multi-layer tool that requires numerous input data. ENVI-met tool simulations are set in a way that certain factors which have no impact on the simulation goals of the thesis were excluded (such as anthropogenic heat sources, cloud cover, etc.) and some values were assumed (including building temperature, building materialisation, etc.). In this case the simulation goal is not to get the precise prediction of the microclimate conditions, but rather to record the microclimate condition deviations between different scenarios. One of the recommendations for further work is to include all factors and replace the assumed values with the actual data in order to have a more precise quantification of the impact of BGD measures on microclimate conditions.

Further, the thesis has covered three ESS (water balance, UHI, PMV – amenities - and their correlation and integration). As the integration matrix has shown the positive effects of the interpolation of different ESS, the suggestion is that additional ESS should be included, such as biodiversity, CO2 Sequestration, noise reduction, aesthetics values, pluvial flooding, primary production, etc.

By including other ESS in further analysis, the scope of urban design factors can be broaden from environmental (which was the focus of the thesis) to social, economic and cultural. In this case recommendations refer to the performance of the cost-benefit analysis. The resource usage, initial investment, operational and maintenance costs (lifecycle cost) should be included in the simulation. Three simulation modelling tools are recommended to be used for further research: a) Green Infrastructure Validation Toolkit (GIVaT), b) The Value of Green Infrastructure CNT and c) Selling Sustainability in SKINN (SSIS). From them, the GIVaT is directly linked with the UK government policies and based on the Defra’s guidelines on the economic valuation of ESS, thus this could be an adequate choice.

Cultural urban factors can be supported by other factors through cross checking. This means that while solving the economic issues of the city (e.g. flood risk management) and improving microclimate, the aesthetic value of open public spaces could be improved in order to be used for tourism and recreation purposes.
Figure 6.2 Illustration of the proposed further work
6.4. Implications and Conclusions

The results of the thesis create possibilities for the proposed models and the principles, which could be applied in the practice of the improvement of urban design of open public spaces. This research is a good base for the specialization of different experts in the field of urban design practice. The aim is to bring the results closer to urban practice, but also to develop initiatives to analyse other ESS in the innovative BGD manner. Future work could be the analysis of the interaction between different ESS. For example, microclimate has a direct influence on energy consumption and the efficiency of the surrounding buildings (Reinhart et. al, 2013). Open public spaces are the basic elements of urban design, so the principles used in the scenarios (explained in Chapter 4) need to be tested within a different scope. The goal is to test and compare the application and the efficiency of the principles within the different scope of urban planning in the city. In that way the patterns of open public spaces could be established, as well as their mutual interconnections.

The technology for improving the local micro climate explained and modelled in the previous chapter has high potential for the application in the following areas:

- Sponge cities in China
- Dry/arid climates
- Open air restaurants, cafes

Sponge city, the term used for the first time by Xi Jinping, professor at Jiaotong-Liverpool University in Suzhou is the next phase in thinking how to deploy BGD infrastructure to handle and utilize the runoff. It is originally based on the same principles as SUDS in the UK, thus the application of the BGD philosophy shown in this thesis is highly applicable to the sponge city concept (Fig. 6.2).

Fig. 6.2 Sponge City China [Source: http://www.gochengdu.cn/images/upload.x/images/spongecity4.jpg]
The Ministry of Housing and Urban-Rural Development in China tested several of the Sponge City implemented projects and found out that in terms of flood the 85% reduction of the rain runoff could be controlled. This is a very good base for preventing floods and providing water resources for the GI.

Thermal microclimate is extremely important in dry climates. Vegetation plays a key role in enhancing the comfort in space. However, dry climate requires special thinking about water availability and the provision of water to green infrastructure. Rainwater harvesting and the implementation of GI in function of air temperature reduction are proved, as good combinations in this thesis are excellent candidates for such climates.

Fig. 6.3 Rain Garden, Denver [Source: Green Reserve Report: https://www3.epa.gov/npdes/pubs/arid_climates_casestudy.pdf]

Fig. 6.4 K66 Project, Ljubljana [Source: EnPlus, industrial partner of BGD project http://www.enplustech.com/]
All of the above-mentioned areas are the solutions for larger scale interventions. The final aim of the thesis is to improve human amenities in the city and increase the social connectivity. BG infrastructure can provide a nice and refreshing cool breeze to provide natural ventilation. A good example of this is the Café bar in Project K66 in Ljubljana (Fig 6.4), where the café and the restaurant terraces are cooled by natural ventilation.

As a scientist and humanist, the author is aware of his professional obligation to act preventively in the context and promote the development of the present-day city, as well as to connect theory with practice. A part of these recommendations and guidelines is expected to become the tool necessary for all the architects and urban planners who make the changes in the city. Architects who want to be political advisers and managers in the process of creating the sustainable city in the future can find helpful hints. Certainly, urban planners who want to be city and regional managers should not be ignored in order to successfully implement the result of the research in practice. The dissertation is intended for all the people who want to participate in this process in order to improve the quality of life in the city and achieve social cohesion. The author hopes that the above-mentioned participants will perceive the need for human connections and relationships. Synergy effects of the research can create a humane city, influencing all the participants in the process. The urban design is improved and its application is increased in the following ways:

- urban planners and designers need to verify and prove their ideas through simulations and experiments;
- blue and green components, together with biodiversity, should be dominant in the city;
- it is necessary to make green roofs, facades, and parking spaces in order to make up for the built spaces in the city that were taken from nature;
- Paving areas must be reduced to a minimum, and the drainage of water from them has to be regulated by permeable places;
- Pedestrian communication, squares and places of recreations in the city should be integrated into the blue-green component in order to enable people to feel comfortable in these places;
- The relationship between the permeable and waterproof surfaces in the city must be in favour of the permeable;
- Waste water, grey water and rain water should be accepted, stored, reused and filtered locally (rainwater should be treated at site);
- Open public spaces should be adapted to the needs of their citizens and users.
7. References

A


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Y


Z

8. Appendix

A: Published Papers


Blue Green Dream Project’s Solutions for Urban Areas in The Future

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Abstract
The adverse effects of intensifying climate extremes [floods, droughts and extreme heat] combined with increasing urbanization call for a new paradigm for efficient planning and management of the urban environment: one that maximizes ecosystem services and increases the capacity to changing climate. The new paradigm, which enhances rethinking of planning, design, construction, operation and maintenance of urban water systems [blue] and urban vegetated areas [green assets], not separately but in combination, placing emphasis on their mutual interactions. The Blue Green Dream [BDG] project enhances the synergy of urban BG systems of multifunctional Blue Green Solutions [BGS] including an Integrated Modelling System [BGD IMS]. The benefits include: increased amenities and urban health, enhanced resilience to drought and flood risk, reduced air pollution and noise, mitigation of urban heat islands, enhanced energy efficiency of buildings and enhancement of biodiversity and quality of life.

Keywords: Urban adaptation for CC, Blue Green Solutions, BGD Project, regional BGD centres, collaboration potential International Conference Places and Technologies 2014, Faculty of Architecture, University Belgrade
A2: Two papers at 1st International Academic Conference Places and Technologies (April 2014) University of Belgrade, Serbia

A2a: 1st. Blue Green Dream and Daylight – analysed social aspect of urban design

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Abstract

"The variety and charm of life and all its beauty consists of light and shadow." Leo Tolstoy.

The principles of blue green design and daylight permeate and produce very powerful life energy - the core value of wellbeing, development and human health. Today, the era of knowledge offers more certain scenarios for the creation of urban development strategies through integrative blue green [BG] approach, an integral part of which is daylight. The aim of this paper is to demonstrate that solutions based on interaction of urban water infrastructure and urban vegetated areas [i.e. BG solutions] are generally more sustainable and cheaper than the congenital [silo] solutions. They are more environmental friendly and more resilient to negative impacts of climate changes. In addition to economic and ecological benefits, comprehensive BG design also has psychological, emotional, intellectual and sensory influence on humans. It contributes to urban amenities and creates new perceptions of space value. The paper will present potential ecosystem indicators modelling and quantification. The analysis is based on the case study in which ESS indicators of daylight, photosynthesis and evapotranspiration will be illustrated for a new master plan of a commercial development.

Keywords: BG Solutions, daylight, healthy life, ESS, parametric design
Blue-Green Integrated Modelling Solutions in Urban Planning and Architectural Design—placing the BG solutions in the process of Urban Design

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Abstract

Increasing urbanisation and adverse effects caused by climate change extremes have brought into foreground necessity of rethinking existing ways of planning, designing, constructing and maintaining urban environments. Comprehensive parametric blue-green design and its cost-benefit trade-off still remain out of urban and architectural practice. Integrated modelling solutions are mostly implemented on small scale and only when client is particularly savvy of concept’s cost-cutting effects. However, if design process, from building to city scale, is essentially about providing comfort for all users, strategic planning that includes comprehensive blue-green approach, could significantly improve social, economic, political, environmental and health conditions in urban areas and reduce negative manmade impact on the urban environment. The blue-green approach [www.bgd.org.uk] significantly improves design methods and results in architecture and urban planning.

This paper aims to position blue-green integrated modelling solutions in the complex process of design and define how those differ from scale of one single building, one block or a whole city [structure design, urban planning and master planning]. In addition to presenting this innovative methodology, a convincing example will be used in the paper to illustrate the methodology.

Keywords: Urban planning, integrated modelling, blue-green infrastructure, climate change
‘Spatial Criteria for Microclimate Comfort of Communal Open Spaces’

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Abstract

Public open spaces are very important urban elements for sustainable contemporary cities as generators of different uses and different activities. The concentration of both users and activities in outdoor spaces produces livability and vitality of neighborhoods and cities. Recent research has shown that the urban microclimate is a very important factor of intensity of use of public open spaces, as thermal conditions of environment affect people’s behavior. On the other hand, the microclimate comfort of public open spaces depends on urban design and morphological characteristics of environment. Understanding the relationship between environmental conditions, human behavior and the patterns of usage of public open spaces can contribute to better design of outdoors environment and to the positive social and environmental effects of design. The purpose of this paper is to highlight the complexity of the relationship between microclimate comfort in public open spaces and its morphological and other spatial features and to emphasize the importance of this relationship to be taken into account in the context of contemporary urban design. Paper presents the case study of residential block in New Belgrade in which the correlation between urban form and microclimate comfort has been analysed.

Keywords: public open space, urban microclimate, thermal comfort, user needs, New Belgrade
B: Involvement in Projects

B1: Collaboration with the Sainsbury’s - improvement of store design by BGD paradigm, October 2013

Executive summary

Following the request by Sainsbury to provide a pragmatic [“quick fix”] solution: to comply with legal requirements by improving storm drainage [flood reduction] to its Leicester store which is about to start construction this report provides a brief description of the propositions made. It includes suggestions on how several benefits can be made by implementing interactions of roof water harvesting, its storage and recycling i.e. implementation in irrigation of green spaces and especially trees.

The work done can be summarized in the following bullets:

- In collaboration with Sainsbury’s managers, emphasis was placed on the issues of the rainwater harvesting and reduction of water consumption, as well as the energy efficiency of buildings. However, as explained in various occasions, these issues are mutually interdependent and optimum solutions can only be obtained if all aspects are analysed integrally.
- The proposed redesign of the site provides the opportunity to reduce surface runoff discharge into the surrounding public sewer system, which is separate in the vicinity of the site but turns into combined one not far from it. By reducing runoff peaks at the site, reduces frequency and volume of combined sewer overflows and reduces load of the wastewater treatment plant.
- Acceding to the BGD paradigm, green elements are used as tool to reduce effect of UHI [Urban Heat Island] and to enhance energy efficiency of the buildings. In this case at the micro scale in Leicester this means at least creation of much more pleasant environment for the customer by reduction of air temperature in summer in the vicinity of the main entrance and reduction direct heating of the façades.
- The “quick fix” solutions presented in this report are based on the experience of the BGD team members [without detailed modelling]. They will require future detailed design and verification as the project progresses. For implementation at other locations, the modelling enhanced design is essential.
- Provided drawings and brief explanations on what is possible to implement at this stage of the project development in the above selected areas. The proposed solutions can now be incorporated into the project by the designer’s team.

In the section [separate letter also submitted to Sainsbury’s] “Evaluation of the missed opportunities, conclusions and suggestions for the follow-up” goodwill has been expressed to rectify the opportunities missed in the year 2013 and to carry out full-scale modelling and optimization of all ecosystem services in a site, which can then be replicated in the other sites.
E-Learning Course on Multiple Uses of Water Services

**Scope:** The goal of this course, which will be built around three modules, will be to enable course participants to understand, critically analyze and apply key concept of multiple uses of water services in the design, implementation and evaluation of infrastructure projects at the city level. The course will elaborate upon the nexus between multiple uses of water services.

**Target Audience:** The course will target policy makers, natural resource managers and development practitioners from government, non-governmental organizations, think tanks and universities in developed, developing and emerging countries.

Module 1: Rethinking Infrastructure Design for multi-use Water Services; An overview

**Main Section Titles:** Where do we stand now in terms of water services in the city [developed, emerging, developing world view]? What are the key problems with the status quo? Make the case for a move from a single use perspective to a multiple use perspective [in line the nexus approach]. Alternative approaches: Holistic approaches to water management and water service provision in the urban environment; Integrated Urban Water Management; Water Sensitive Urban Design, the Blue-Green paradigm change. What is different between these interrelated concepts [and how did they evolve through time]? What types of nexuses does the BGD approach advocate? E.g. Reuse and recycling, blue & green, water-energy; water-food; water-ecosystem services. Some high level examples [e.g. Gardens by the Bay].

Module 2: [a] Options and [b] Tools for multi-use Water Services

**Main Section Titles:** What are the main options for implementing BGD paradigms? Provide illustrative explanations of main nexus items [introduced in module 1]: reuse and recycling, blue & green, water-energy; water-food. Discuss them in both new built and retrofit modes. Pros and cons of BGD/retrofitting existing water and wastewater systems when compared with investing in newer networks [from the point of view of overall investments but also higher costs that consumers may have to bear in the form of higher tariffs]. For each “option” we will provide key messages, incl. [a] characterization of a typical system both from the point of view of engineering design and operation and maintenance and also changes that would follow for consumers: use and billing practices, [b] steps involved in retro-fitting existing systems and [c] qualitative assessment of costs associated with a move towards BGD systems [providing context in terms of scale of discussion and political economy factors like availability of electricity and labor costs associated with running utilities in developing countries].

A focus on interactions between processes: a systems approach [what is a system and why do we need to think this way?]. Introduce integrated modelling [approaches, paradigms, examples, incl. Open MI]; integrated toolboxes for water service management [incl. UWOT to be used in exercises]; Explain that to design for multiple uses we need multi-objective decision making [key concepts [e.g. pareto optimality, multi-criteria evaluation]]. Introduce some metrics for managing and valuating water services: full economic costing of water services, Ecosystem Services.

Module 3: Practical Applications and Case Studies
Examples of applications of the concepts and tools [introduced in modules 1 and 2] in developed, developing and emerging countries: Europe [BedZed Development; Berlin developments]; Australia [Melbourne Water], Singapore [Gardens by the Bay, residential areas]. Multi-purpose water resources management [e.g. supply-agriculture]; Examples from developing and emerging countries [Uganda, Egypt, Mozambique, Central and Latin America, India]. For each case study provide: [a] context [b] intervention [c] assessment and [d] key lesson learned.

Learning Objectives:

- Explore the nexus between water in the city and other themes – notably energy, food, supply, health, and security.
- Understand key concepts and frameworks that have been developed to examine this nexus
- Explore key methods and tools that are needed to quantify the associations between different processes.
- Understand key concepts in multi-criteria decision making needed to design MUS.
- Understand the concept of multi-parametric assessments [incl. KPI and ESS]
- Become aware of cases around the world where the nexus between water services and other themes was identified and addressed – and discover key [transferable] lessons.

Didactic Approach:

Each course will consist of a storyline per topic, supported by additional literature and internet resources. Examples will be included in the text in the form of boxes to highlight lessons or noteworthy implementations of key concepts. The students will repeat the key lessons from each topic at the end of the topic section to ensure uptake. The total length of each course will be between 25-30 pages.

Evaluation methods and key milestones:

Own research will be encouraged by the availability of short assignments on selected [but open-ended] topics at the end of each module. Simple demo tools will be provided to solve exercises related to systems modelling and multi-objective optimization. The tools will be downloadable to the students’ desktop and example datasets will be provided within the course. Self-learning will be re-enforced by multiple-choice quizzes. A short quiz will follow the end of each module [week 3; week 7; week 10]