Kaunas University of Technology

Faculty of Civil Engineering and Architecture

Adaptation to climate change using landscape architecture solutions

Master's Final Degree Project

Andrii Fedoronchuk

Project author

Assoc. Prof. dr. Indrė Gražulevičiūtė-Vileniškė

Supervisor

Kaunas, 2022

Kaunas University of Technology

Faculty of Civil Engineering and Architecture

Adaptation to climate change using landscape architecture solutions

Master's Final Degree Project

Architecture (M000M168)

Andrii Fedoronchuk

Project author

Assoc. Prof. dr. Indrė Gražulevičiūtė-Vileniškė

Supervisor

Doc. Vytautas Baltus

Reviewer

Kaunas, 2022

Kaunas University of Technology

Faculty of Civil Engineering and Architecture

Andrii Fedoronchuk

Adaptation to climate change using landscape architecture solutions

Declaration of Academic Integrity

I confirm the following:

1. I have prepared the final degree project independently and honestly without any violations of the copyrights or other rights of others, following the provisions of the Law on Copyrights and Related Rights of the Republic of Lithuania, the Regulations on the Management and Transfer of Intellectual Property of Kaunas University of Technology (hereinafter – University) and the ethical requirements stipulated by the Code of Academic Ethics of the University;

2. All the data and research results provided in the final degree project are correct and obtained legally; none of the parts of this project are plagiarised from any printed or electronic sources; all the quotations and references provided in the text of the final degree project are indicated in the list of references;

3. I have not paid anyone any monetary funds for the final degree project or the parts thereof unless required by the law;

4. I understand that in the case of any discovery of the fact of dishonesty or violation of any rights of others, the academic penalties will be imposed on me under the procedure applied at the University; I will be expelled from the University and my final degree project can be submitted to the Office of the Ombudsperson for Academic Ethics and Procedures in the examination of a possible violation of academic ethics.

Fedoronchuk Andrii

Confirmed electronically

KAUNAS UNIVERSITY OF TECHNOLOGY
Faculty of Civil Engineering and Architecture

Topic (thematic) of the Master's Final Degree Project **Adaptation to climate change using landscape architecture solutions**
The topic of the Master's Final Degree Project is approved by the Dean's Order

Master's **Final Degree Project** (study module M000M168)

1. T A S K

2. Objective of the work:

To prepare the Master's final degree project based on the previous stages of the research work.

3. Tasks of the work:

To connect and summarise the data from the literature sources, analytical paper, research in situ report and experimental project, and prepare the Master's thesis – to present the reasoned solutions to theoretical and practical problems.

4. Structure of the work:

Text. Title page, heading page, declaration of academic integrity, the task of the final degree project (FDP) (if needed), summary, santrauka, content, list of figures (if needed), list of tables (if needed), list of abbreviations and terms (if needed). Main part: introduction (relevance and novelty of the work, research problem and the level of its examination, object, objective, tasks, and methodology of the FDP); augmented and summarised data of theoretical research, empirical research and experimental design; conclusions of individual chapters and the entire work. List of references, list of information sources (if needed), appendices, copies of the graphical part (reduced in size).

The volume of the text (main part) is 2 – 3 quires (1 quire is 40 000 characters with spaces), i.e. around 60 – 80 pages of printed text (recommended font is Times New Roman, size 12, line spacing multiple 1.15 (Methodological Guidelines for the Preparation of Written Works)).

Graphical part.

The graphical part of the work is presented in posters (70x100 cm). It should reflect the most important results of the analysis of theoretical material, empirical research and experimental design, as well as general conclusions and proposals. The graphical part of the work should be arranged and exhibited in a way to form a visually unified whole and reflect the content of the work. It should be attractive aesthetically. When preparing the graphical part of the work, it is necessary to exclude the non-essential information, highlight the most important research results and ideas, and unify the notes, graphical expression, and colours.

The most expressive part of the project should be the experimental project, illustrating the conceptual proposals of solutions to problems. The experimental project should make from **3/5** to **4/5** of the graphical part.

The volume of the graphical part is 10 – 16 posters, of 70 x 100 cm size – B1 (vertically oriented).

Inscriptions of the graphical part should not be smaller than 5 mm in size.

Model or virtual tour within the planned area/ designed object.

Digital copy of the text and graphical part of the final work.

Timetable of the performance of the tasks:

1. Discussion of the task	02 02 2022
2. Constitution of the writing programme of the final work and the work's structure	09 02 2022
3. Supplementation, structuring, analysis and generalisation of the present data	until 16 03 2022
4. Review and evaluation of the supplemented and generalised data	**16 03 2022**
5. Writing of the FDP text and finishing of the graphical part	until 04 05 2022
6. Review of the first edition of the FDP text	**04 05 2022**
7. Defence of the FDP at the commission of supervisors	**11 05 2022**
8. Public defence of the FDP	**31 05 2022**

Supervisor of the final degree project Assoc. Prof. Dr. Indrė Gražulevičiūtė-Vileniškė

(name, surname, signature)

Student Andrii Fedoronchuk

(name, surname, signature)

February 2022

Fedoronchuk, Andrii. Adaptation to climate change using landscape architecture solutions. / Master's Final Degree Project / supervisor assoc. prof. dr. Indrė Gražulevičiūtė-Vileniškė; Faculty of Civil Engineering and Architecture, Kaunas University of Technology.

Study field and area (study field group): Architecture.

Keywords: climate change, adaptation to climate change, landscape architecture, modular design.

Kaunas, 2022. 92 p.

Summary

Climate change, the result of continuous long-lasting emissions of greenhouse gases, raises numerous threats and challenges to the cities aground the world. In many instances the existing urbm infrastructure is not adapted to cope with the risks induced by the changing climate, such as floods, droughts and extreme temperatures.

The aim of the work - based on the analysis of literature. theoretical and empirical research and experimental design to develop the principles of adaptive reorganimtion of the existing green ore of the city in the most vulnerable territories in order to increase the sustainability and avoid the devastating effects of climate change through landscape architecture.

The work consists of theoretical analysis. empirical analysis and experimental design section, and general conclusions. The methodology of the research encompasses the following methods: literature review, analysis, and synthesis; content analysis of documents; analysis and comparison of design examples; SWOT analysis; sociological survey using questionnaire; application of urban sustainability compass methodology; fractal analysis; experimental design.

The research has demonstrated that sustainable landscape architecture solutions implemented in multiple scale using modular approach and advanced technologies have potential to contribute to adaptation of urban environments to climate change even in sensitive historic settings.

Fedoronchuk, Andrii. Prisitaikymas prie klimato kaitos taikant kraštovaizdžio architektūros sprendimus. / Magistro baigiamasis projektas / vadovė doc. dr. Indrė Gražulevičiūtė-Vileniškė; Kauno technologijos universitetas, Statybos ir architektūros fakultetas.

Studijų kryptis ir sritis (studijų krypčių grupė): Architektūra.

Reikšminiai žodžiai: klimato kaita, prisitaikymas prie klimato kaitos, kraštovaizdžio architektūra, modulinis projektavimas.

Kaunas, 2022. 92 p.

Santrauka

Klimato kaita - nuolatinės ilgalaikės šiltnamio efektą sukeliančių dujų emisijos rezultatas - kelia daugybę grėsmių ir iššūkių pasaulio miestams. Daugeliu atvejų esama miesto infrastruktūra nėra pritaikyta susidoroti su kintančio klimato keliamais pavojais, tokiais kaip potvyniai, sausros ir ekstremalios temperatūros.

Darbo tikslas – remiantis literatūros analize, teoriniais ir empiriniais tyrimais bei eksperimentiniu projektavimu sukurti esamos miesto žaliosios struktūros adaptyvaus pertvarkymo krštovaizdžio architektūros priemonėmis principus, kurie galėtų būti taikomi ir vertingose, labiausiai pažeidžiamose miesto teritorijose, siekiant padidinti tvarumą ir išvengti niokojančių klimato kaitos poveikių ar juos sušvelninti.

Darbą sudaro literatūros apžvalgos ir teorinės analizės, empirinų tyrimų ir eksperimentinio projektavimo skyriai bei bendrosios išvados. Tyrimo metodika apima šiuos metodus: literatūros apžvalgą, analizę ir sintezę; dokumentų turinio analizę; projektavimo pavyzdžių analizę ir palyginimą; SSGG analizę; sociologinę anketinę apklausą; miesto darnumo kompaso metodikos taikymą; fraktalinę analizę; eksperimentinį projektavimą.

Tyrimas parodė, kad darnios kraštovaizdžio architektūros sprendimai, įgyvendinti įvairiais masteliais, naudojant modulinio projektavimo metodą ir pažangias technologijas, gali prisidėti prie miesto aplinkos prisitaikymo prie klimato kaitos net ir vertingoje jautrioje istorinėje aplinko

Table of contents

List of figures

List of tables

Introduction

Relevance of the final degree project

Global climate change has become one of the most pressing environmental issues facing human attention. Its results are dangerous climate cataclysms, abrupt weather changes, strong winds, floods, downpours and rains, droughts, hail, which lead to significant environmental and economic damage all over the world. According to the World Meteorological Organization, the last three years have been the three warmest years in the history of observation. Increasing unpredictability of weather conditions threatens the sustainable development of cities and their internal processes.

Adaptation to global climate change is a process of adaptation in natural or human systems in response to actual or expected climate impacts, which will reduce their negative effects and take advantage of opportunities, hence the need to develop and implement a plan of action to adapt to climate change in each locality . A key aspect of this approach is the development of conceptual and practical adaptation measures that will bring together community, local, business and expert community efforts to reduce the city's vulnerability to climate change, address challenges and prevent threats, strengthening the resilience of the local community and providing more comfortable and safer living conditions in the city.

Landscape architecture is one of the elements that are used to directly affect the climate of the city and make it possible to prepare it for the possible devastating effects of climate change. Lithuania's geographical location and landscape currently minimize the effects of existing climate change on urban residents and allow time for the development and implementation of innovative measures using landscape architecture. Identifying the existing problems in the green structure of the cities and the opportunities for its reorganization, especially in historical parts of the cities, is a key aspect in shaping the concept of implementing adaptation measures, which would help to avoid the devastating consequences in the future.

Landscape architecture is not about plants, decoration or scenery. It is a powerful tool for forming the foundation of the city's strategic development. European examples of the development of adaptive landscape architecture show that this affects the development of social ties, and economic growth of the city, and the quality of life in general. That is, the city gets a lot more from this than just the design of the space.

The aim of the work

Based on the analysis of literature, theoretical and empirical research and experimental design to develop the principles of adaptive reorganization of the existing green structure of the city in the most vulnerable territories in order to increase the sustainability and avoid the devastating effects of climate change through landscape architecture.

Working tasks

- Analyze the existing methods of adaptation to climate change using landscape architecture and the principles of formation of urban green structures.

- To determine the problems of introduction of adaptive landscape architecture measures, their disadvantages and advantages, as well as the peculiarities of their integration into the existing urban environment.

- Create a hypothetical model for the implementation of adaptation to climate change by using landscape design architectural solutions.

- To conduct the empirical research and find out the existing measures for adaptation to climate change specified in the development strategies and determine the peculiarities of the structure of urban networks for the adaptation to climate change of the most vulnerable areas of the city by the means of landscape architecture.

- Find out the characteristics of the climatic features of the Baltic region, to determine the possible consequences of climate change, as well as the implementation of an appropriate adaptive landscape architecture strategy to address them.

- Create a conceptual model of an appropriate adaptation to climate change strategy and possible solutions by the means of landscape architecture.

- Develop a pilot project of a possible strategy for adaptation to climate change of the existing green structure of the city, which focuses on the gradual expansion of measures in accordance with needs, as well as contemporary methods of integration of landscape architecture.

- To generalize theoretical and empirical research, determine the possible results of the experimental project in the context of the conceptual model and to determine the architectural means and features of the integration of adaptive landscape elements into the existing urban structure.

Working methodology

The methodology of the research is aimed at the consistent of the concept of adaptation of urban environments to climate change through landscape design. The methodology encompasses the following methods: literature review, analysis, and synthesis; content analysis of documents; analysis and comparison of design examples; SWOT analysis; sociologiacal survey using questionnaire; application of urban sustainability compass methodology; fractal analysis; experimental design.

Work structure

This work consists of theoretical analysis, empirical analysis and experimental design suctions and conclusions. Each part has its own specific goal and results. which ultimately create a general picture and allow to reveal and explore issues deeply and qualitatively as passible:

1. Theoretical analysis. This stage includes an in-depth analysis of the problem of climate change and the possibility of adaptation through the development of landscape design through the use of international experience and research by other authors. Theoretical analysis section provides a better understanding of the global causes of climate change, its effects and impact on modern cities and their inhabitants. Another important aspect was to get acquainted with the existing strategies of the cities of Kaunas and Ivano-Frankivsk in the field of adaptation to climate change, as this problem is not new.

2. Empirical research. At this stage, according to the research program, the level of urban sustainability of Kaunas and Ivano-Frankivsk was analyzed using a sustainability compass to determine their current sustainability level, which allows to assess the importance and possible prospects of adaptation measures. The next step was to assess the potential of the urban green structure of Kaunas and Ivano-Frankivsk using fractal analysis and identify the most vulnerable areas of Kaunas using cartographic analysis based on the results of which to model its sustainable development using the principles of New Urbanism and other theoretical models. The final step is a sociological survey of residents, the results of which are an assessment of the impact of residents themselves on climate change and their attitude to adaptation measures in a given design. After evaluating all the results obtained, a conceptual model is formed, which reflects the sequence and principles of formation of landscape adaptation measures.

3. Experimental project. At this stage the territory, the final determination of the area, which according to the study is in the risk zone of climate change impact, was selected for experimental design in the historic center of Kaunas. A typological approach was developed for the implementation of landscape measures in areas of different scales, and if necessary, a more detailed analysis of the state and needs of the particular area. Based on the principles of the conceptual model, experimental project is was developed to adapt the selected area to the effects of climate change and the results if the experimental design were evaluated.

4. General conclusions General conclusions are formed that substantiate and evaluate the developed landscape measures, methods of their application and opportunities for further implementation.

1. Theoretical analysis of climate change issues and related landscape architecture solutions

Global climate change is a definite environmental problem of our time. Review, systematization and generalization of the exesting experience of scientific research and projects for the development of adaptive landscape architecture was divided into two blocks: international experience and examples, and local experience and examples. The main object of the literature review is publications of the the past 20-10 years in English and other languages related to climate change and landscape architecture. Articles in leading scientific, professional and popular journals, books, monographs and other publications were considered.

Threats of climate change, such as rising temperatures, flooding, overgrowing of traditional crops, and economic instability, have a huge impact on society. Currently, there is no single strategy in the world that has solved the climate crisis on its own. The atteampts to mitigate the effects of climate change or to adapt to them include a variety of approaches, both in the political and economic sectors and in the sector of architecture and landscape design. The main tasks in the fight against climate change are to reduce greenhouse gases and fight floods in urban areas. Achieving a local result also contributes to solving global problems, thanks to the cumulative impact of countless individual actions. Each of these separate cases matters.

Landscape architecture helps to address climate change locally. One of the main elements of solving the problem is such means as water-efficient design, green roofs, the use of sustainable materials and construction practices. These strategies contribute to the expansion of carbon sequestration areas, such as forests, restricted areas and meadows, and reduce carbon dioxide in the atmosphere. All of these efforts can also allow the communities to better adapt to climate change and improve their resilience.

One important factor is understanding the differences in climate change issues in different regions. It is necessary to take into consideration landscape features and local environmental problems that have a changed climate, which are significantly exacerbated. Each city muct conducts its own development assessment and develop its own adaptation plan. For example, the real challenge for some cities is the issue of excessive rainwater. In the Northern European climate region, the nature of precipitation has changed greatly, they have become "tropical" - when in a short period of time falls a few norms of rainfall. Due to the large paved areas in cities, the sewer system does not work properly, it causes large floods.

Theoretical analysis of materials shows that landscape design is one of the most important methods of combating the effects of climate change. The formation of varieties of local concepts that have an impact on solving local problems, create a basis for the organization of global influence on climate change and the formation of a special microclimate for human life.

1.1. Issues of climate change

Climate change is having a negative impact on geosystems, biodiversity, water and biotic resources, and human health. All components of this general complex problem are now being actively studied. The main attention is paid to the assessment of changes in the physical parameters of the atmosphere, ocean, land and cryosphere due to anthropogenic impact on the climate system and their consequences. Climate change is already happening and this process will intensify.

Climate change is caused by two factors, natural and anthropogenic. Natural causes of climate change include tectonic, astronomical and radiation causes. These factors are related exclusively to natural processes that are not or only partially affected by humans.

Anthropogenic factors are factors caused by human activity. In the past, climate change was natural in nature, but in the last 50 years it has been largely due to human activities. This type of factor causes climate change due to changes in the concentration of greenhouse gases and aerosols in the atmosphere (IPCC, 2007). Of the six types identified by the Kyoto Protocol, three of them – methane, carbon dioxide, and nitrous oxide - occur naturally in the atmosphere, but their concentration has increased significantly as a result of human activities. The other three greenhouse gases are synthetic chemicals. One kilogram of these gases in the atmosphere is equivalent to 20 tons or more of carbon dioxide. Greenhouse gases and aerosols affect the climate by changing the amount of incoming solar radiation and infrared radiation (OECD, 2008).

From the beginning of the industrial period, the consequence of human activity on the climate was its warming. Human impact on the climate far outweighs the impact of changes in natural processes, such as changes in the sun and volcanic eruptions. The increase in the Earth's surface temperature coincides with the increase in the concentration of carbon dioxide and other greenhouse gases in the atmosphere over the past century, is one of the main evidence of the impact of anthropogenic factors on climate change.

The consequences of global climate change are changes in the frequency and intensity of precipitation. The climate on the planet will become wetter, but the amount of precipitation on Earth will not be uniform. In regions that currently receive sufficient rainfall, rainfall will be more intense. Drought periods are becoming more frequent in regions with insufficient moisture. Another consequence will be rising sea levels. During the 12th century the average sea level has risen by 0.1-0.2 m. During the 21st century the sea level will rise to 1 m. In this case, the most vulnerable will be the coastal areas and small islands. Countries such as the Netherlands, the United Kingdom, and the small island nations of Oceania and the Caribbean will be the first to be at risk of flooding (UNFCCC, 2007).

Threat to ecosystems and biodiversity. Species and ecosystems have already begun to respond to climate change. Migratory bird species began to arrive earlier in the spring and leave later in the fall. Up to 30-40% of plant and animal species are predicted to become extinct, as their habitats will change faster than they can adapt to these changes. With an increase in temperature by 1 ° C, a change in the species composition of forests is predicted, which are a natural store of carbon (80% of all carbon in terrestrial vegetation and about 40% of carbon in soil) (UNFCCC, 2007).

Agriculture. The impact of warming on crop yields is ambiguous. In areas with temperate climates, yields may increase in the event of a slight increase in air temperature, but will decrease in the event of significant temperature changes, which will pose a threat to food security. In tropical and subtropical regions, fields will generally decline. The main factor limiting the field is the lack of water during the growing season. With further global warming, the decline in fields may exceed 20% and become critical for the economies of these regions. The fertile regions of the North Caucasus and the Volga region can turn into dry steppes (IPCC, 2007).

Water consumption and water supply. One of the consequences of climate change may be a lack of drinking water. In regions with arid climates (Central Asia, the Mediterranean, South Africa, Australia), the situation may worsen due to reduced rainfall. Insufficient moisture will lead to a decrease in water supply to the population (up to 1000-1500 m3 per year per person), which according to the international classification is considered to be very low or critically low water supply (Crichton, D., Fergus, N. (2009).

Intensification of negative processes. Climate change will affect the recurrence and intensity of dangerous phenomena and processes (droughts, floods, floods, avalanches, landslides, villages, strong winds, etc.), increasing unfavorable. The causes of climate change are summarized in the Fig1.

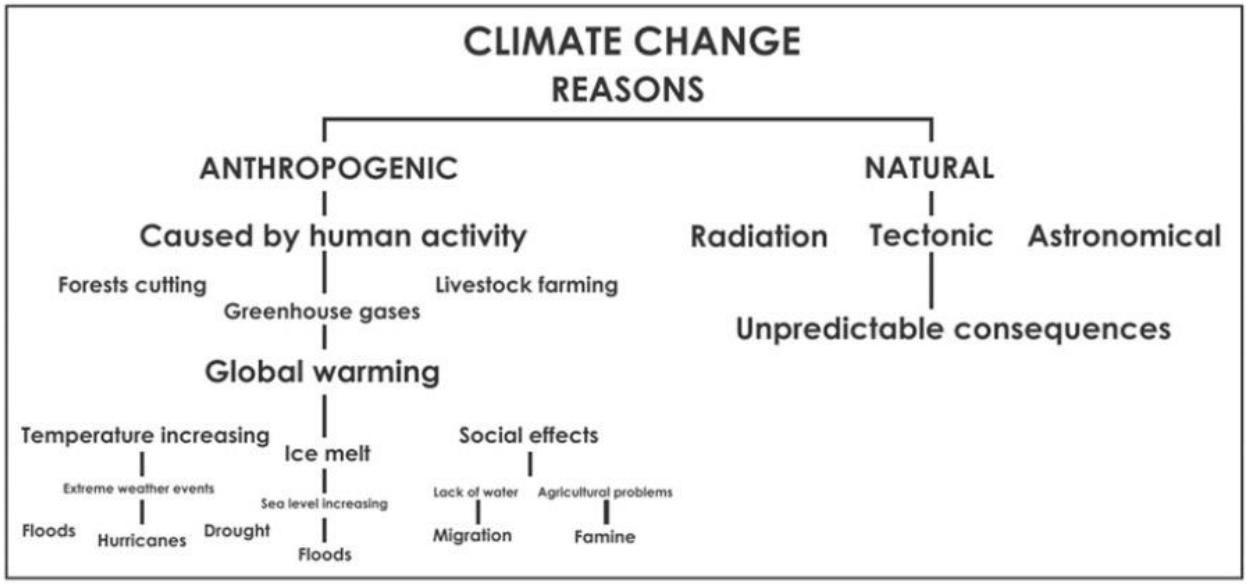


Fig 1. Climate change reasons. Scheme by the author.

1.1.1. Analysis of reports of international organizations

One of the most important international instruments related to climate change is the UN Framework Convention on Climate Change. The purpose of this document is to stabilize the concentrations of greenhouse gases in the atmosphere at a level that would not allow a dangerous anthropogenic impact on the climate system. Such level shoud be reached in the time required for the natural adaptation of ecosystems to climate change. This will make it possible not to risk food production and will promote further economic development on a sustainable basis.

The UN Framework Convention on Climate Change defined only the general principles of international cooperation on climate change and did not contain the numerous obligations of the participating countries, which were set out in a separate document - the Kyoto Protocol, adopted later as a step forward. It requires countries to promote the conservation of living things and to ensure the equitable distribution of the benefits of the use of biological diversity. It is the conservation and use of biodiversity that is particularly important to meet the needs of the world's growing population for food, health, and so on (OECD, 2008).

The Kyoto Protocol is an international legal instrument that establishes the qualitative responsibilities of member countries to limit and reduce greenhouse gas emissions. It identifies the main mechanisms to be used by countries for the purposes set out in the Convention, including the establishment of national systems for estimating the level of emissions and removals of greenhouse gases, both at the international and national levels.

In these documents, the UN has adopted very important features from the most successful multilateral environmental agreements in history - it has obliged states to act in the interests of present and future generations of mankind, even in conditions of scientific uncertainty.

In general, analyzing the text of the Convention, we can identify three main blocks of its provisions:

- General declaration of the importance of climate change;

- Consolidation of the purpose of the parties to the Convention, the general responsibilities of its members and the responsibilities of developed countries;

- Defining the features of the status of developing countries;

- General legal and organizational issues.

The Kyoto Protocol was the first step towards a genuine global emission reduction regime, which established that the total anthropogenic emissions of greenhouse gases by developed countries could not exceed the Protocol's targets to reduce their total emissions of such gases by at least five percent compared to 1990 period of validity of obligations (OECD, 2008).

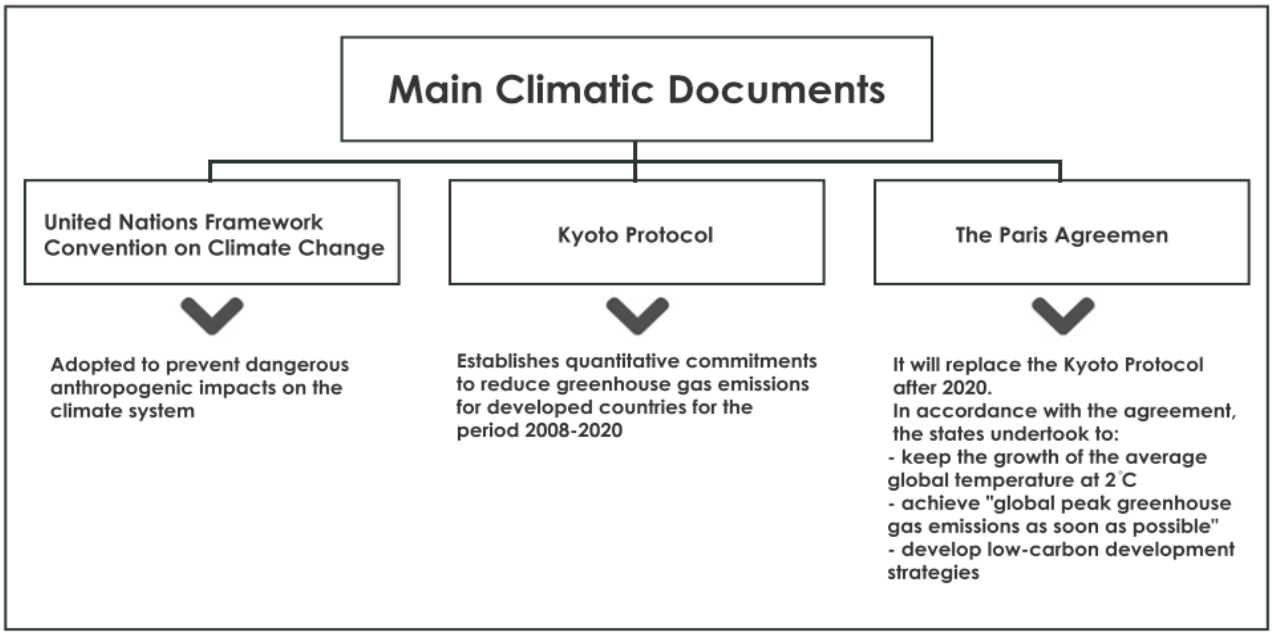
The Paris Agreement was adopted by 196 Parties at Climate Change Conference in Paris in 2015 and entered in 24 force on the 4 November in 2016. The goal of this documents that replaces the Kyoto Protocol is to limit global warming to well below 2, preferably to 1.5 degrees Celsius, compared to pre-industrial levels. In order to reach this goal, countries aim to reach global peaking of greenhouse gas emissions as soon as possible to achieve a climate neutral world by the middle of the century. The Paris Agreement is viewed as a landmark in the international climate change process as it brings all nations into a common cause to undertake ambitious efforts to combat climate change and adapt to its effects for the first time in history (The Paris Agreement, 2022).

Summarizing the results of a comprehensive study of the international regulatory framework, which operates in the field of climate change, it can be noted that it is quite complex, multi-layered and multi-vector, very rapidly evolving and enriched with new mechanisms and norms.

Currently, according to research, we get a not very comforting forecast for climate change. The report emphasizes the obvious and growing gap between the agreed goals for overcoming global

warming and reality. The report “The impact of Climate Change on Human Health in the United States: A Scientific Assement” says that over the past few years, rising sea levels, global warming, shrinking ice sheets and carbon dioxide pollution have accelerated. In the coming years, the temperature will rise to more than +1.5 degrees Celsius. There is a 20% probability that the average annual temperature, which rises from year to year, can reach +1.5 in any year between 2020 and 2024. Meanwhile, the temperature each summer will be at least +1 higher than usual (USGCRP, 2016). At the same time, these are data from short-term forecasts, as the temperature is constantly changing and passing in "waves". The main international documents related to climate change are summarized in Fig.2.

Fig 2. Main climatic documents. Scheme by the author



1.1.2. Ways of adaptation to and mitigation of climate change

Recently, the international community has been making more efforts to influence climate change and analyze adaptation measures. At the international level, states have linked the allocation of funds for adaptation to climate change and the preparation and implementation of plans for adaptation to climate change at the state level. In April 2013, the European Commission understood the EU (European Union) Adaptation Strategy. The following state level examples can be mentioned in Slovakia, the first important document in this area was the National Adaptation Strategy, approved by the Government of the Slovak Republic in March 2014 (Turner, 2020). Lithualia has adopted national climate change policy and its implementation document in 2012 (Nacionaline…,2012).

Although climate change is a global problem, it is largely affecting changes at the local level. Therefore, active involvement of local authorities is essential for effective adaptation. Local authorities need to be at the forefront of inviting and adapting processes at the local level and take climate change into account when preparing medium- and long-term strategies and the day-to-day decision-making process. For example, urban development planning is carried out so as not to decrease the ecosystem services (Hunter, 2011); the construction or restoration of neighborhoods of the city or other development projects should not take place at the expense of reduction of natural and agricultural areas.

One of the most important steps is the preparation of adaptation strategies for a specific settlement (city, town, village) or region (district, region). This strategy should be based on the following aspects (Hunter, 2011; Turner, 2020):

1. The description of potential danger of individual impacts that change the climate in a given place (expected impacts that change the climate, the risks caused by such impacts are described in terms of climatology).

2. Assessment of blur due to such impacts - assessment of the assessment of population, territory, infrastructure and other systems that are sensitive to specific impacts (for example, houses, buildings in the flood zone, more likely to be flooded than houses built in other areas; or people over 75 are more sensitive to heat than people of other ages).

3. Assessment of the adaptive capacity of the territory - due to the rapid speed and creation of a reaction in the event of a division (flood, heat waves, storm winds) or after it happens (for example, the readiness of rescue, medical services, warning systems informing the population, etc.).

4. Based on the impact assessment (sensitivity and adaptation of opportunities) in a given area, an adaptation strategy is prepared to reduce the impact and maintain resistance to the given area, which affects climate change. Such a strategy may contain long- and short-term goals, as well as specific adaptation measures.

Development of climate change adaptation strategy includes the following steps (Turner, 2020):

Step 1 - Identify the future expected impacts of climate change and create the conditions for successful implementation of adaptation processes
Step 2 - Assess the vulnerability of the territory
Step 3 - Defining the directions of the adaptation strategy
Step 4 - Selection and implementation of adaptation measures

Step 1. At this stage, the likely impacts of climate change that can be expected in the area should be identified. Such a climate scenario should be based on recent facts and events in the area, as well as on the climatological expectations specific to the area or region. Threats or opportunities that result from the climate scenario become the basis for deciding whether they need to be taken into account by local governments (Turner, 2020).

Step 2. Vulnerability means the level of potential future damage caused by the effects of climate change. It is not only about the extent to which the system is significantly affected by climate change, which makes the system vulnerable (state of vulnerability), but also about its

sensitivity to these influences and the ability to adapt to them. The EU uses the definition of the Intergovernmental Panel on Climate Change: "vulnerability to climate change will be determined by exposure, sensitivity and adaptability" (Turner, 2020).

The dee of vulnerability is the starting point for developing an adaptation strategy. Therefore, it is important to consider the vulnerability of a particular system / area to something, such as heavy rains or related damage (such as floods). For example, the location of risk areas, floodplains, heat islands, are among the factors affecting exposure. Sensitivity to exposure depends on the quality characteristics of the system, such as the quality of housing or the quality of construction work (the quality of thermal insulation used for facades reduces heat transfer to the interior of buildings the quality of construction reduces the risk of damage). Adaptive capacity, such as the ability to cope with the effects of climate change, can be enhanced, for example, through quick and easy access for vulnerable populations to health facilities or by insuring against the effects of climate change (Turner, 2020).

Step 3. Local adaptation strategies, based on the vulnerability assessment carried out during the previous step, $120 ld be designed to focus on specific priority areas where the most serious threats are present. It is important to consider the existing constraints (the availability of time and resources to implement measures) so that the strategy can be implemented (not all issues related to the effects of climate change need to be addressed immediately) (Turner, 2020).

Step 4. To implement the strategy in real life, it is necessary to prepare a detailed action plan, which identifies those responsible for the implementation of adaptation measures, ways and timing of their implementation. Such a plan should be prepared by consulting and obtaining the approval of key actors so that they play an important role in its implementation. Based on existing information and experience (own or other territories), it is desirable to compile a catalog of activities that can be implemented in response to the climatic vulnerability of the area identified in the second stage. It is possible to offer several possible options to achieve the desired result, including the option of "doing nothing" for a particular risk - that is, to accept possible losses (Turner, 2020).

There is a variety of adaptation measures that can be used abd it’s important to select the most appropriate for each case. Some are worthless, others are expensive; some are very effective for mitigation, others are less effective. When choosing the necessary adaptation measures, it is necessary to follow the developed comprehensive adaptation strategy - otherwise the funds might be spent on measures that should not be determined as optimal, but also even not sufficiently effective, and will no longer be used for the needs of this city or region.

Adaptation methods can be divided into the following categories (Hunter, 2011):

• Reinvestment (soft), which includes measures such as planning, management of research and development, general management of the territory and changes in the behavior of those who in decision-making should study the existing and expected climate change in this area. Examples of minimum measures include teaching people how to respond to a heat wave or flood; avoiding planning investments in winter sports that require constant snow cover, at an altitude of up to 1000 m; improving the coordination of rescue teams and public administration bodies (Hunter, 2011).

• Technological (gray), focused on technological solutions. These include, for example, thermal insulation of construction, the use of light tones and reflective materials to mitigate the effects of heat; the use of wastewater and rainwater to help reduce the long-term effects of drought or the construction of flood defenses as part of the implementation of flood protection measures.

• Natural (green) containing natural elements (vegetation, water elements). These may include green roofs and walls, parks, wetlands, lakes, fountains, and more.

The report - The Rile of Green Structures in the Development of Sustainable City" states that urban growth perceives various envimnmental problems. Changing the urban green structure to account for urban growth can lead to increased economic services, air quality, recreation and aesthetics. However, when organizing solutions, urban planners rarely report the role of green structures in many cities around the world. Very often greenery is treated as residual sites, sometimes as a reserve potential for future activities (Cheng. 2004). The following key aspects important for this research are distinguished:

Blue structure: in Scandinavia blue structure is more embedded and hidden in the natural landscape. Smaller watercourses often pass-through pipes and are covered in cities and are therefore not always visible in the daily lives of citizens. Moreover, in physical planning, watercourses and wetlands are often seen as integrated, although very important elements of a green structure. (Cheng, 2004).

Greenery: greenery is understood as individual green elements such as trees, shrubs and green environment (larger green area such as sport fields, woods, and shrubberies) make up most of the urban landscape (Cheng, 2004).

Green corridor: Green corridor is a system of balanced natural urban areas associated with suburban greenery, linear street greenery and elongated greenery, often of great recreational and or environmental value. Existing landscape nature is a source of use for the distribution of wild plants and animals in urban areas. Thus, green corridors are important out in the countryside and leading into urban areas as the coridors is the transitional zone between urban and meal (Cheng, 2004)

As a rule, greenery occupies a significant part of the city. Yet, the official green structure is only green areas maintained by local authorities, while the actual green structure repeats all areas that meet the general definition of a green structure (Cheng, 2004; Beer 2000). The green structure can be classified as following according to A.R. Beer (2000):

- Paved city spaces with plants: courtyards & patios, roof gardens & balconies, tree-lined allees, promenades, city squares and schoolyards;

-Parks, gardens and sports grounds: public parks, pocket parks, gardens, public sports grounds, public recreation areas and public playgrounds;

- Burial places: crematorium, burial ground and churchyard;

- Private open spaces: institution grounds, residential home grounds, health services grounds, private sports grounds, private estate grounds, local authority services grounds and commerce grounds;

- Domestic gardens: house gardens, allotments, communal semi-public gardens and communal private garden;

- Farmland and horticulture: arable, pasture and orchard;

- Transport corridor verges: canal sides, rail sides and roadsides;

- Water margins: wetland, riversides and lake-sides;

- Water still water. running water;

- Woods, woodland, timberreio-fuel woodland, wild wood and semi-natural woodland;

A theoretical study by E. L. Alm (2003) of the functions of green areas in cities has demonstrated that in relation to a sustainable urban development, green structure is important as functions and meanings for (Alm. 2003; Cheng, 2004),

-Urban climate, noise moderation, air cleaning and handling surface water:

-As an indicator of environmental changes;

-Cultivation of energy plants;

-Biodiversity - to save valuable urban species, as refuges for species from rural biotopes and as spreading corridors;

-Social and cultural values - for health, recovering and rehabilitation, to give beauty and comfort, to give room for passivity and activity, as a cultural heritage, as an arena for citizenship, for education;

-Urban design: to give a city understands able structure to connect different scales and parts of the urban landscape.

1.1.3. Main features of Estern European climate zone

The following types of climate are represented in Europe: arctic, subarctic, temperate and subtropical. In the Arctic zone, which covers the islands of the European Arctic sector, the climate is harsh, with long frosty winters, frequent storms, hurricanes, short cold summers (average July temperature, usually not higher than 5 ° C); precipitation falls mainly in the form of snow, evaporation is low. In the subarctic zone (Iceland, northern Fennoscandia, and the Eastern European Plain), summers are longer and warmer (up to 10, 12 ° C in July), and winters are mild in the western regions and frosty in the eastern regions; precipitation is about 1000 mm in the west, 400 mm in the east: evaporation is less than precipitation. In the temperate zone (other parts of

Europe, except the Mediterranean and the southern coast of Crimea), a colder, boreal climate of the northern part of the belt and a warmer, subreal - in the southern part (OECD, 2008).

In the east, the climate is moderately continental, with frosty snowy winters (except the southern regions), cool in the north, warm in the center and hot in the south in summer, with a large annual temperature range; annual precipitation is greater than evaporation in the north, almost equal to it in the center and less evaporation in the south. This climate is characterized by a large seasonal temperature difference and warm summers (at least four months on average above 10 ° C, but the average monthly temperature does not exceed 22 ° C. In the east of the ecoregion continentality increases (OECD, 2008).

Lithuania's climate is moderately mild and changes as it moves inland - from the sea on the coast, to the mainland in the easternmost regions. The average temperature on the coast is -1.6 ° C in January and +17.8 ° C in July. In Vilnius, the average temperature is -2.1 ° C in January and +18.1 ° C in July. The annual rainfall averages 717 mm on the coast and 490 mm in the eastern parts of the country. The growing season lasts 202 days in the western parts and 169 days in the eastern parts of the country (Monge-Barrio & Sánchez-Ostiz Gutiérrez, 2018).

In Lithuania there is almost no snow in winter. The climate here is maritime, the terrain is flat (the highest hill does not reach up to 300 meters). as a result, three factors follow from this - frequent winds from the Baltic, which permeate the entire country to the border with Belarus, high humidity and thaws. with a fairly mild winter - the average temperature at this time of year - 5 degrees below zero. The peculiarity of Lithuania's climate in autumn is, first of all, frequent rains - about 1 millimeter of precipitation falls here every day, but 50% of all this water mass falls on October and November. The climate in Kaunas is cold and temperate. Kaunas receives a notable amount of rainfall within the year. Even during the driest month, a lot of rain falls. The climate here is classified as Dfb by the Köppen-Geiger system. In Kaunas, the average annual temperature is 6.6 ° C. About 614 mm of precipitation falls annually ().

1.1.4. Possibilities to apply landscape architecture solutions for adaptation to climate change

Landscape architecture is one of the best ways to combat climate change. There is a wide array of adaptation measures from which you can choose the most appropriate for each case can be selected. These cases are divided according to the type of impact of climate change on the environment: drought, floods, excessive heat. Some are worthless, others are expensive; some are very effective at mitigating, others are less effective. Landscape architecture forms a comprehensive approach to solving these problems because the use of this type of architecture creates the possibility of its adaptation to the effects of climate. Landscape design and landscape planning means can be distinguished analyzing the ways of adaptation to climate change using landscape architecture:

Landscape design. Basically, landscape design focuses on the formation of small-scale objects using a variety of technological approaches, which allow creating you to create a local impact on the environment. One of the most common methods is to create an architecture that reduces the overall heating effect and absorbs most of the rainfall. Also, one of the important elements in

landscape design is the creation of green islands in the most problematic areas, enabling to avoid the negative and destructive effects of climate change.

Landscape planning. Landscape planning focuses on shaping a larger approach to adapt to climate change. One of such approaches is the formation of urban development strategy to avoid possible problem areas, through the creation of an integrated green network in the city connecting some adaptation elements with others and the introduction of innovative materials in addressing adaptation to climate change in the large scale.

The choice of adaptation measures must be based on comprehensive adaptation strategy, otherwise the selected measures might be neither optimal nor sufficiently effective, and also will not be consistent with the needs of a given city or region.

One of the possibilities of applying landscape architecture is to increase the share of vegetation, especially in built-up urban centers. Diverse vegetation has a significant impact in terms of microclimate formation, including cooling of the territory in the hot period. The intensity of this effect depends on the proportion of trees in the total green area. The larger the area covered with green plants, the greater the cooling effect. Measures against more frequent and intense heat waves should be aimed primarily at increasing the number, area and quality of city parks and other green areas, planting trees in such a way as to form green corridors, including near parking lots. Another important factor is the availability of water in the urban environment. This factor is important for many reasons because water effectively cools the environment, while its evaporation creates a pleasant microclimate. During evaporation (conversion of liquid to gas), thermal energy is absorbed and, thus, the medium is cooled. Among other factors, the cooling rate depends on the mass of water that evaporates (Hunter, 2011).

Based on a number of studies, it has been proven that the temperature measured on the leeward sides is on average 3 ° C lower, and the cooling effect can be felt at a distance of as much as 30–40 m from water elements (Xuepeishan, 2016).

Therefore, landscape architecture has a broad range of applications for adapting cities to climate change. But the most important thing is to form a holistic strategy and concept of applying these benefits to maximize the effect and interaction of some adaptation measures with others (Fig.3).

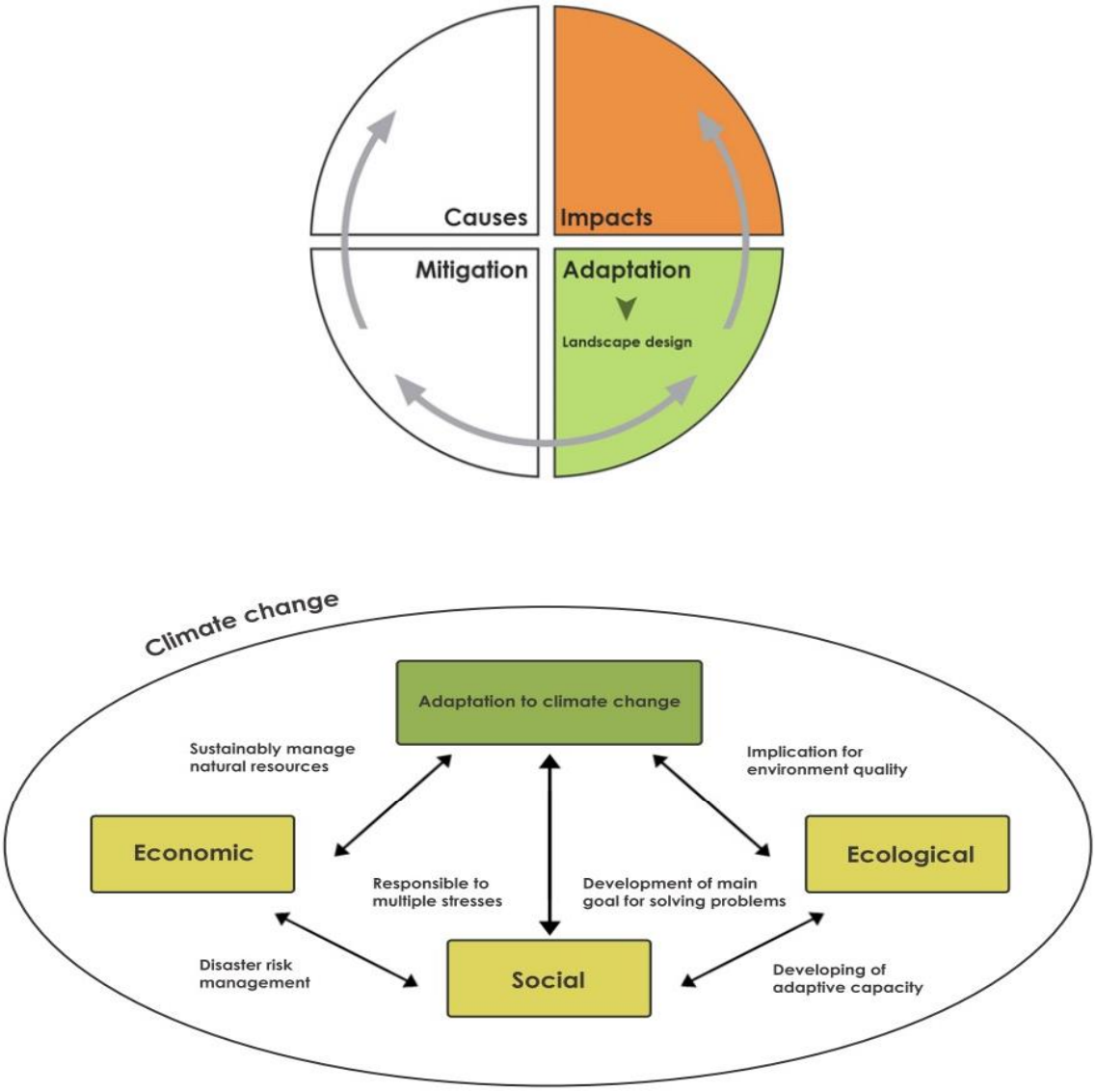


Fig 3. Posibilities to apply landscape architectural solutions for adaptation to climate change. Scheme by the author

1.2. Review of experience in adaptation to climate change using landscape architecture solutions

Adaptation to climate change policies in the EU member states are based on the assertion that the first and most important step for effective adaptation is a clear understanding of the expected consequences, vulnerabilities and risks of climate change in the short, medium and long term for key socio-economic sectors. Therefore, at the level of the EU, key sectors vulnerable to climate change have been identified, in which the implementation of adaptation measures is a priority. These include agriculture, fisheries, cohesion policy, inland water and forestry issues, biodiversity, infrastructure, buildings, migration and social issues (Buondonno, 2021).

At the national level, vulnerability assessments are carried out both on a sectoral basis (in Austria it was carried out for 14 sectors; Cyprus has assessed the water and coastal sectors and extends it to other sectors) and on a territorial basis; Belgium has assessed the country as a whole

and at the level of Brussels, Flanders and Wallonia, France has completed the assessment of the situation at the national and regional levels and moved to the local level) (Buondonno, 2021).

It is important to emphasize that the main role in this activity is played by scientific and research institutions, which is one of the features of the EU approach to the formation of national policy in the field of combating climate change.

In some EU member states, adaptation measures are in placelegislation (climate change laws in Hungary in 2007 and in the United Kingdom in 2008), but the main tool for their implementation is national action plans. To date, 19 countries in the community have adopted such documents, and Bulgaria has already adopted the Second National Adaptation Plan for 2013-2020 (Turner, 2020).

According to them, regional and local action plans are adopted, which once again demonstrates the multilevel policy of adaptation. Thus, in Belgium, in addition to the national adaptation plan, plans have been adopted at the level of Walloon Brabant and Flemish Brabant (Lenzholzer, Brown, 2013). We point to the variety of action plans for adaptation, which have both general and sectoral nature. For example, Finland has adopted three plans: an Action Plan (adopted annually), an Action Plan for the Implementation of the National Strategy for Adaptation to Climate Change in the Administrative Sphere and a National Plan for Adaptation to Climate Change of the Ministry of Agriculture and Forestry. The documents adopted in Poland concern the coastal zone, and in Gdansk, Warsaw, Krakow and Wroclaw there are flood control plans, which provide for a number of adaptation measures (Turner, 2020).

City strategies for adaptation to climate change can be mentioned as well. The adaptation strategy of London adopted in October 2011 by Mayor Boris Johnson was created in reaction to rising concerns about drought, regular flooding, and severe heat waves in the city. The mayor's office started the initiative in early 2010 by calling on London's 8.1 million inhabitants to share ideas and expertise in an online forum (Gallucci, 2015).

The adaptation plan of London is based on national climate change predictions from 2009 created by the UK's official center for climate change research, the Met Office Hadley Center. Unlike New York, the city does not report on the expected cost of implementing the proposed initiatives. The separate flood risk management plan of London for the Thames River would cost the city approximately $2.3 billion in its first 25 years (Gallucci, 2015).

Launched in late 2008 by the Rotterdam Climate Initiative Rotterdam (Netherlands) adaptation strategy is a joint program of the regional environmental protection agency, the city government, the port employers' association and the port authority (Gallucci, 2015).

"Rotterdam Climate Proof" has a goal to make the city of 1.3 million people "fully resistant to climate change impact by 2025 as well as to preserve Rotterdam's status as one of the safest port cities in the world. The strategy includes five differenet subjects: adaptive buildings, flood management, urban water systems, accessibility for ships and passengers, quality of life within the

city. The city allocate around $40 million for implementation of the plan’s upcoming projects (Gallucci, 2015).

A further report for 2010 states the initiative is making “full progress” in relation to its initiatives and broader purposes. Perhaps the most notable project to come from the plan is Rotterdam’s trio of floating pavilions. The bubble-shaped domes are attached to the city’s waterfront and a total area measure of 12 000 square feet. It is mentioned that the project is a pilot for future floating urban districts. These districts will be able to rise with the changing sea levels (Gallucci, 2015).

Thus, the implementation of the EU's global climate change adaptation policy demonstrates an example of a balanced, integrated and consistent approach; It is already possible to state significant successes of the EU member states in the development of this direction of climate policy

1.2.1. Project examples of adaptive landscape architecture

Landscape architecture often played a significant part in the conservation of the environment and in the development of communities. The profession has to provide leadership in all aspects of management, planning and design that mitigates the changing climate, protects our environment and helps communities adapt to the changing circumstances.

Landscape architects work to meet both the needs of human society and the natural environment, respecting the cultural landscapes of the past and planning for a sustainable future. Recognizing that mitigation efforts can reduce the speed and intensity of, but not compensate for, future climate change.

Analysis of international experience is one of the most important parts of the study. Proper selection and analysis of projects provides an opportunity to better understand current trends in the fight against climate change.

These projects were selected in the direction of preventing flooding of urban areas and reducing the effect of heating. The purpose of this part is to determine the main directions of development of landscape architecture, to form in the future a holistic approach to the organization of landscape space, which will help change the current situation with the devastating effects of floods in cities and towns. Taking into account current trends will allow the use of the latest methods and materials, which plays a significant role in addressing this issue.

The soul of Norrebro. Proposed to ease floodings in Copenhagen.

Location: Copenhagen, Denmark
Architects: Ramboll architects

Fig 4. Hans Tavsens park visualisation (SLA, Beauty and the Bit, 2016)

SLA Architects, planning and landscape company, and Ramboll engineering office have won an international contest for redesigning Hans Tavsens Park and its surrounding area in the central Copenhagen district of Nørrebro (Fig.4-6). At the contest the architects were tasked to create a park and street landscape that would benefit the biological, hydrological, and social ecosystems of the neighborhood. The Soul of Nørrebro was the winning proposal provides the solution by creating a system of drainage areas and an adaptable park designed to redirect runoff and purify and contain water during floods (Lynch, 2016).

Fig 5. Project Plan (SLA, Beauty and the Bit, 2016).

Nørrebro is located on relatively flat land and along the water. It makes the district particularly vulnerable to heavy rains. During heavy rains, called as cloudbursts, flooding of major roads and

basements is quite common. Water surplus runs directly into Peblinge Lake, one of Copenhagen's three distinct rectangular shaped lakes, pulls debris or dirt from the street (Lynch, 2016).

Fig 6. Climate adaptation through the city's nature (SLA, Beauty and the Bit, 2016).

The proposed project, worth 140 million DKK ($ 20 million) will use Hans Tavsens Park as a rainwater catchment area capable to holding up to 18 000 cubic meters of water at a time. According to the project rainwater should then be naturally filtered as it is slowly led into Peblinge Lake through planted drainage paths, which are located along an existing Korsgade street. It is assumed that irrigation paths will give the streets a new identity and microclimate, and will become a visible part of the urban landscape (Lynch, 2016).

The new park will have courts and fields for various sports, which will serve as places of detention during floods. The other facilities include a pavilion designed in cooperation with Saunders Architecture, a fountain, a children's playground and paths to a nearby cemetery. On the way to the lake, a drainage pool will also run past the Blågaards school, where it will irrigate playgrounds and gardens maintained by school classrooms. Drainage paths along Korsgada will serve as a barrier between the road and the sidewalk, flowing into the final biotope along the edge of the lake (Lynch, 2016).

Climate Tile. Designed to catch and redirect excess water.

Location: Copenhagen, Denmark.
Architects: IBF and ACO Nordic

Fig 7. Climate tile diagram (Courtesy of Third Nature, 2021).

According to Baldwin (2021) The Climate Tile is a pilot project designed to capture and redirect 30 % of the estimated additional rainwater coming from climate change. The project created by THIRD NATURE with IBF and ACO Nordic will be open on a 50-meter sidewalk in Nørrebro, Copenhagen.

Created by THIRD NATURE with IBF and ACO Nordic, the project will be inaugurated on a 50m pavement stretch at Nørrebro in Copenhagen. The first sidewalk was created as an innovative climate project which uses Climate Tile to create a beautiful and adaptable cityscape. Designed for densely populated cities, the tile processes water through a technical system that considers water as a valuable resource (Baldwin, 2021).

Fig 8. Climate tile diagram (Courtesy of Third Nature, 2021)

Firstly, the Climate Tile is an adaptation system for the cities of the future. The pilot phase in Copenhagen is the beginning of a multiannual development process with the City of Copenhagen, Realdania, the Market Development Fund and other partners. The Climate Tile restores the natural water circuit in existing cities with a simple process that manages rainwater from roofs and sidewalks and ensures that water enters the right place for plants or waterfronts. It can capture and redirect 30% of the estimated additional rainwater coming from climate change, thus preventing congestion in existing drainage infrastructure (Baldwin, 2021).

According to the team, Climate Tile traditionally develops and combines separate functions. With the development of The Climate Tile, future sidewalks will collect and manage water, while contributing to the growth of urban nature and the improvement of the microclimate. In this way, the tile creates additional value for citizens and improves the quality of life and general health in the city. The project is considered as an overall solution that works together with bike paths, roads, urban furniture, signage, town squares, and urban nature (Baldwin, 2021).

Fig 9. Diagram of street section (Courtesy of Third Nature, 2021).

Hybrid Street furniture

Location: Italy
Architects: Stefano Boeri

Fig 10. Visualisation of Superverde street furniture (Block, 2020).

Superverde is a project by Italian architect Stefano Boeri for modular outdoor furniture for cities with plants, trees, and benches. Stefano Boeri Interiors, architect's practice, created Superverde for Metalco, an Italian street furniture maker. The metal edge will frame the pot, which will contain a suitable mixture of soil and greenery for the climate in which they are installed. Metal benches can be fixed to certain points of the frame so that passersby can sit and rest amongst the foliage. Due to a system of edges, modules, and hidden side structures, it allows to create landscapes of various sizes and shapes (Block, 2020).

There is also mentioned that Superverde comes with an energy-efficient autonomous maintenance system. With a dense irrigation system and sensors for the control and analysis of the wellness and moisture of the soil, you can both manage the use of water and all resources, and assure plant health. In addition to being a decoration, a pleasant place to sit and a habitat for insects, Superverde can improve the climate according to S. Boeri (Block, 2020).

Also, greenery will reduce the effect of "urban heat island" and decrease the temperature in areas with high density. An Urban Heat is a place where the built-up area becomes warmer than the surrounding countryside, because the land is covered with dark surfaces that absorb heat. Greenery can be used strategically to reduce the air temperature by casting shade and through evapotranspiration, the combination of water evaporating from the soil and plant transpiration (Block, 2020).

Fig 11. Visualisation of Superverde street furniture (Block, 2020).

The smallest version of Superverde has an area of 9 to 20 square meters and can accommodate up to 3 trees and 20 shrubs along with grasses and perennials. An extra-large version covers between 60 and 100 square metres and holds up to a dozen trees. Superverde increases the number of trees in the city, thus improving air quality and, consequently, the lives of citizens (Block, 2020).

1.2.2. Classification of analyzed projects according to their way of influence on climate change

The first step in adapting to the effects of climate change is to significantly reduce human contribution to climate change. Such adaptation requires and depends, among other factors, on the successful implementation of mitigation measures at the local level.

The main consequences of climate change with the most negative potential impact at the local level are the following:

a) more frequent occurrence of heat waves;
b) increase in average annual temperature;
c) more frequent and stronger storms, strong winds and hurricanes;
d) reduction of precipitation - more frequent periods of drought;
f) increasing the frequency of heavy rainfall.

More frequent occurrence of heat waves

The measures described here are aimed primarily at reducing high temperatures in public spaces, building areas and in transport infrastructure.

1.1. Activities implemented in public spaces

1.a) Design of urban facilities (buildings and green areas) for better air circulation. This measure is about identifying and improving air exchange between areas of the city and natural suburbs, which in the summer helps to reduce high temperatures in overheated areas of the city, as well as improve air quality.

1.b) Increasing the share of vegetation, especially in built-up urban centers

Diverse vegetation has a significant impact in terms of microclimate formation, including cooling of the territory in the hot period. In addition, different areas of vegetation have a cooling effect of different intensity, depending on the number and type of vegetation and, above all, the proportion of woody plants. The larger the area covered with greenery, and the higher the proportion of trees in this area, the higher the cooling effect. Measures should be aimed mainly at increasing the area of city parks and other green areas, creating green areas in parking lots and green dividing lanes on roads.

1.c) Planting of urban and suburban plant communities

This measure includes local planting of vegetation in industrial areas and settlements in urban areas of cities and villages, as well as planting of suburban tree plant groups in rural areas around cities and villages. Groups of woody vegetation, especially tall trees, help to mitigate the effects of high temperatures much more effectively than individual plants or so-called low vegetation. Forests and other groups of trees, respectively, can significantly affect the composition of air, its purity, temperature, humidity, ionization, etc. As a result, they have a significant impact on the microclimate of the group itself, and can also affect the surrounding, in particular, the urban environment.

1.d) Use of water elements

Water bodies in the urban environment are not only attractive but also very important from many points of view. Water effectively cools the environment, and thus creates a pleasant microclimate.

1.2. Implementation measures in buildings and outside

2.a) Use of green roofs.

The cooling effect of green roofs is mainly caused by water evaporation, shading from vegetation, the ability to reflect solar radiation, the consumption of thermal energy for photosynthesis and the accumulation of undistributed water. Green roofs can lower the temperature in the rooms under the roofs by a few degrees Celsius.

Green roofs can reduce the penetration of heat from the outside to the inside by more than 90%. Measurements recently taken on hot summer days in Germany have shown that in very hot weather with temperatures above 35 ° C, the temperature under green roofs does not exceed 25 ° C (Lenzholzer & Brown, 2013).

In general, vegetation can be planted on any roof that has the ability to maintain high static weight with a frame structure. In this case, the determining criterion is the weight. Green roofs can be divided into two groups: extensive and intensive.

Extensive roof consists of roof structures with a bearing capacity of 60-300 kg / m2 (Sijakovic & Peric, 2020). It may contain plants that grow in large areas (perennials) and xerophytic plants that can withstand sudden changes in temperature, drought and frost. The thickness of the substrate in the form of a grass carpet is usually 3-6 cm, in the case of planting grass - 6-15 cm, and in the case of twisted plants - 15-20 cm (Sijakovic & Peric, 2020). The intensive roof is arranged in the form of a structure with a bearing capacity of up to 1000 kg / m2, where soil layers with a thickness of 1 to 1.3 m can be used (TERI, 2010). They are suitable for creating gardens with flowers, shrubs and small trees

2.b) The use of vertical twisted plants.

Twisted plants that form a continuous curve of the facades, contribute to the insulation of buildings - the leaves reduce external vibrations that affect the building, and the layer of air formed between the leaves and the wall can more efficiently store heat. Accordingly, the leaves protect the wall from overheating in hot summer weather, and when the temperature drops - maintains the required temperature inside. Thus, the winding vegetation helps to improve the microclimate inside buildings and at the same time the climate in cities.

2. Increasing the average annual temperature

1. Selection of trees and shrubs to be planted in cities

Harmonization of the process of selection of the main species of woody plants to be planted in urban areas, taking into account the expected increase in temperature and climatic conditions for certain species of vegetation, can also be achieved by including species with higher resistance to dry periods and heat in summer. It is important to remember and avoid planting some invasive plants, the spread of which contributes to the increase in average annual and seasonal temperatures. The ecological amplitude of planted species should be wide enough to meet both current and future climatic conditions. This can be achieved by using species with a wide ecological valence (birch, poplar, aspen) and continental species (oak, hornbeam, maple, linden and ash) (Gradzinski, 2019).

2. Functional vegetation on river banks.

Decreased water quality due to rising temperatures is another expected effect of rising air temperatures. Tree vegetation along watercourses helps to improve water quality, increases the water's ability to self-clean, protects the riverbed from overgrowing with unwanted vegetation, as it obscures the water surface, and thus reduces the water temperature. The size of the river, the type, height and density of trees and shrubs on the river, as well as the width of the coastal

vegetation must be taken into account (Gradzinski, 2019). The wood cover on the banks should be at least 3–15 m wide, depending on the width and size of the river (Shaw et al., 2007). However, on the river bank, vegetation strips are most effective when they exceed 20 m in width and 150 m in length (Shaw et al., 2007). They should consist mainly of varieties of trees with deep roots and shrubs with a developed root system, as well as a flexible aboveground part with a high ability to regenerate.

3. Stronger and more frequent storm winds - strong winds and storms

Promoting the creation of forests or woody plant communities in rural areas landscape in connection with the mitigating effect they create on the negative effects of strong winds. Woody plant communities can also be used as a barrier to protect against winds, as they are able to absorb the kinetic energy of the air flow and, therefore, mitigate the potentially harmful effects of wind (windbreaks) (Shaw et al., 2007).

The cost of forests and other protective tree plant communities in rural areas are not very high, their positive impact is long-term and significant in terms of projected climate change. The costs of creating forests and other plant communities are partly related to the adjustment of the terrain (change of relief before planting), with the planting itself and care after planting. Agricultural lands are sometimes used for such plantations (Shaw et al., 2007).

4. Decrease in precipitation - higher frequency of droughts

1. Stricter measures to protect water resources

With regard to projected climate change scenarios, which provide for more frequent periods of drought, stricter protection of water sources should be ensured. Stricter protection of water sources will help reduce the risk of contamination and reduce the need for further decommissioning. As with the restoration of existing sources, this measure will also help streamline the use of water sources.

2. Sustainable management of water supply systems

In the conditions of expected reduction of capacity of water sources as a result of climate change, it is necessary to check balance qualities of water sources so that their excessive use, destruction or even destruction did not occur. At surface and groundwater drainage points, controlled drainage should be provided in order not to exceed the level of environmentally optimal costs in the part of the watercourse downstream in the relevant basin (Noran, 2019).

3. Preservation and expansion of forest area

Forests reduce the effects of extreme rainfall by reducing flood runoff and slowing water runoff. Forests also reduce surface runoff. These functions are optimally performed in forests with close to the natural structure or, in other words, forests with different species, age and spatial structure, which at the same time corresponds to the ecological conditions of the area (Jakob & Steckel, 2016). The quality of the forest as a complex system directly affects the water

holding capacity of the territory, i.e. when the forest cover decreases, the holding capacity of the landscape decreases and vice versa.

1.2.3. SWOT analysis of selected projects and their comparison

This SWOT analysis is primarily a method of strategic planning that identifies the strengths and weaknesses of landscape projects to prevent climate change, calculate risks and ensure the future prosperity through a comprehensive approach.

The traditional method of SWOT - analysis allows for a detailed study of the external and internal factors. The result of rational SWOT-analysis, aimed at the formation of generalized information potential, should be effective solutions for the appropriate response (influence) of the subject (weak, medium and strong) in accordance with the signal (weak, medium or strong) environment.

SWOT-analysis is a kind of tool, it does not contain final information for management decisions, but allows you to streamline the process of considering all available information using their own opinions and assessments.

Such analysis of projects will allow to understand them better and will help to form a system of measures to prevent climate change with minimal risk to the city both in terms of investment and in terms of the effects of climate change.

1. The Soul of Norrebro

The project is a series of measures to adapt the city to the effects of climate change in the form of controlling flooding through landscape design and it's functional use (Fig.12).

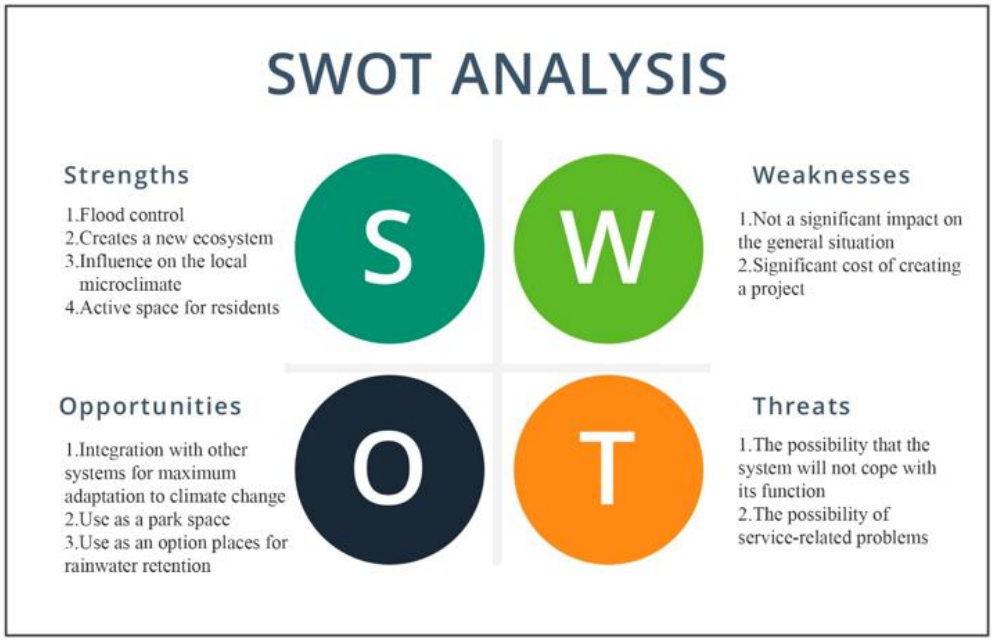


Fig 12. Swot analysis of the project "The Soul of Norrebro". Scheme by the author

2. Climate tile

The project aim is the use of climate tile to reduce the effects of heavy rains and the ability to increase the area of the city`s drainage system (Fig.13).

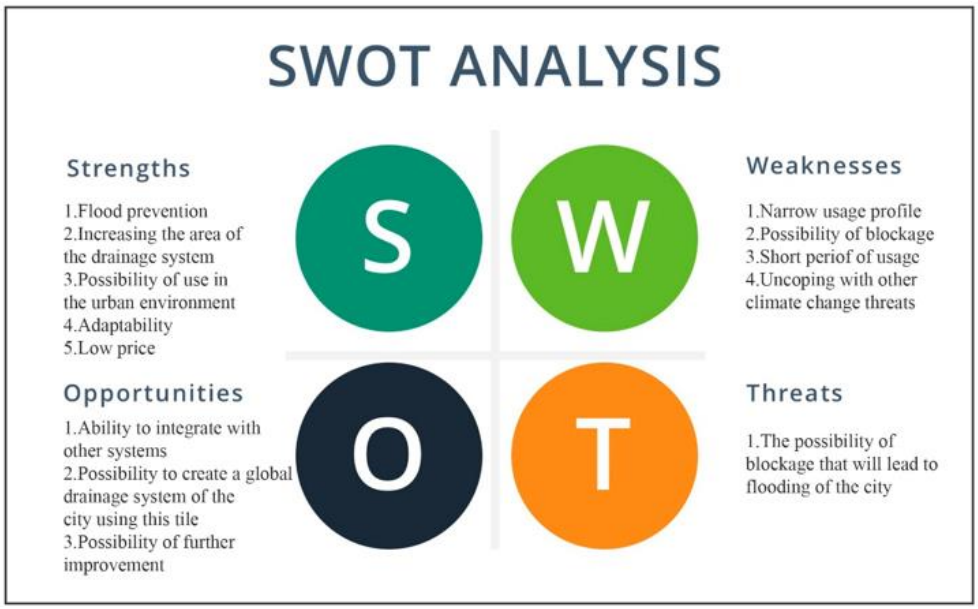


Fig 13. Swot analysis of the project “Climate tile”. Scheme by the author

3. Hybrid Street furniture

The project aims to create integrated green islands in the urban environment that will absorb a significant amount of rainwater and create cooling islands of cold for local people (Fig.14).

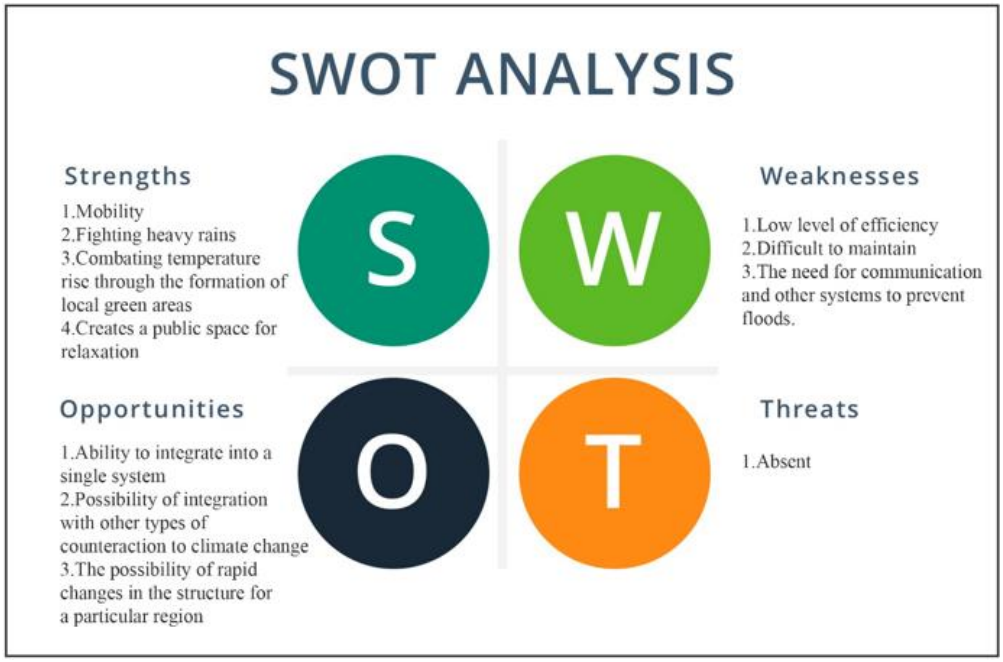


Fig 14. Swot analysis of the project “Hybrid Street furniture”. Scheme by the author

The analysis showed that almost all of the considered projects of adaptation tn climate change prevention with the help of landscape architecture have both their pros and cons.

The best option is to form a combined system of measures to prevent floods in urban areas, which will compensate for the weaknesses of different methods and maximize their positive effects.

Also, one of the important aspects is the financial component of these projects, because the implementation of large-scale projects requires significant investment and a long period of time. One of the possible options for development is the creation of a project that will reduce the threats floods in the shortest possible time, and will constantly develop and expand its capabilities.

SWOT-analysis helped to classify and better understand the implications of implementing an approach of adaptation to climate change in urban environments.

1.3. Hypothetical model of adaptation to climate change using landscape architecture solutions

This model (Fig.15) was built on the principle of logical sequence and how climate change occurs. A key factor is the anthropogenic impact on the environment. Human activities are causing significant climate change, such as global warming and melting glaciers, which is causing much more rainfall and rising ocean levels.

The next step is division of factorst of influence on two groups: the impact on the environment and the impact on human life. The first category identifies the main factors and results of the impact of climate change on the habitat, such factors are the destruction of the habitat, increasing levels of extreme weather events, freshwater loss, drought and social impact. The key in this category is to identify the main risks, their understanding, and anticipate possible future changes and impacts on the environment.

The impact on human life includes consequences such as flooding of cities, loss of agricultural land, destruction of cities, significant economic losses and migration of people to more habitable places. Some of the options for exposure are related to the factors influencing the environment, because a person's life in one way or another depends on the environment in which he lives. The target factor is the analysis and development of optimal options for the fight to reduce economic costs, the feasibility of measures, the prospects of possible scenarios and their benefits.

The next step in building the model is to set goals and objectives for combating climate change and its effects before the identification of appropriate measures. Activities using landscape architecture are divided into two categories: landscape design and landscape planning. Landscape design focuses on local issues and uses appropriate local measures such as the formation of small parks, the use of modern building materials, green roofs and vertical landscaping. Landscape planning forms a general approach to solving the problem of the whole city through such measures as: the formation of an adaptive system for the prevention of climate change or the formation of large-scale projects.

The final step is to apply a developed approach that will meet all the requirements of the specific situation and will also create a positive impact on climate change itself. It is also important to annually review the applied model, develop measures to improve it and analyze the results, which will maximize the effect of measures to adaptation with the usage of landscape architecture.

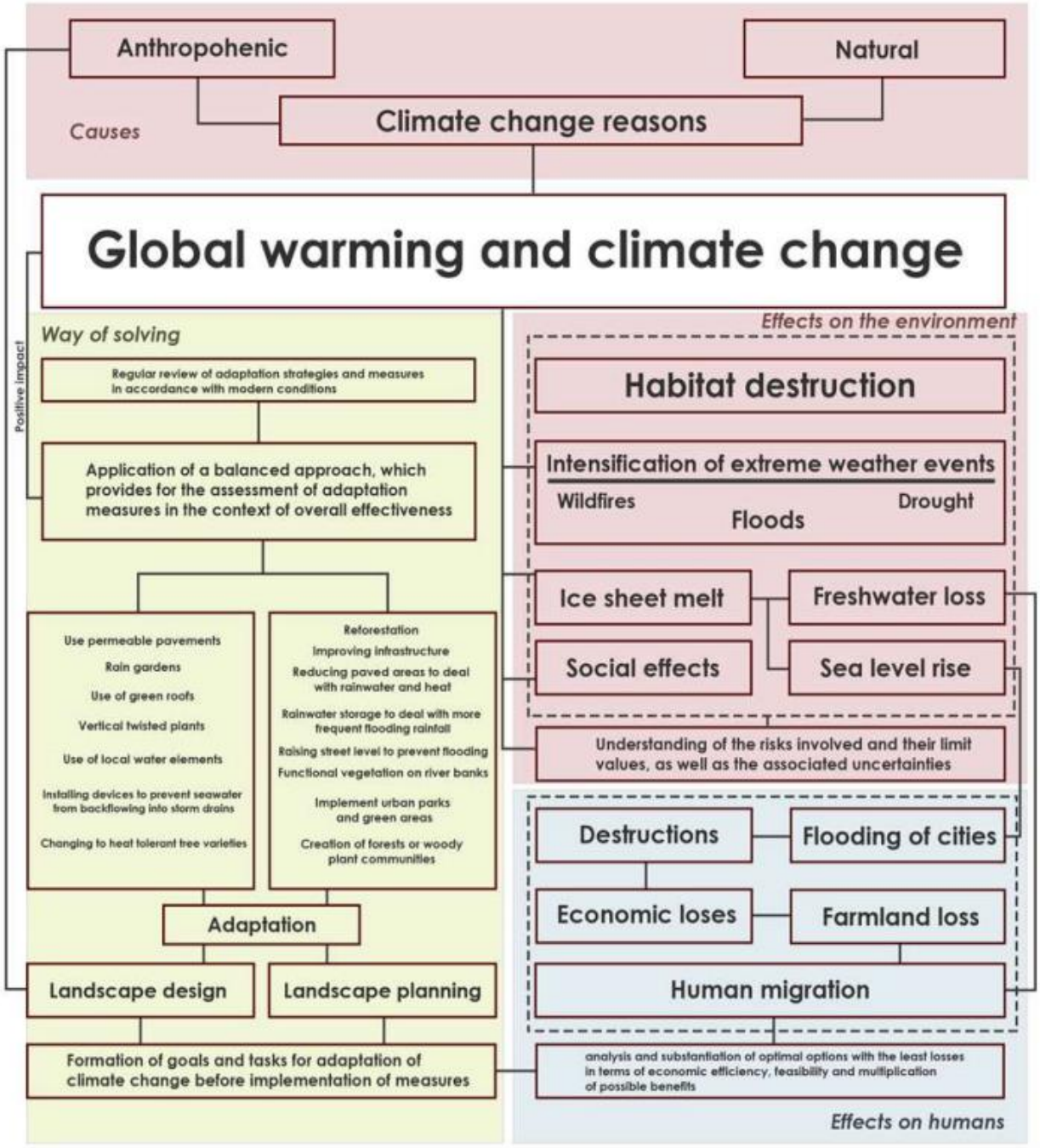


Fig 15. Hypothetical model of adaptation to climate change using landscape architecture solutions. Scheme by the author

2. Empirical research of possibilities to influence climate change using landscape architecture solutions

Empirical studies of the possibilities of influencing climate change can be conducted and analyzed using qualitative or quantitative methods.

Quantitative research. Quantitative research methods are used to collect information using numerical data. They are used to collect and evaluate information on climate change, as well as the potential consequences and the city's readiness to resist it. One such aspect is the assessment of urban resilience expressed in numerical terms with the help of appropriate tools.

Qualitative research. Qualitative research methods are used in empirical research to collect non-numerical data. They are used to find the meanings, opinions or root causes of subjects. One of the key elements is a sociological survey using photographic data of urban residents, which aims to quantify the level of understanding and visual preferences of urban residents towards ecological landscape architecture.

Data analysis. Empirical data can also be analyzed quantitatively and qualitatively. This allows you to answer empirical questions that need to be clearly defined and answered with the acquired knowledge.

2.1. Working hypothesis and research program

Green infrastructure considered as a strategic approach to landscape and environment planning that applies key principles of landscape ecology to the urban environment, and in particular multi-scale planning. The approach was developed and adopted in consequence of the opportunities occered in different disciplines to meet environmental, ecological, social challenges of landscape planning. Multiple use of green infrastructure can help adapt to climate change in different scales and regions.

Climate change as a result of historic greenhouse gas emissions will threaten the city. Deficit of existing urban systems to cope with the risks posed by these changes, such as droughts, floods, and extreme temperatures, make citizens vulnerable to these changes. Green infrastructureplays an important role in combating climate change by providing a range of ecosystem services.

Working hypothesis and research programare focused on adopting to climate change in urban landscape scale. The principles, methods, and impacts of climate change adaptation and green infrastructure were distinguished and compared. Then through this comparison, a conceptual model was developed clarifying their complementarity and relationship.

The research program (table 1) consists of six research statements, which must be confirmed during the research in order to establish their relevance and value. Both quantitative and qualitative methods act as research methods: content analysis of documents including the analysis of territorial planning documents, analysis of urban sustainability using sustainability compass tool, fractal analysis, sociological survey including photographic data.

Most of these statements were formed on the basis of previous research using new approaches in landscape architecture for climate change adaptation using theoretical data sources, analytical articles and existing projects.

The importance of the program is that it is a strategic element, helps to form a multi-level plan to achieve the goal in conditions of uncertainty and includes several skills and involves many disciplines to achieve the goal or goals.

The working hypothesis is the possibility of identifying problem areas that have the highest risk of destruction or damage due to climate change and related processes, to implement adaptive landscape measures through practical research. These measures should be aimed at eliminating, anticipating or protecting against possible natural disasters, as well as developing the sustainability of the city and improving the conditions of the green structure of the city, which has a significant impact on its inhabitants.

Table 1. Working hypothesis statements and research Program

№	Research statement	Research object	Research method	Research tool
1	Landscape design and landscape planning create the most necessary conditions for adaptation to climate change In urban areas	Researches proving the importance and necessity of adaptive measures in urban areas	Document analysis	Check list
2	The level of urban sustainability is one of the main criteria in the implementation of adaptive measures through landscape design and planning	Level of urban sustainability in cities under research – Ivano-Frankivsk and Kaunas	Analysis of territory planning documents	Urban scale sustainability compass
3	Assessment of the urban environment allows to determine the urban sustainability and the possibility of implementing adaptive measures	Resilience of urban environment in cities under research	Analysis of urban sustainability	Urban scale sustainability compass
4	Implementation of adaptive measures requires data related to the influence of residents on the existing infrastructure of the city	Urban data which can show influence of residents on the existing infrastructure of the city	Sociological survey	Questionary
5	Detailed analysis of the existing infrastructure in the city will form better picture for the quality implementation of adaptive measures	Urban infrastructure of the cities	Research on the site	Check list
6	Which landscape design and planning measures can be applied into the cities	Public spaces and network of public spaces, urban planning features	Photographical survey	Check list

Various research tools such as the Compass of Urban Sustainability, various checklists based on theoretical research, surveys of local residents, analysis of cartographic materials based on previous research by other authors, as well as fractal analysis of the green structure of the city were used to study and confirm these positions. which made it possible to explore the possibilities of development and the existing network of green areas qualitatively and quantitatively.

2.2. Content analysis of Kaunas and Ivano-Frankivsk strategic, planning documents and studies

The function of documentation as a source of data in empirical research is widely acknowledged and used. The analysis of the documentary base of strategic development and planning documents can allow to form a clear vision of its development, to provide advantages and limitations, to offer concrete examples of use of various actions in the course of research and development. Organization and institutional documents, reports, studies of particular cases etc. have been a major factor in qualitative research for many years. As a research method, the analysis of development documents is included in qualitative research (Cheng, 2004).

The analysis of such documents as general documents, reports related with climate change and documents related to development of the city by the approved higher governing bodies, gives the chance to receive the comprehensive information on a direction of general development of the problem and development of the city, the priorities and the established goals in the forthcoming years. The documents may also allow to study the already formed measures combat climate change and adaptation of the city to them. This will allow forming a clear picture for further research and development of adaptation measures using landscape architecture, avoiding contradictions with already established measures and the formation of integrated approaches to solving problems in the city.

The following documents and studies related to the city of Kaunas were analyzed in this section:

1. Strategic development plan of Kaunas city municipality up to 2022 (ERDF, 2016);
2. Master plan project of Kaunas;
3 Kaunas Sustainable Mobility plan (2020).
4.GIS-based Flash Flood Risk Estimation in Urban Areas. Kaunas City Case Study (Dumbrauskas & Vyčienė, 2018);
5.Participatory aspects of strategic sustainable development planning in local communities: experience of Lithuania (Čiegis & Gineitienė, 2008).

The main statements from the analyzed documents were formed and identified, which clearly reflect the direction of the city's development and the set priorities and existing problems of the city:

1. Developing the public infrastructure that improves the public tourism and general image of the city;
2. Renewing and developing the water supply and wastewater management infrastructure;
3. Running a sustainable development of urban areas and their infrastructure;
4. Equipment and renovation of the infrastructure of pedestrian walkways, cycle and other non-motorized transport paths, roads and other related infrastructure;
5. Preparation and 20 plementation of programmes for improvement of environment quality;
6. Renovation and development of the city's parks, public spaces, recreational zones.

The analysis of the documents has already shown that Kaunas is currently one of the most important cities in Lithuania, and it has a stable qualitative and quantitative development. Also documents showed a clear focus on the development of the city's sustainability by improving the existing infrastructure. A significant advantage is given to the development of accessibility and attractiveness of the city to attract new investments that will allow to qualitatively develop the tourist and recreational potential of the city.

The following documents related to development of Ivano-Frankivsk city were analyzed:

1. Ivano-Frankivsk development strategy up to 2028 (IFCM, 2017);
2. Determination of economic and innovative potential of Ivano-Frankivsk city (IFCM, 2019)
3. Substantive provisions of the master plan of development of the city of Ivano-Frankivsk and the project of planning of its suburban zone (IFCM, 2020);
4. Master plan project of Ivano-Frankivsk

The city of Ivano-Frankivsk is today one of the 24 regional cente 129 of Ukraine, the administrative, economic and cultural center of Ivano-Frankivsk region, with a total area of 83.73 sq. km, with a population over 250 thousand inhabitants. Ivano-Frankivsk is a city with meaningful economic, industrial, and scientific potential, great opportunities for the development of both internal interregional and external interstate relations. The great prospects of the city are connected with the neighborhood of the Carpathians as a unique region of tourism recreation (IFCM, 2017).

Strategic directions of the city development (IFCM, 2017):

1. City of investment support and business development;
2. A city of comfortable living, energy efficient and environmentally friendly infrastructure;
3. The city of open government and modern governance;
4. The city of quality education, medicine, diverse cultural environment.

In view of the above, it can be argued that in general, the development of the Development Strategy of the city of Ivano-Frankivsk for the period up to 2028 was carried out taking into account the probable environmental impacts and with a desire to minimize them. The implementation of the Strategy, subject to compliance with environmental requirements, should help reduce the anthropogenic burden on the environment (IFCM, 2017).

Combining efforts to promote entrepreneurship, including green business, with efforts to create energy-efficient and environmentally friendly infrastructure will ensure the development of Ivano-Frankivsk as a city of high quality of life (IFCM, 2017).

The main statements from the analyzed documents were formed and identified, which clearly reflect the direction of the city's development and the set priorities and existing problems of the city:

1.Improvement and development of the architectural and planning structure of the city in accordance with the requirements of modern urban planning;

2. Development of a system of green plantings with expansion of city park area;
3. Creation of a suburban forest park green zone around the city of lvano-Frankivsk with an increase in the total area of greenery by 4.2 thousand hectares;
4. Wide development of the system of institutions and places of mass recreation with their placement within the forest park belt.

Analysis of the documents of the strategic development of the city shows a strong emphasis on the development of industrial infrastructure and construction industry in the city. A large amount of territory is allocated for housing, while park and recreational areas in the city are almost not developing. The development strategy considers of the formation of recreational green areas only outside the city. The main result of this is that currently the city is not significantly interested in increasing the level of its sustainability and development of green infrastructure, which are the key aspects of modern European cities and to combating with global warming process.

2.3. Analysis of urban sustainability of Kaunas and Ivano-Frankivsk

Over the last decades sustainability became the key concept aimed at understanding existing urban dynamics and responding to the challenges of creating livable urban futures. Urban sustainability is a multi-scale and multidimensional issge (Bureau Urbanisme, 2021), as, according to K. Zaleckis & J. Kamičaitytė – Virbašienė (2012), "city is a complex system consisting from various sub-systems: social, economic, spatial, aesthetic, ecologic, and etc." For the general sustainability analysis of Kaunas and Ivano-Frankivsk urban sustainability compass methodology (Bureau Urbanisme, 2021) was selected. This complex methodology alows to evaluate different systems and subsystems of the cities for the better understanding of green structures of the cities, which are very important in the context of sustainability, climate change, and landscape architecture, fractal analysis method was selected.

2.3.1 Urban sustainability compass methodology and its application

The theoretical framework based on 'Six Fields of Sustainable Urbanism'. This forms the foundation of Sustainability Compass approach. The 'sustainability compass' applied in this research was developed by the consultation company Bureau Urbanisme (2021) and combines six Fields: *Environment*, *Society*, *Economy, Technology, Space* and *Process.* These six fields are distributed in a circle as all of then are of the equal importance. In the circle each field has strongest connections with the field beside it: for example *Space* is most related *to Society* and *Environment*, while *Technology* is most related to the *Environment* and the *Economy* (Fig.16) (Bureau Urbanisme, 2021). Each field of the compass is shortly presented below.

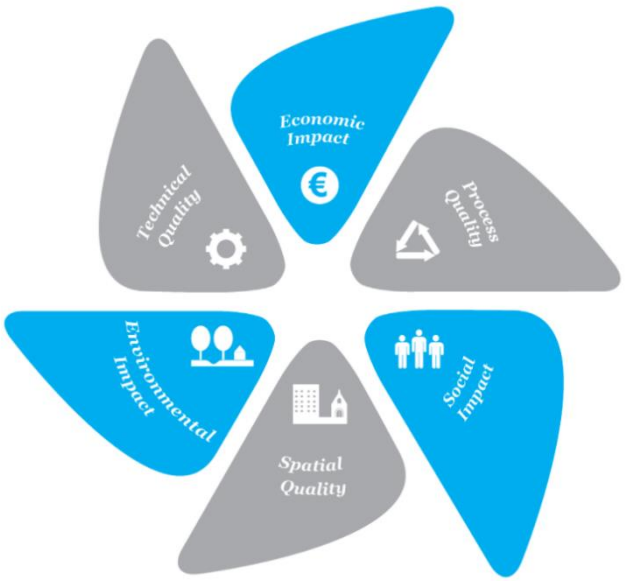


Fig 16. Diagram of sustainability compass (Bureau Urbanisme, 2021).

Social impact deals with is about the ways physical space affects the way people interact. This involves identifying links between space, functions and the way people act from the point of view of urban planning. Social impact category then involves finding functions, which may have a positive effect or further improvement of quality of life (Bureau Urbanisme, 2021).

Spatial quality category allows analyzing the value relationship between the physical environment and the quality of experience of the usage of it. Perception and experience are key to the spatial quality: spatial logic, cultural identity and readability. The space is not seen as an abstract context in this methodology, but as a subjective framework that makes activities possible and which is inseparably linked to its social and cultural environment (Bureau Urbanisme, 2021).

Environmental impact is the degree to which the use of the physical environment affects the functioning of ecological systems in the area.There are the various elements covered by the natural environment including: water, resources, air, soil, resources, land use and biodiversity (Bureau Urbanisme, 2021).

Technical quality focuses on the technological facilities, structures and processes that are used to generate social, ecological, and economic advantages. In an urban environment, especially energy, transport and utilities play an important role in the technical quality (Bureau Urbanisme, 2021).

Economic impact focuses on the connection between places and their generative economic capacity. To define it, it is necessary to determine the conditions between the functions, skills and productivity of the space to ensure sustainable prosperity. Spatial planning must also take into account direct and indirect investments and profits in terms of economic impact (Bureau Urbanisme, 2021).

Process Quality refers to the relationship between investment in staff and activities for the organization and implementation of sustainable urban planning. Without an appropriate strategy of

consultation, implementation and support from the project, it is possible that the "sustainable" project will not be implemented (Bureai Urbanisme, 2021).

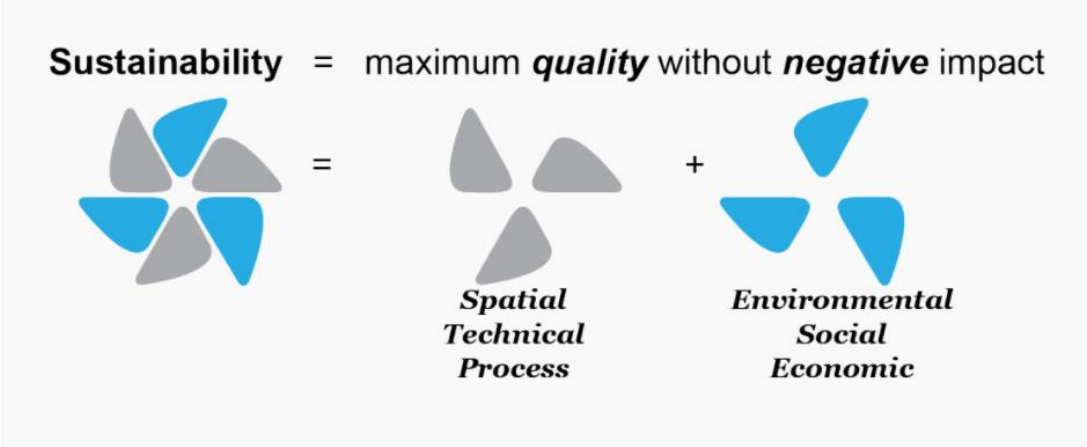


Fig 17: Diagram: relation between impact and quality in sustainability compass methodology (Bureau Urbanisme, 2021).

Analysis of the urban sustainability of the two cities using sustainability compass methodology (Fig.18) allows to perform a comparative analysis and see the current situation from *Environment, Society, Economy, Technology, Space and Process* fields pints of view. Tables 2 and 3 were formed using sustanability compass criteris provided by Bureau Urbanisme (2021). In this case criteria were selected that are in one way or another related to the green structure of the caty and have a significant impact on it. The tables show the evaluation and explenations for each element and provide an oportunity to learn more about the evaluation results. Table 4 shows the values and explanations of each of the ratings that were used ti acess the resilence of the cities using an urban sustainability compass.

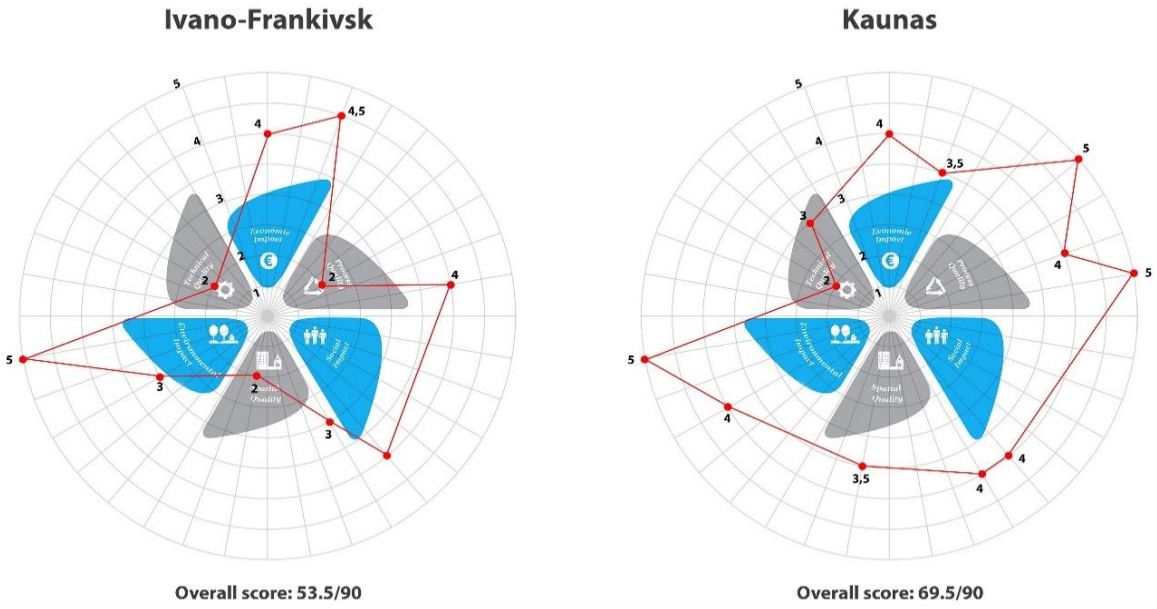


Fig 18. Urban sustainability compasses of Kaunas and Ivano-Frankivsk created using Bureau Urbanisme sustinability compass methodology (Bureau Urbanisme, 2021).

Table 2. Ivano-Frankivsk urban sustainability evaluation according to the criteria distinguished Bureau Urbanisme sustainability compass methodology (Bureau Urbanisme, 2021).

Ivano-Frankivsk	Economic impact	Financial flows	Investments	The best region in Ukraine for investment, so that' s mean that city have a good possibilities for development of sustainability	4 points	8.5 points	53.5 points
		Local economic resilience	Spatial flexibility	Ivano-Frankivsk is a developing city, many territories change their function, which creates flexibility and opportunities for formation	4.5 points		
	Process quality	Design and development	Development strategies	One of the main problems of the city is the lack of development strategy, which leads to problems with infrastructure and chaotic construction in the city.	2 points	17 points	
			Strategic vision and transition	The city does not have a clear vision for development, and yet there are qualitative changes in the planning structure, which is close to the European	3 points		
		Integrated planning	Enviromental planning	The lack of previous aspects does not allow to form a qualitative approach to enviromental planning of the city, which also creates certain problems	2 points		
			Spatial planning	The lack of previous aspects does not allow to form a qualitative approach to spatial planning of the city	2 points		
		Residents and users	Participation	Projects that are unreasonable or harmful to the environment are often banned due to local residents and their influence.	4 points		
		Site management	Construction management	Currently, the construction industry is actively developing and there is a transition to European building codes, and their control is carried out by independent experts.	4 points		
	Social impact						
	Social quality	Urban structure	Building shape and density	The city is divided into two parts - the historic center and the Soviet periphery. The historic center has remained unchanged with dense Austro-Hungarian buildings and small streets. Currently, modern construction is in line with European trends in the creation of residential areas	4 points	11 points	
			Plot structure	The city is divided into districts, the main of which is the historic part of the city. Also, the territory is being built in accordance with the already formed boundaries of these areas.	3 points		
		Public space	Network of public space	One of the problems of the city is the lack of sufficient public spaces, as a consequence of the lack of a clear development strategy and spatial planning.	2 points		
		Integration	Landscape integration	Currently, the city has no tendency to integrate and develop the landscape, as well as the development of green landscape areas.	2 points		
	Technical quality	Land use	Integration with context	The city is well integrated with the context of the environment and also conlributes to its development and improvement	3 points	13 points	
		Air and atmosphere	Urban climate	The urban climate is positive as the city does not currently suffer significant economic losses due to climate change, which provides a good opportunity for adaptation in the future.	5 points		
			Air quality	The city is located in a mountainous environment and one of the main factors is the lack of large enterprises that create harmful emissions into the atmosphere	5 points		
	Environmental impact	Energy production	Non-renewable energy production	The city does not create and does not use a significant amount of non-renewable energy resources, instead there is a tendency to use solar panels.	2 points	4 points	
			Biomass energy production	Not produced	0 points		
		Energy consumption	Transport use	The main transport in the city is private cars and public buses with internal combustion engines, which has a detrimental effect on air quality and urban climate.	2 points		

Table 3. Kaunas urban sustainability evaluation according to the criteria distinguished Bureau Urbanisme sustainability compass methodology (Bureau Urbanisme, 2021).

Kaunas	Economic impact	Financial flows	Investments	Kaunas is the second capital city in Lithuania, with significant investment potential, which allows to implement infrastructure and architectural projects	4 points	7.5 points	69.5 points
		Local economic resilience	Spatial flexibility	The city of Kaunas is still in its infancy and yet much of the city has already been formed and creates some constraints on flexibility.	3.5 points		
	Process quality	Design and development	Development strategies	Currently, Kaunas has a clear plan for the development of the municipality, which allows for sustainable development.	5 points	28 points	
			Strategic vision and transition	Strategic Development Plan of Municipality of Kaunas District for Year 2013 -2020	5 points		
		Integrated planning	Enviromental planning	Has a clear development of enviromental planning, which is spelled out in the development strategy of the Kaunas municipality	5 points		
			Spatial planning	Kaunas has a good level of spatial development and a clear plan for its development, but still have some existing problems	4 points		
		Residents and users	Participation	Kaunas residents have a significant influence on the formation of the city and actively participate in its formation	4 points		
		Site management	Construction management	Kaunas uses European norms and approaches in the formation and construction of urban architectural and infrastructural objects	5 points		
	Social impact						
	Social quality	Urban structure	Building shape and density	Kaunas is not a densely built-up city that creates comfortable living conditions, the shape and trends of buildings meet modern European standards.	4 points	15 points	
			Plot structure	The city is clearly divided into districts and the historical part of the city. Currently, the structure of the city is in satisfactory condition and has sample opportunities for improvement	4 points		
		Public space	Network of public space	Currently, the network of public spaces in Kaunas is in a satisfactory condition and despite this there is a significant need for their development and improvement.	3.5 points		
		Integration	Landscape integration	Currently, the network of public spaces in Kaunas is in a satisfactory condition and despite this there is a significant need for their development and improvement.	3.5 points		
	Technical quality	Land use	Integration with context	Kaunas has a positive level of integration with the context of the environment	4 points	14 points	
		Air and atmosphere	Urban climate	A city with a good urban climate, located in a temperate climate zone and currently not significantly affected by climate change	5 points		
			Air quality	A city with high air quality, without significant pollution from businesses and cars.	5 points		
	Environmental impact	Energy production	Non-renewable energy production	The city actively produces non-renewable energy sources, which creates a positive urban climate	2 points	5 points	
			Biomass energy production	.	0 points		
		Energy consumption	Transport use	The city mainly uses private cars with internal combustion engines and public transport that partially uses electricity.	3 points		

Table 4. Rating scale for evaluation of the city sustainability

Scale	Rating	Definitions
5 points	Excellent Exceptional Mastery Much more than acceptable	Should ensure extremely effective performance. Significantly above criteria for successful performance. Reserved for the exemplary set of oportunities that field a particularly sophisticated approach to handling the situation. Meets all major / essential / core criteria or acceptable equivalents
4 points	Very Good. Full Performance Behaviours Above average	More than adequate for effective performance Generally, exceeds criteria relative to quality and quantity of behaviour required for successful sustainability performance. Meets all of the major / essential / core criteria or acceptable equivalents and several of the minor / addiitional criteria. No major deficiencies exist in the areas assessed. Consistently demonstrated better than average level of performance. Describes / demonstrates the full range of possibilities appropriate for handling the situation and the desired result, or outcome is obtained.
3 points	Good Acceptable Satisfactory Average	Should be adequate for effective sustanable performance. Meets criteria relative to quality and quantity of behaviour required for successful job performance.
		Meets several of the major / essential / core criteria one or two of the minor / additional criteria or acceptable equivalents. Describes / demonstrates a sufficient range of possibilities for handling the situation and the desired outcome is obtained. Some of the major and minor criteria were met; some deficiencies exist in the areas but none of major concern.
2 points	Weak Less than Acceptable	Insufficient for performance sustainable requirements. Generally, does not meet criteria relative to quality and quantity of behaviour required for successful work performance e.g. meets half or less of criteria. Does not describe / demonstrate a sufficient range of possibilities appropriate for handling of the situation, or describes plausible but inappropriate behaviours for handling the situation or the desired result or outcome is not obtained.
0-1 point	Unacceptable. Poor Much less than acceptable	Significantly below criteria required for successful job performance. Few or no criteria met. Many deficiencies. A major problem exists. No answer or inappropriate answer. Describes/demonstrates counter-productive behaviours that have negative outcomes or consequences (make the situation worse).

The analysis using a sustainability compass methodology clearly shows a significant difference in the sustainability of the two cities. The graph (Fig.18) clearly shows which groups of fields predominate or lag behind in the two cities. From the overall score of the two cities, it follows that Kaunas is a more developed and sustainable city, and yet leaves room for improvement. The results of lvano-Frankivsk showed that the city needs a significant reorganization and revision of the main elements to increase the level of sustainability, which will allow the city to sustainably develop in the future.

2.3.2. Fractal analysis of green structures of Kaunas and Ivano-Frankivsk

According to Zaleckis & Kamičaitytė-Virbašienė (2012) "Urban structure (spatial system) of the city also can be divided into sub-systems of the lower level: structures, streets, greenery, and public spaces. The urban potential of these sub-systems reveals the overall potential of the urban structure: its multi-functionality, livability, degree of complexity, potential of adaptability and evolution, and spatial capacity etc. This potential can be fully, partially used or unused at all (Zaleckis & Kamičaitytė -Virbašienė, 2012). Cosidering this, the main aim of the fractal analysis of green structures of Kaunas and Ivano-Frankivsk is the evaluation of the potential of urban green structure of these cities.

According to Zaleckis & Kamičaitytė-Virbašienė (2012), fractal index D shows how much and how the fractal fills the space in various scales. The results of the analysis will allow to assess and compare the potential of qualitative and quantitative development of the green framework of cities, which will also indicate its strengths and weaknesses (lvano-Frankivsk and Kaunas), which will also indicate its strengts and weaknesses.

Considering peculiarity and complexity of cities urban structure it is possible to state that sustainable development of cities is dependent on the sustainable development of its subsystems. (Zaleckis & Kamičaitytė-Virbašienė, 2012). The system approach applied in this analysis is presented in fig.19.

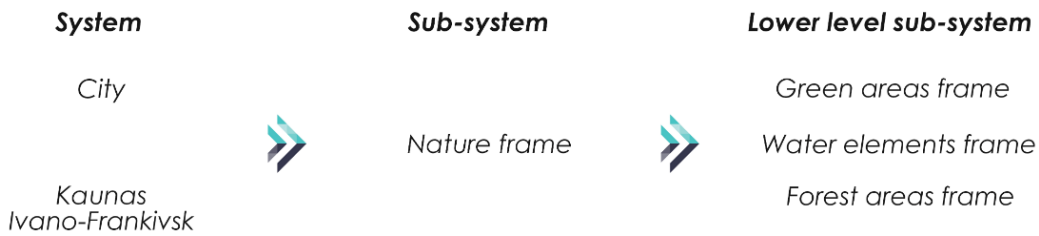


Fig 19. Fractal analysis systems. Sheme by the author

Fractal analysis results

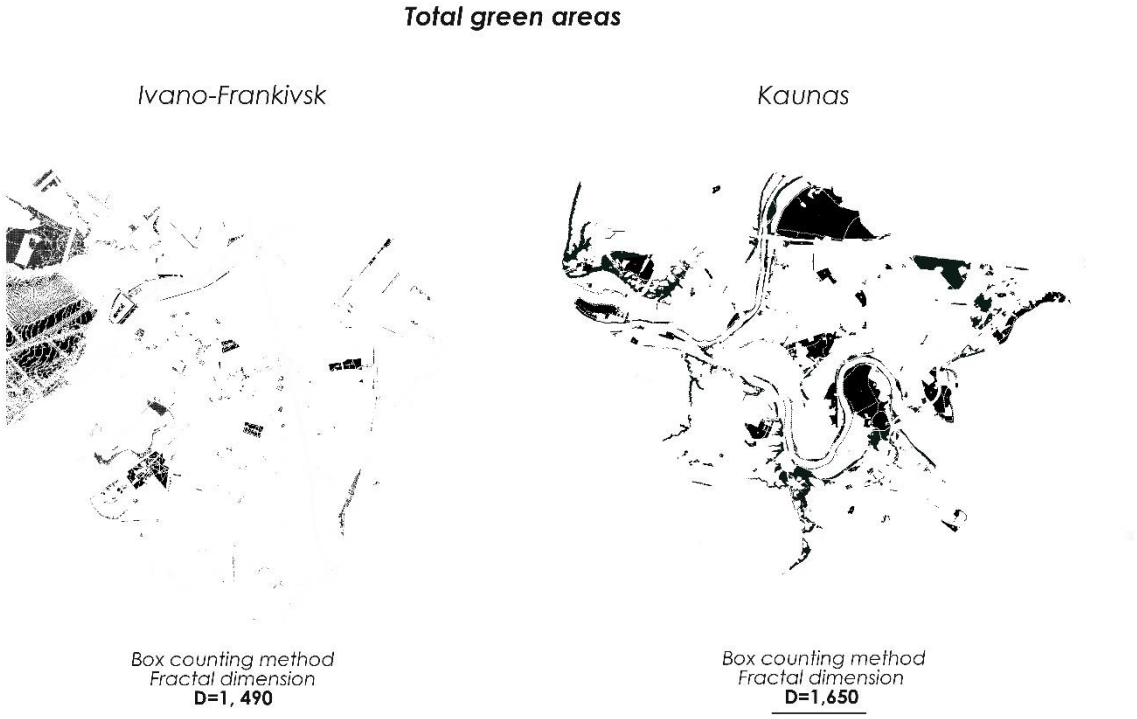


Fig 20. Comparison of total green areas fractal analysis results. Schemes by the author.

The fractal index D of the city of Kaunas is much higher in comparison with the fractal index of Ivano-Frankivsk. It can be explained by the fact that the territory of the city of Kaunas is more covered with greenery compared to Ivano-Frankivsk, and also shows a quantitative assessment of the existing green network of the city. For a more detailed acquaintance with what factors influence the fractal indexes, the overall green area was divided we divided into subsystems, which will allow to see in what aspects Kaunas demonstrates better results.

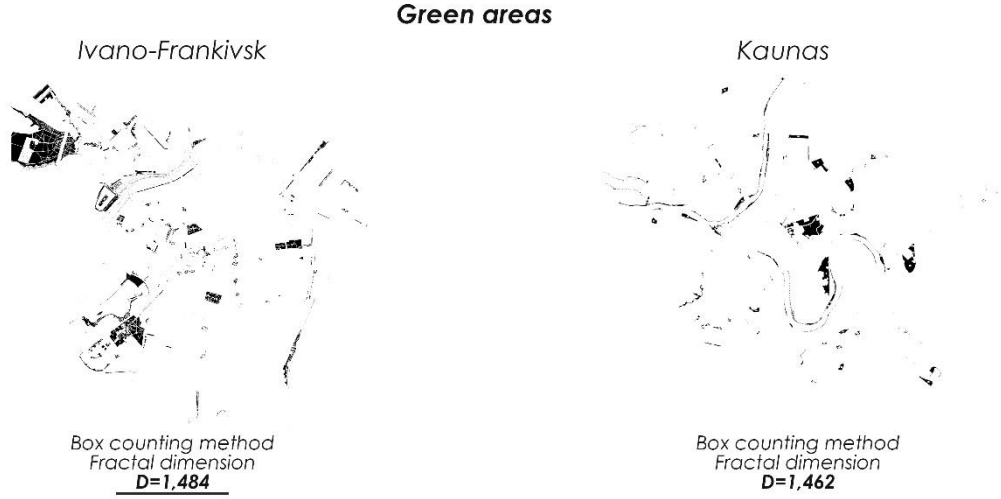


Fig 21. Comparison of green areas fractal analysis results. Schemes by the author

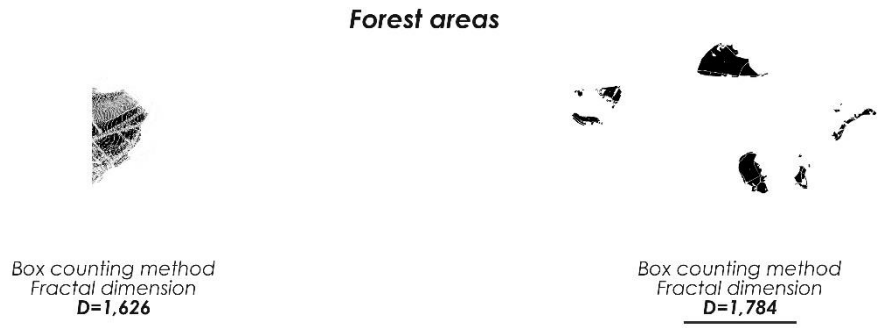


Fig 22. Comparison of forest areas fractal analysis results. Scheme by the author

This division into subsystems has demonstrated that urban green areas have approximately the same fractal index, and crucial in this aspect is the forest area, which is significantly predominant in the city of Kaunas, which creates a significant difference in the final result.

The next step is the fractal analysis of the green structure of cities, taking into account water elements as well and determining their impact on the overall result.

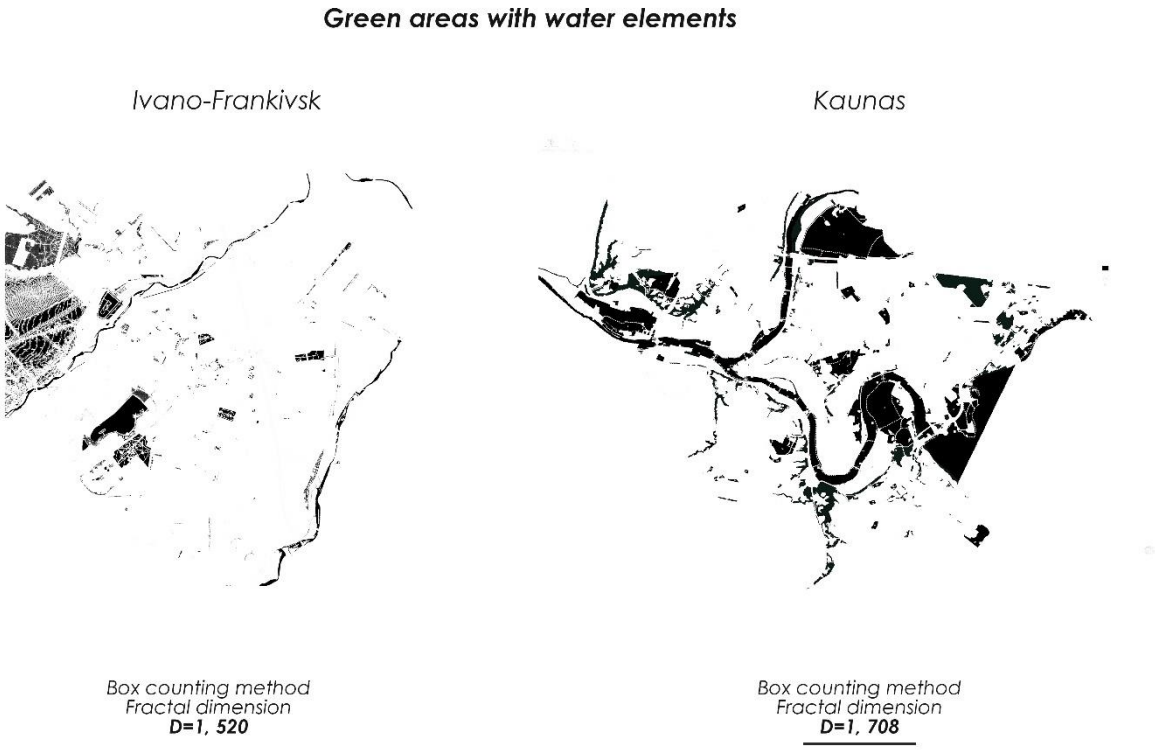


Fig 23. Comparison of green areas with water elements fractal analysis results. Schemes by the author

In this case, the fractal index of the city of Kaunas is much higher, and compared to the previous result, the difference between the fractal indices of cities has increased. This suggests that the water elements of the city of Kaunas have higher complexity potential compared to the city of Ivano-Frankivsk.

Thus, according to the fractal analysis results, the water network of the city of Kaunas significantly determines higher fractal index score, which leads to an increase in the difference between the total fractal index of the two cities in favor of the city of Kaunas.

It is possible to conclude that the fractal analysis of the green structure of cities showed a significant advantage of Kaunas in most cases, except for green areas that do not consider forests.

These results are closely related with the results of the analysis of the sustainability of the two cities, in which Kaunas is also significantly outperformed Ivano-Frankivsk. This suggests that, as a rule, urban sustainability depends in part on the level of green structure in the city, which also has a significant impact on the comfort and health of its residents.

2.4. Map analysis of existing infrastructure of Kaunas city

This analytical method is used to identify potentially flood-prone areas in the city of Kaunas and to get acquainted in detail with its landscape on the structure. Existing maps based on previous research by other authors as well as the online maps of flood threats of Kaunas (Flood hazard and risk maps, 2020) were used for the study. The analysis of this materials allows to identify areas that are at potential risk and to map potential measures to adapt or prevent the effects of climate change through the use of measures of landscape architecture.

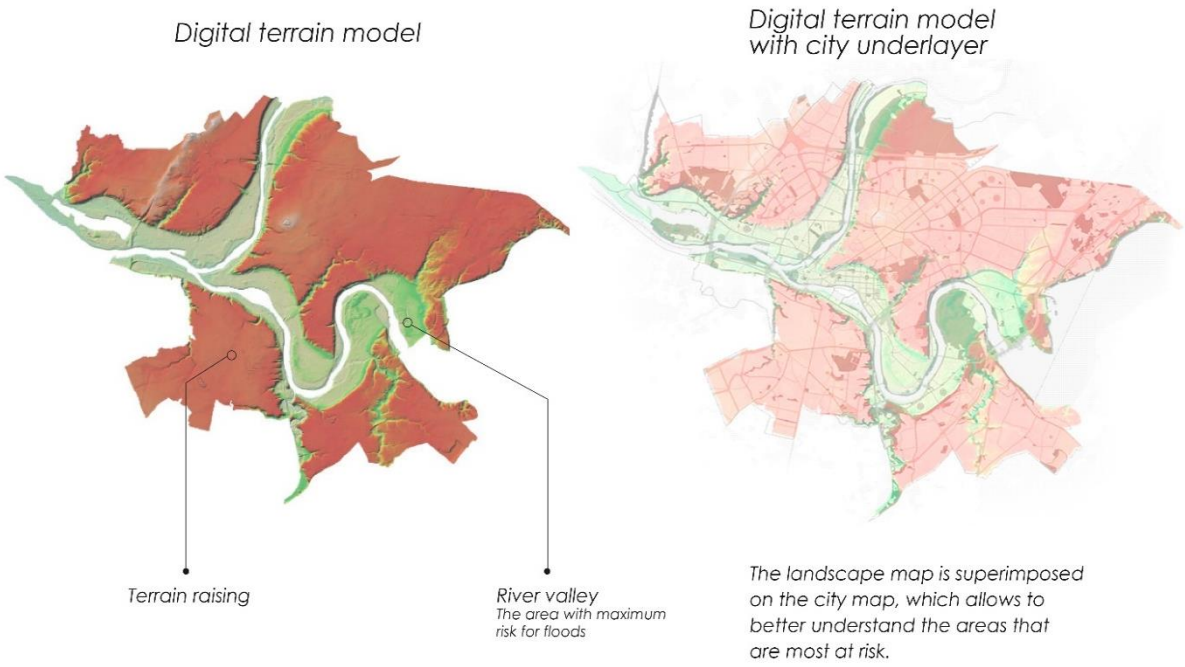


Fig 24. Terrain map analysis with reference to A. Dumbrauskas & G.Vyciene, (2018)

This model of the relief of the city of Kaunas (Fig.24), clearly depicts the division of the city into two parts, plain and lowland formed by the rivers Nemunas and Neris. According to the topography of the city, it can be concluded that during the periods of heavy rainfall, the lowland area has a potential risk of flooding. Also by superimposing a terrain map on the city map, it is possible to see that the developed part of the city is in the area of potential risk and needs more detailed analysis.

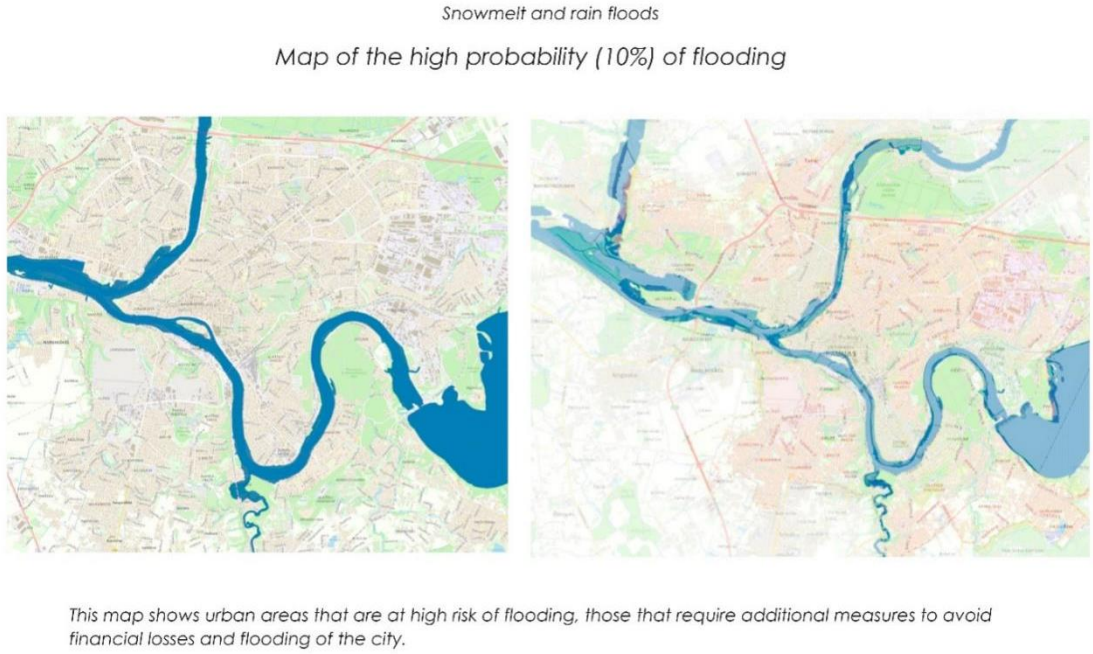


Fig 25. Map of high probability of flooding with reference to Flood hazard and risk maps, (2020)

The map in the fig. 25 shows potentially dangerous territories of the river area, which is in 10% zone of high probability of flooding and is the risk zone of use with permanent occupants and snow consolidation, which requires more attention and the introduction of special management and prevention measures.

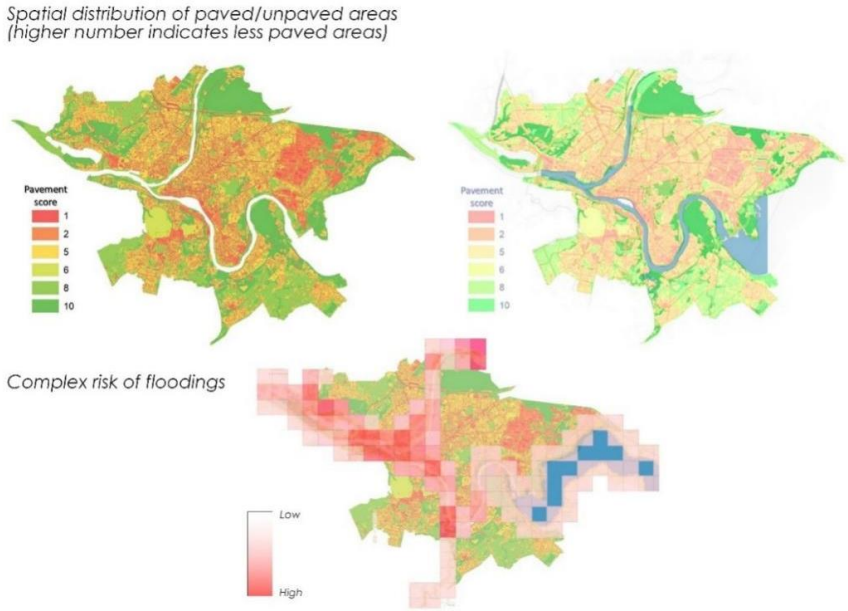


Fig 26. Map of spatial distribution of paved and unpaved areas with reference to A. Dumbrauskas & G.Vyciene, (2018)

The maps in the fig.26 depicts the most and least paved areas of the city. The larger the area covered with impermeable pavements, the greater the likelihood of flooding. The maps demonstrate that the central part of the city is covered with red and orange, which means a high level of paving, and is in a potentially dangerous area of flooding on the river side and due to heavy rainfall. Drainage drainage systems should function well in this area to minimize possible damage due to weather conditions. This area also needs the introduction of green areas to adapt to and prevent the possible effects of climate change.

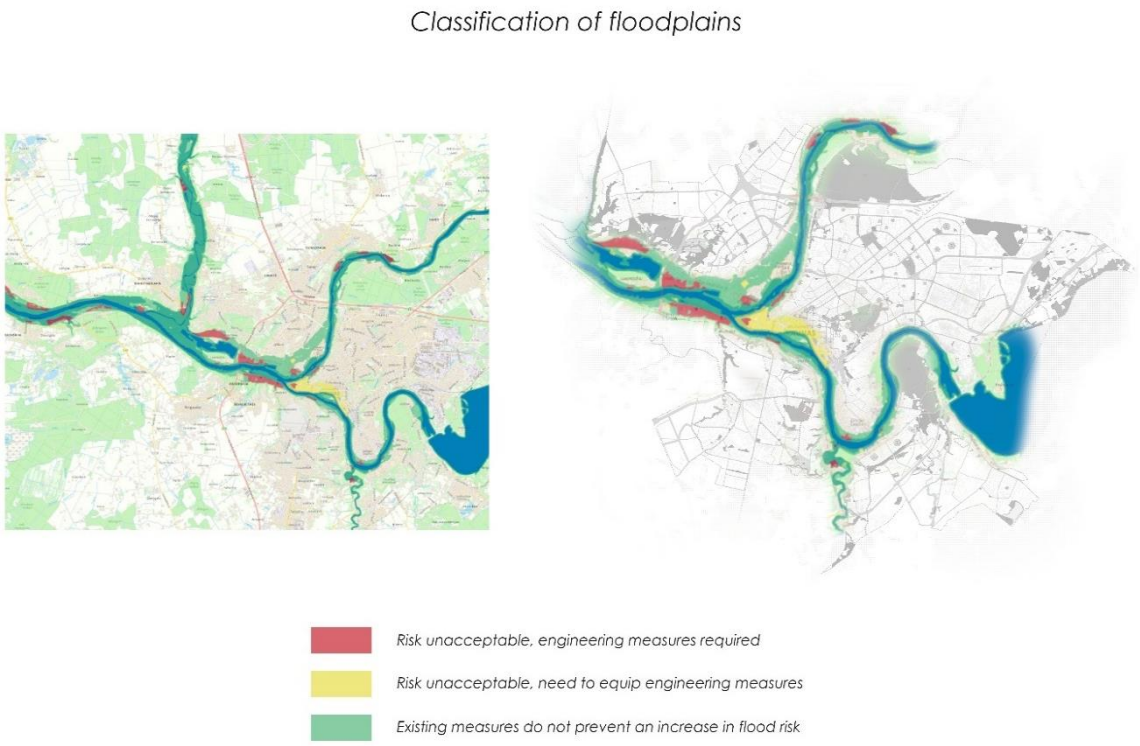


Fig 27. Map of floodplains and it`s classification with reference to Flood hazard and risk maps, (2020)

The maps in the fig.27 show the classification of floodplains according to their level of possible risk. The central part of the city, which according to preliminary data is also at risk, is marked in yellow on this map, which indicates the need to implement engineering measures, as well as the introduction of adaptive landscaping to minimize potential hazards.

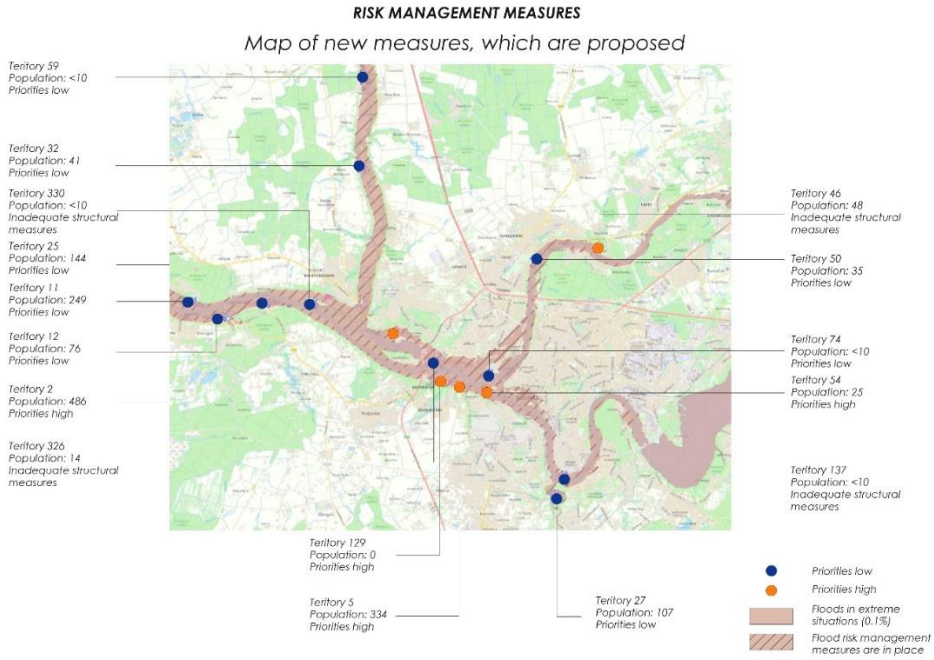


Fig 28. Map of risk measurements with reference to Flood hazard and risk maps, (2020)

This map in fig. 28 demonstrates the existing territories and classifies them according to the priority of implementation of certain adaptive and engineering measures with reference to Flood hazard and risk maps (2020). The central part of the city is marked as an area that has a high priority for the implementation of certain measures.

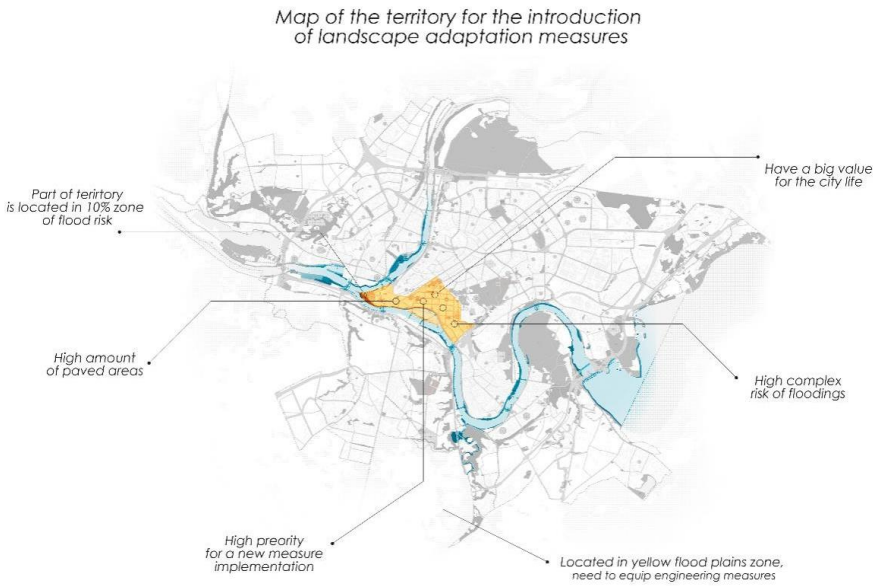


Fig 29. Map of the territory of Kaunas with the proposed introduction of landscape adaptive measures, (2020)

The map in the fig.29 is a cumulative result of the preliminary analysis of the maps and reflects the area that is in a significant risk area and is also important for the proper functioning of the city of Kaunas. That is, it means the priority and the need to implement adaptive and preventive landscapee measures in the area, to minimize potential economic costs and other loses due to the effects of climate change.

2.5. Sociological survey on general attitudes towards climate change and related landscape architecture solutions

On-line sociological survey was conducted among the residents of different cities, most of whom were the residents of Ivan-Frankivsk and Kaunas. The survey was conducted in April and May of 2021. 55 respondents filled the online-questionnaire, 11 of them were from Ivan-Frankiysk and 18 from Kaunas. The main purpose of this sociological survey was to form a portrait of a city resident, his vision of the environment, attitude to climate change and visual preferences in the design of green areas and spaces in urban environments. The questionnaire included 12 questions, 3 of them were targeted at social-demographic characteristics of respondents and the remaining 10 were aimed at highlighting respondents relationships with green areas, understanding of climate change and sustainability. For example, respondents were asked if they notice some problems related with floods or temperature increase in their city: respondents were asked to evaluate their own influence on sustainability of the city (Fig. 30); questions were asked about transportation choices, riversides and green areas uses.

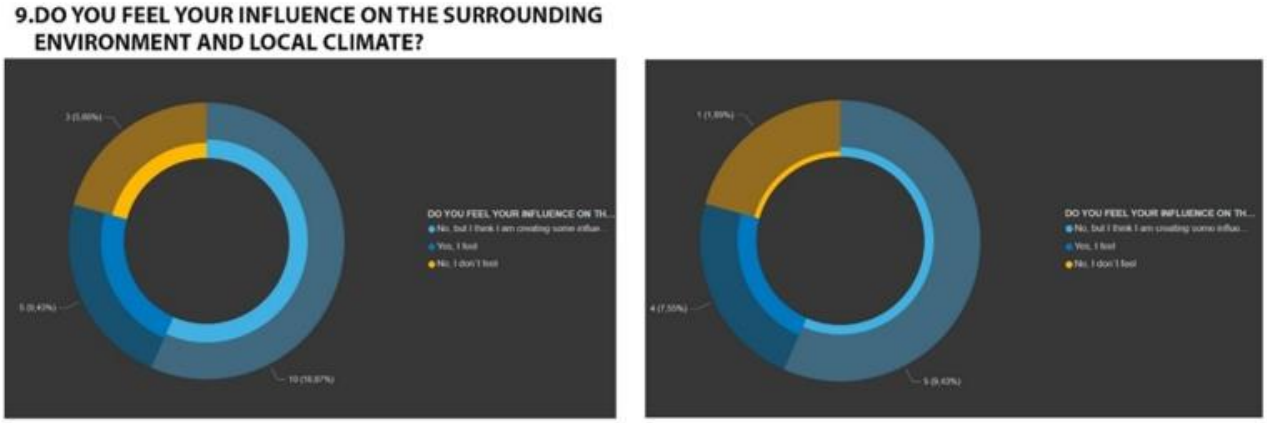


Fig 30. The answers of the respondend to the question “Do you feel your influence on the surrounding environment and local climate?” and the comparision between the answers provided by the residents of Kaunas (graph to the right) and Ivano-Frankivsk

Survey using photographic data. In the following questions the respondents were presented with photographic material depictng landscape architecture solutions of urbar spaces: street design, river side design, water features in the urban environment and green island design. The respondents were asked to evaluate the images in scale from 1 (unacceptable) to 5 (excellent) (Fig.31). The analysis of survey results included statistical, graphical, and descriptive analysis.

The survey results had demonstrated thal the majority of repondents from both cities had similar attitudes about the impacts of climate change and about the issues related to the sustainable development of the city. The majority of the surveyed resdents from both cities are interested in contributing to sustainability of their living environment. However, more than a half of surveyed residents of Kaunas reported that they do not notice such phenomena as floods and temperature increase in their city; meanwhile the majority of surveyed Ivano-Frankivsk residents notice such phenomena in their everyday environmets. The majority of the respondents from both cities use riversides and green areas for recreation. Nevertheless, it was determined that the respondents in Kaunas lead more ecological and active lifestyles. Moreover, the respondents from the city of Kaunas rated the possibilities of implementing adaptive landscape architecture measures in their city much higher compared to the residents of Ivano-Frankivsk.

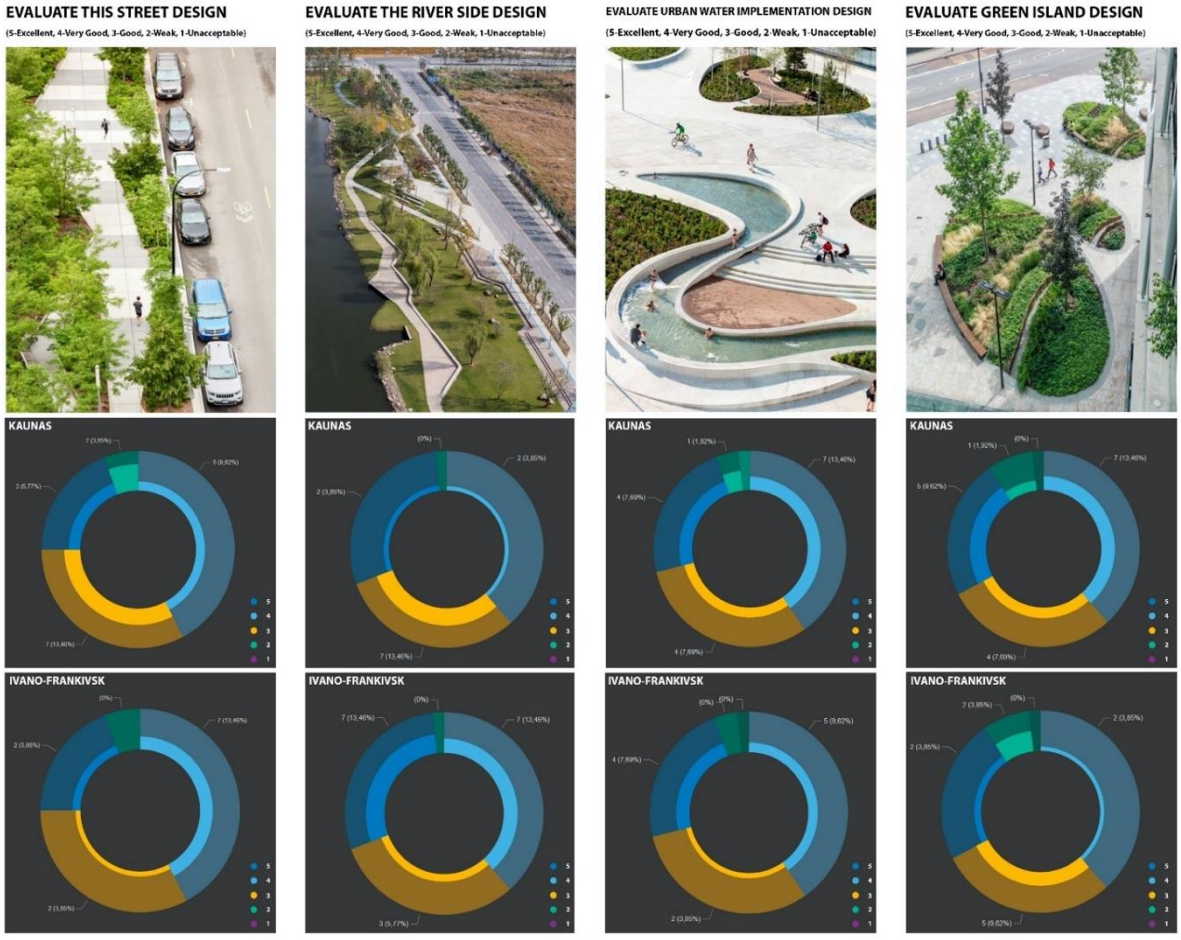


Fig 31. The results of the urban environment design examples by the residents: dark blue represents excellent, light blue – wery good, orange – good, green – weak, and dark green unacceptable evaluations

The evaluation of the photographic material presented in the questionnaire has revealed similarities in the responses of the residents of two cities. In general, most of the respondents support the idea of implementing adaptive landscape architecture measures. Basically, there is a

tendency to choose a design with the most pronounced use of such landscape elements as trees, shrubs, ponds, they are attractive both visually and have significant functionality.

2.6. Conceptual model of climate change mitigation using landscape architecture solutions

This conceptual model is a continuation of the hypothetical model of adaptive landscape architecture.

The model is based on empirical research and theoretical information. The adaptive measures are divided into two groups. The first group is related to the landscape, its functions and classification. The next step is to assess the landscape design, determine its sustainability, attractiveness and vulnerability. As a result of this analysis, it is possible to create opportunities for the development of a landscape in accordance with its assessment and functions.

The second group is related to the existing urban environment and its sustainability. The first step in this subsystem is to determine the level of urban stability, and to determine the full vision of the existing structure of the city. The next step is to analyze the documentation base to provide the necessary information on existing measures to combat climate change, understand the city's development strategy and its strengths and weaknesses. Next is the analysis of the structure of the city with the help of various maps, which were formed on the basis of previous studies, which in turn make it possible to identify the most vulnerable areas of the city, to establish their priority and classify. Therefore, the final result of this part is to identify the main problems in the city and the territory that has the highest priority for interventions and implementation of adaptive measures.

In accordance with the results obtained from the two previous analysis steps - andscape and urban sustainability assesment, it is necessary to form a design strategy in accordance with the identified problems, as well as to establish the necessary scope for the implementation of adaptive measures.

Based on the obtained sociological research data, it is possible to determine the most visually attractive design for the residents of a city, to better understand the needs of residents and their expectations from the implementation of new measures in the city.

The final result should be a ready-made concept of adaptive ecological landscape design, which will meet all the norms and needs of the city and its inhabitants.

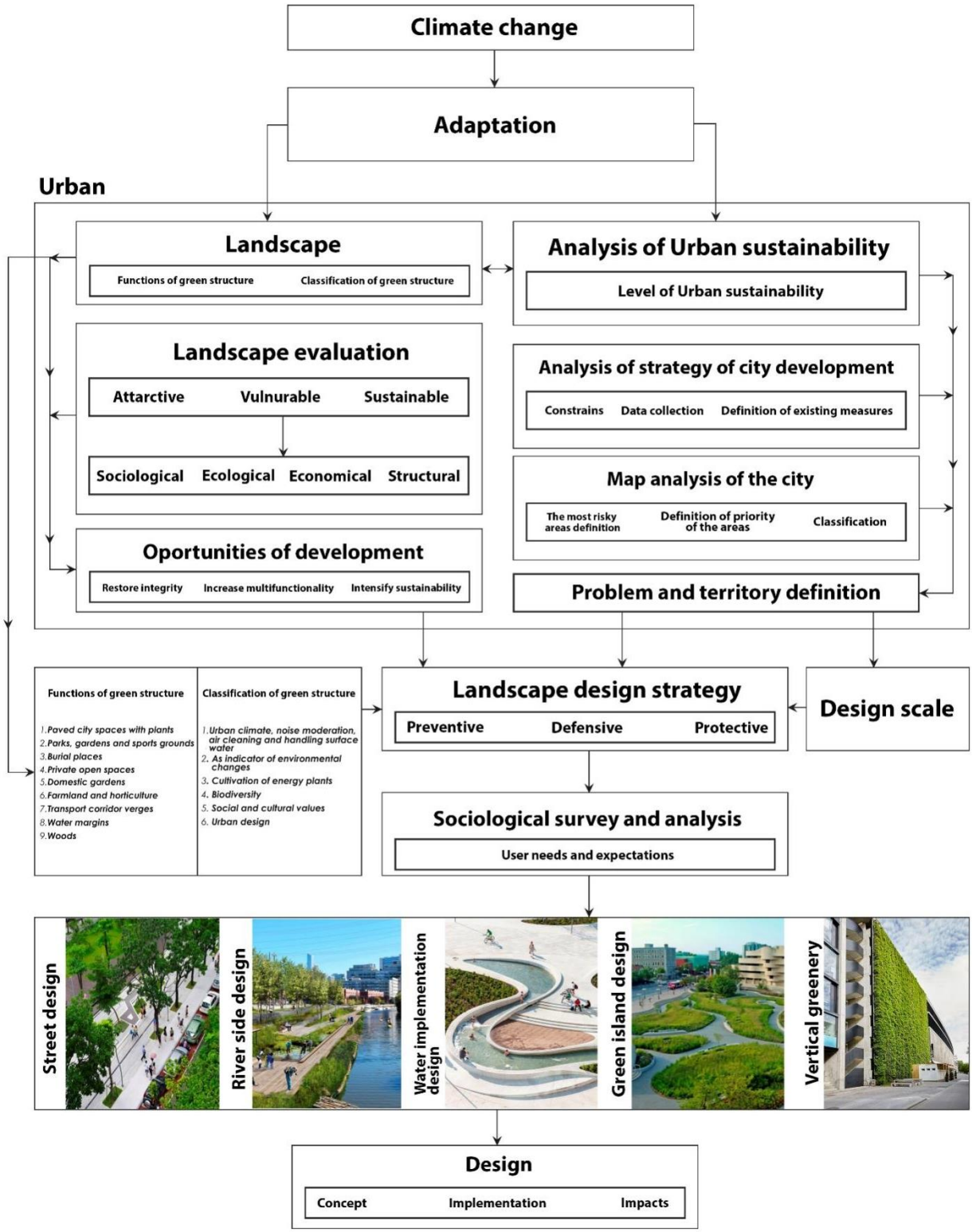


Fig 32. Conceptual model of climate change mitigation using landscape architecture solutions. Scheme by the author

3. 3. Experimental project of Kaunas Old Town urban green structure adaptation to climate change

The concept of this project solution consists of developing existing green areas and providing them with additional typological functions to increase areas ability to cope with the effects of climate change. The project aims to create a green route from the island to the central part of the city, with further prospects for the development of green structure in additional areas. Since the project is implemented in a historically formed environment, architectural solutions take into account the restrictive measures in force in the selected area and must be properly integrated to preserve the historical integrity of certain areas.

Existing plots that need functional adaptation and fit for the modern design implementation have been identified in the selected area. Plots by their area are divided into three groups: small, medium and large. A certain method of design formation was developed for each of the groups by using typological functions. According to the scale, the site may contain an appropriate number of functions to adapt to climate changes. The main aspect of the formation is to increase site's drainage capacity to prevent flooding, as well greenery usage to form better local climatic zones.

Two small-scale plots and two medium-scale plots were selected for the final project. A large-scale site is proposed as a possible conceptual extension to the further development of this part of the city.

3.1 Site selection

The selection of site for the experimental project was determined by a number of qualitative and quantitative factors that allow to obtain reasonable data on the feasibility of landscape design interventions in this area. The purpose of site selection is to show the possibility of implementing adaptive landscape design in limited urban conditions as usually historically formed urban areas need to adapt to the effects of climate change. The empirical research included analysis of cartographic data on the city's most vulnerable areas to floods caused by heavy rains and melting snow. As a result of this study, the maps were developed reflecting the results of the study and indicating the areas that have the greatest need and potential for the implementation of adaptive landscape design. Previous research included analysis of the green structure of the city, analysis of maps of spatial distribution of paved soil areas, analysis of floodplain maps and their classification, analysis of risk measurement maps, analysis of high probability maps of Kaunas flooding and terrain maps.

The central part of the city is located in close proximity to water resources and is in a 10% flooding risk zone due to rain or melting snow, has a high level of paving. As such, it is necessary to assess and test existing drainage systems, and implement new ones for increasing drainage capacity. Another important factor in the selection of this site was the low level of invasive green areas, determined by fractal analysis of the city of Kaunas, which indicates the possibility of their implementation taking into account the historical and urban context. These factors have become key in determining the area for landscape design intervention.

Selected due to previous analysis site includes historically protected areas where architectural monuments of local significance are located. This situation leads to determining the historical

value of buildings located directly in the selected area for further evaluation and determining the possibility of implementing a new landscape intervention, which would not affect the perception of the identity of the area by residents and tourists in a negative way and would improve the quality of life in it.

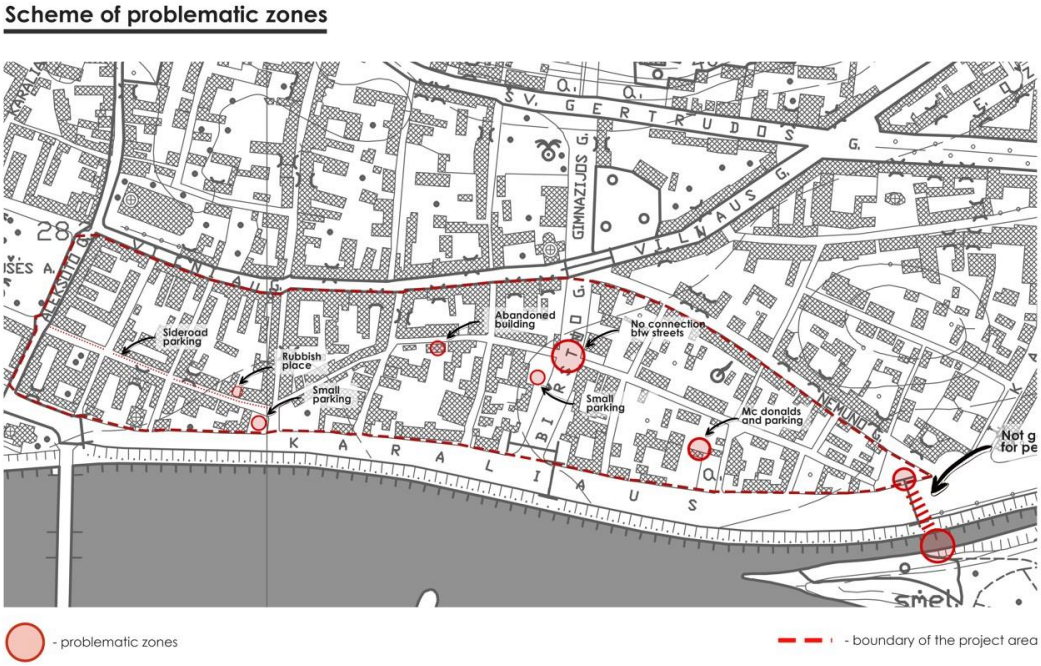


Fig 33. Scheme of problematic zones of the selected design area. Scheme by the author

After conducting field research, the main problems currently common in this area were indentified (fig.33). The first and foremost problem is car parking, as this part of the city is widely used for living and commercial purposes, and, therefore, has a large number of cars that obstruct traffic and spoil the overall impression of visiting it.

Speaking about existing green areas, it is also possible to conclude that they are fragmented due to dense construction and inappropriate use, for example, some areas suitable for landscaping are currently natural parking lots, while others do not have adequate functions and technical equipment to combat possible climate change.

One more aspect is the issue of Poudziu Street, more specifically, a transport and pedestrian artery of this area. The main problem with this street is the preference for vehicles over pedestrians, who have to use small curbs to move, which creates a feeling of discomfort.

In general, the site has significant potential for development, as the large number of historically formed architecture and proximity to one of the central squares of the city, makes it widely used both in everyday life and for tourists. Another important aspect is that a new bridge over the Nemunas River is being built in the city, which will give a new impetus to the use of the street as a transit between the bridge and the historic city center.

3.2 Site analysis

The site analysis considers site location, size, zoning, building typology, accessibility and traffic conditions, heritage values, green structures. The analysis also needs to consider any future developments, possible changes to the sites surroundings, such as a change of roads designations, changing cultural patterns, or other significant building developments within the area.

3.2.1 Identification of historical values

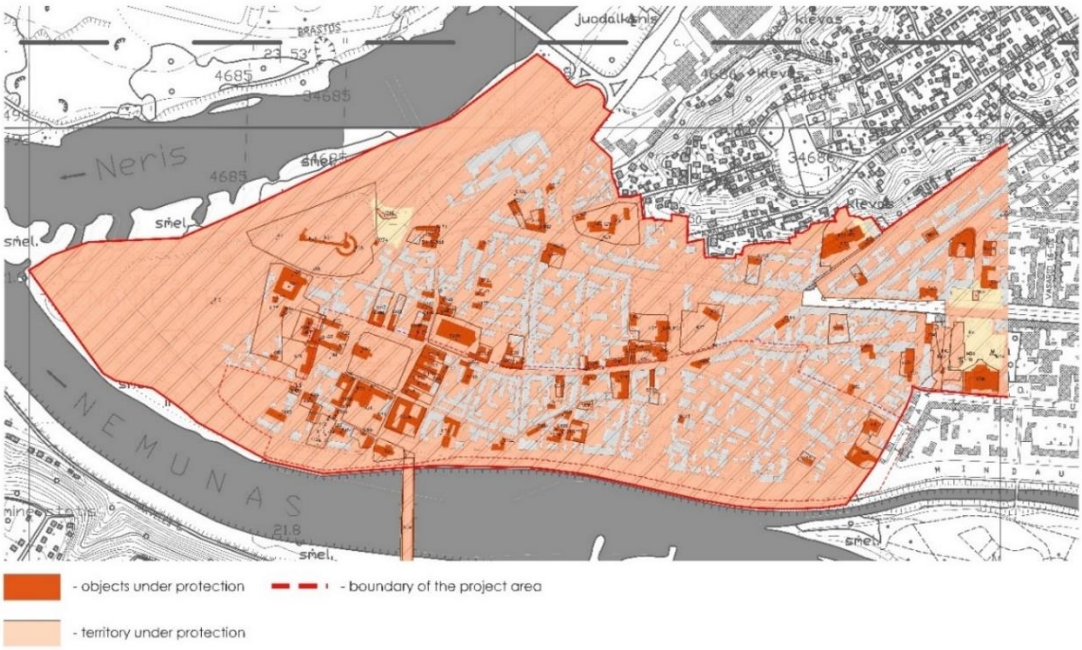


Fig 34. Scheme of protected areas and buildings in the historic center of Kaunas and in designed area. Scheme by the author

The conducted historical analysis showed that the whole site for design is located within the historically protected territory of the city. It has significant cultural and historical values. Accordingly, any measures for implementation of new design interventions must comply with regulatory documents that impose urban planning and design restrictions in the area. Design development must also take into account public opinion and comply with the concept of preserving the historically formed environment and the place identity.

The next step in the study was the definition and distribution of buildings according to their cultural and architectural value. Using the different researches conducted in this area, the diagram that reflects the category of the building according to its status was developed (Fig.35). This allows assessing and weighting the possibilities of landscaping or other changes in the structure of the street near these buildings.

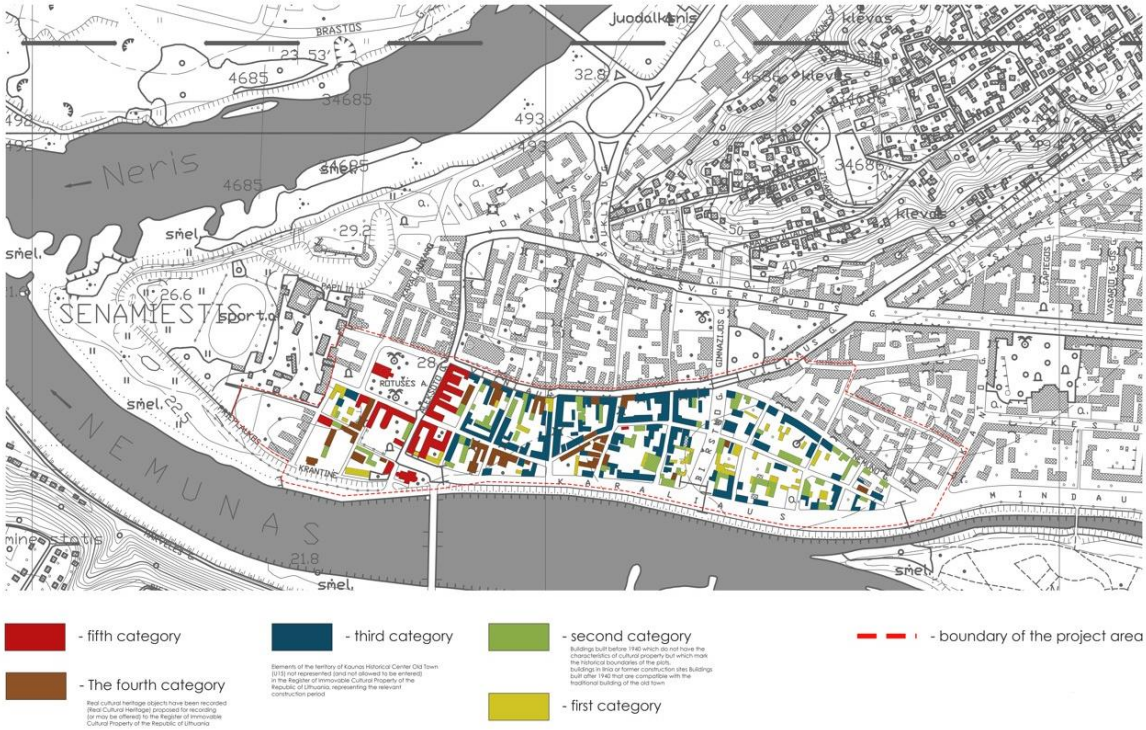


Fig 35. Scheme of building category according to heritage values (from 5 (highest value) to 1(lowest value)) in designed area. Scheme by the author

In general the buildings on the winding territory were divided into 5 categories numbered from one to five. **The first category** - houses that do not have significant historical and cultural value. **The second category** - buildings, which were built before 1940 and do not have the characteristic of cultural property, however mark the histotical boundaries of the plot. **The third category** - elements of the territory of the Kaunas Historical Center Old Town, but not represented in the Register of Immovable Cultural Property of the Republic of Lithuania, representing relevant construction period. **The fourth category** - real cultural heritage object which have been proposed to the Register of Immovable Cultural property. **The fifth category** - architectural heritage objects.

3.2.2 Analysis of infrastructure and functional zoning

The analysis of infrastructure and zoning helped to form a general picture of the selected area. The analysis of the road structure of this part of the city revealed certain problems and opportunities for changing certain parts of it. The Puodziu street is marked as a secondary road, and it has local significance and almost no impact on global traffic in the city scale. This demonstrates the possibility of reorganizing this section of the street to increase the comfort of pedestrians using the shared space street concept.

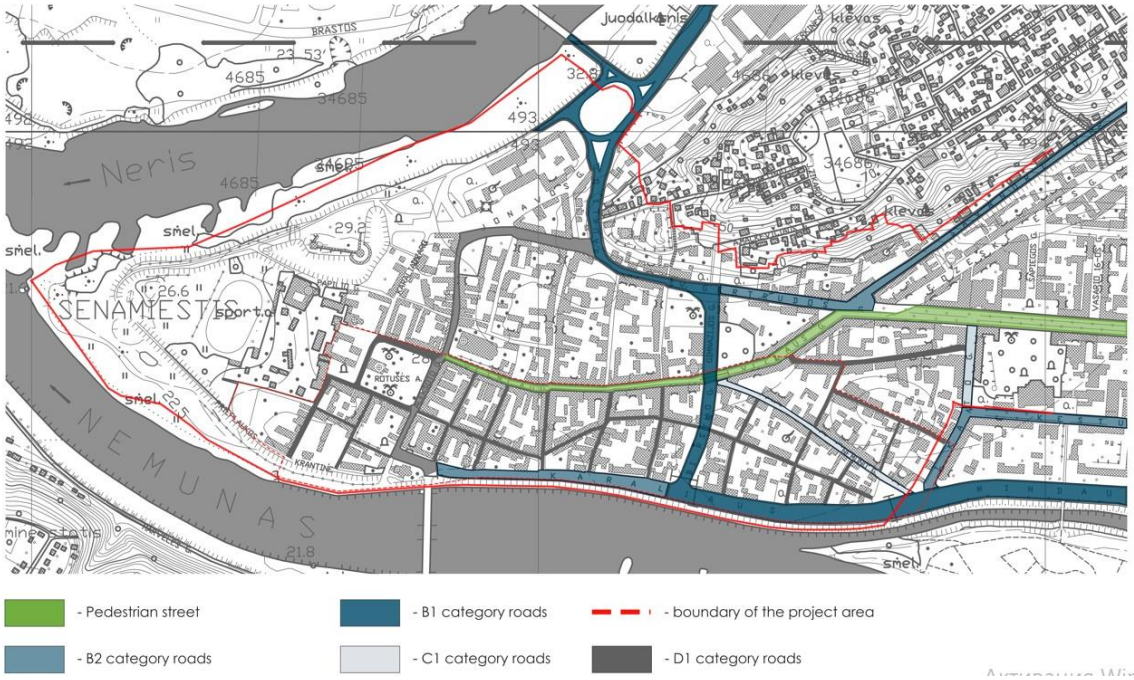


Fig 36. Scheme of existing road structure and typology in the historic cneter of Kaunas and in designed area. Scheme by the author

On the other side of the Karaliaus Mindaugo street is a citywide road with extremely high traffic. This creates significant problems for the historically formed area of the city and architectural monuments. It also has significant potential for the implementation of landscape design and its transformation into a recreational area for city residents. However, this proposal requires large infrastructural changes at the city level.

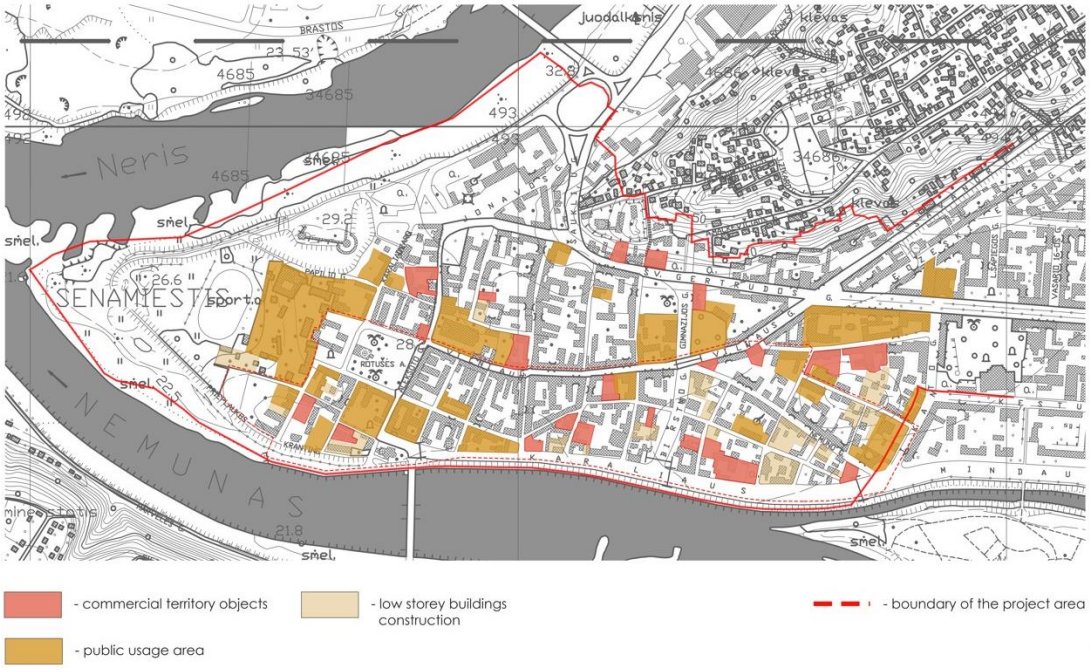


Fig 37. Analysis of functions and built-up area typology in the historic center of Kaunas and in designed area. Scheme by the author

3.2.3 Identification of green zones for possible design implementation

The analysis of the existing green structure of the selected area showed that the site has great potential for its expansion and still needs new design solutions to meet the constraints and opportunities for use in a variety of infrastructural conditions and locations.

The green structure of this area was divided into three types according to its condition and the potential for new landscaping. This analysis allowed forming a holistic picture of the state of the green structure in the designed territory and identify the need for its reorganization.

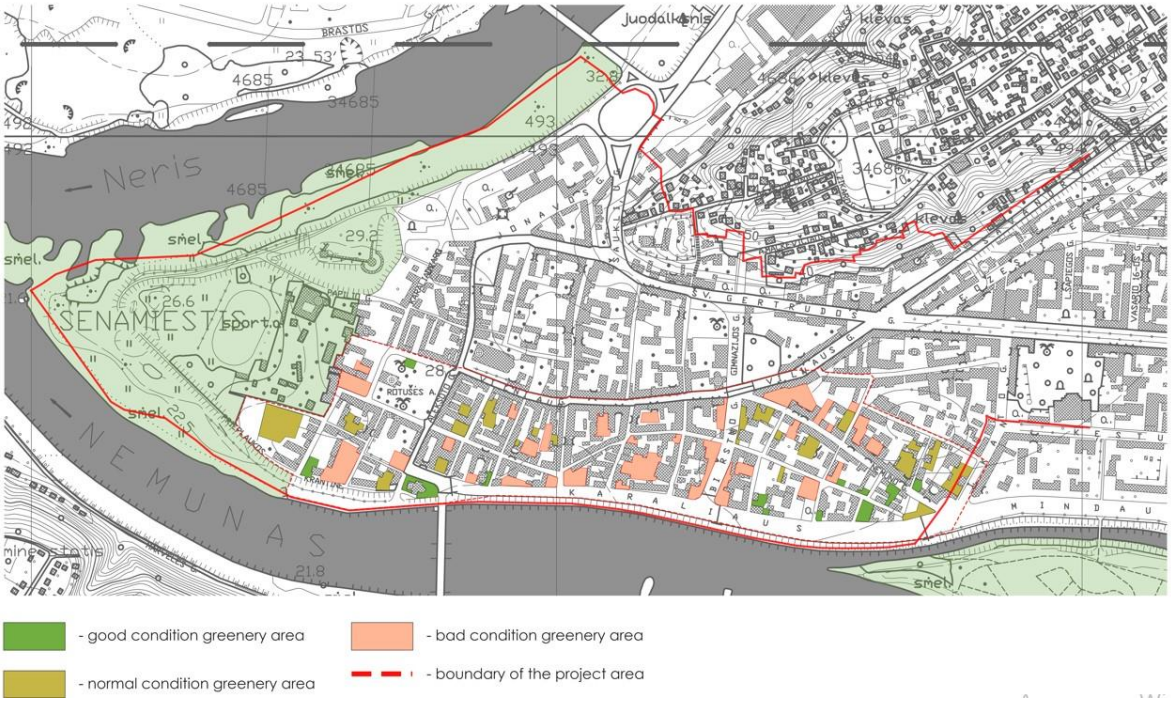


Fig 38. Scheme of existing greenery in the historic center of Kaunas and in designed area. Scheme by the author

There were also three types of areas for possible implementation of landscape design in accordance with the existing green areas: small scale, medium and large.

Small-scale plots are small plots of land that can have no more than one function and do not require deeper research and interaction with the local population. Medium-sized plots are plots that have a large area for reorganization, need local analysis to better understand the needs and functions that should be located on it, and should be agreed in accordance with the restrictions and get the approval of the local population. Large-scale sites are sites that directly require a separate detailed project for their reorganization, deeper infrastructure study of the advantages and disadvantages possible in this case, and should be included in the citywide review.

3.3 Design concept of Kaunas Old Town urban green structure adaptation to climate change

The general design concept of the decision of the chosen sites consists in formation of multi-functional landscape design with use of the developed typological elements. Typological elements are divided into three groups: landscaping, urban furniture and activity, which in turn contain specific sub-elements. The combination of these groups allows not only to create an adaptive space for climate change, but also allows it to actively involve people for its use, which is necessary for any modern design.

According to the environment the design concept is developed, it can be both organic and with use of rectilinear forms. An important aspect is the organic integration of design into the environment to minimize the risks associated with the destruction of the historical environment. Another necessary task is further study the functional connections of the site, its pedestrian routs and ways of actual use by city residents. Such a study is developed only for medium and large scale sites, as small scale sites are mostly simple and have no more than one function or are not used at all.

As the project aims to create a green route from the island to the historic city center, the street on which the route passes also needs to be changed. To modernize it, the method of dividing the space between vehicles and pedestrians is used. This approach will create comfortable conditions for more intensive pedestrian traffic, as well as eliminate certain problems related to parking spaces and traffic on the street.

In this project, a solution design of two sections using organic forms and two sections with rectilinear shapes was developed as an example of possible implementations of this concept.

3.3.1. Shared space street concept

Shared space is a concept of urban design and traffic engineering that brings together vehicles, pedestrians, and other road users by removing traditional street elements such as pedestrian barriers, signs, traffic lights, road markings and curbs. The concept can paradoxically increase safety, as increased risk and ambiguity force all road users to be more careful. Yet, common space is more than just a way to decorate a street; it is about returning the public sphere from the dominance of the car and achieving a better balance between the social roles of the street and traffic. Recent shared space schemes have demonstrated benefits such as reduced congestion, lower vehicle speeds, fewer accidents and injuries, and brighter and more attractive streets (Gillies, 2009). This approach was applied in the project in order to increase pedestrian comfort and to eliminate the issue of chaotic parking along the street.

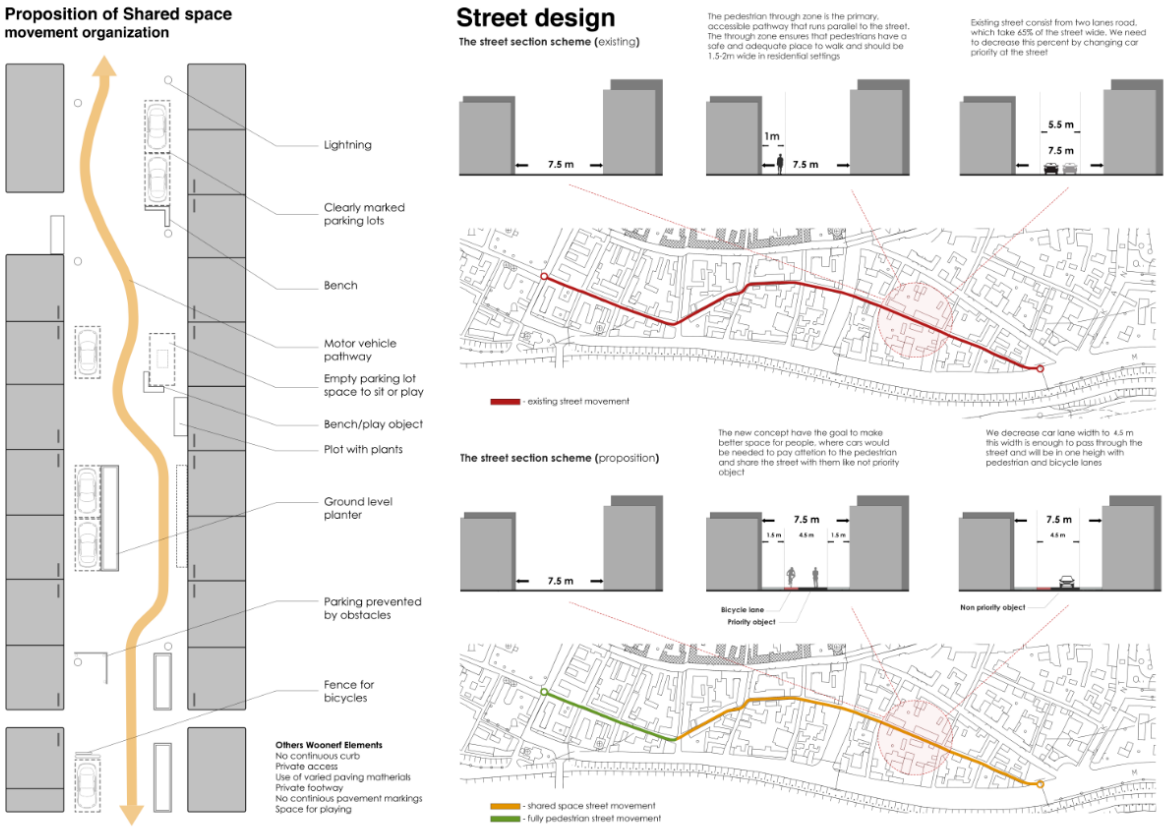


Fig 39. Street design concept. Scheme by the author

The main change proposed in the territory of the project is the widening of the pedestrian section of the street, which is now a narrow section and is uncomfortable to move, as well as the equipment of controlled parking lots every 50-100 meters, which will streamline traffic and make it more attractive to all visitors (Fig.39).

It was also determined the feasibility of introducing a bicycle path for the comfort of cyclists, as well as to support traffic on alternative vehicles for movement.

The width of the roadway was narrowed to 3.5 meters, which allows unobstructed passage of one car. It is proposed to organize paths for pedestrians on both sides of the streets, as well as their expansion from 1 to 1.5 meters each. In this case, street planning will give preference to pedestrians and cyclists and as an alternative may become completely pedestrian in the future.

3.3.2. Typology of possible landscape design solutions

The main goal of this project is to develop a structural approach to the implementation of landscape design using typological design elements. These elements would create the possibility of its implementation in different areas, using certain typological elements that are rational in a particular situation.

As a preliminary study of the existing green structure of the area has determined its fragmentation, the development of an integrated approach will allow with minimal effort to introduce new landscape elements in different areas. This approach, such as developing the area

according to the scale, can also be used later in the further modernization of urban areas, both in Kaunas and in other cities, which will increase the city's resilience to climate change.

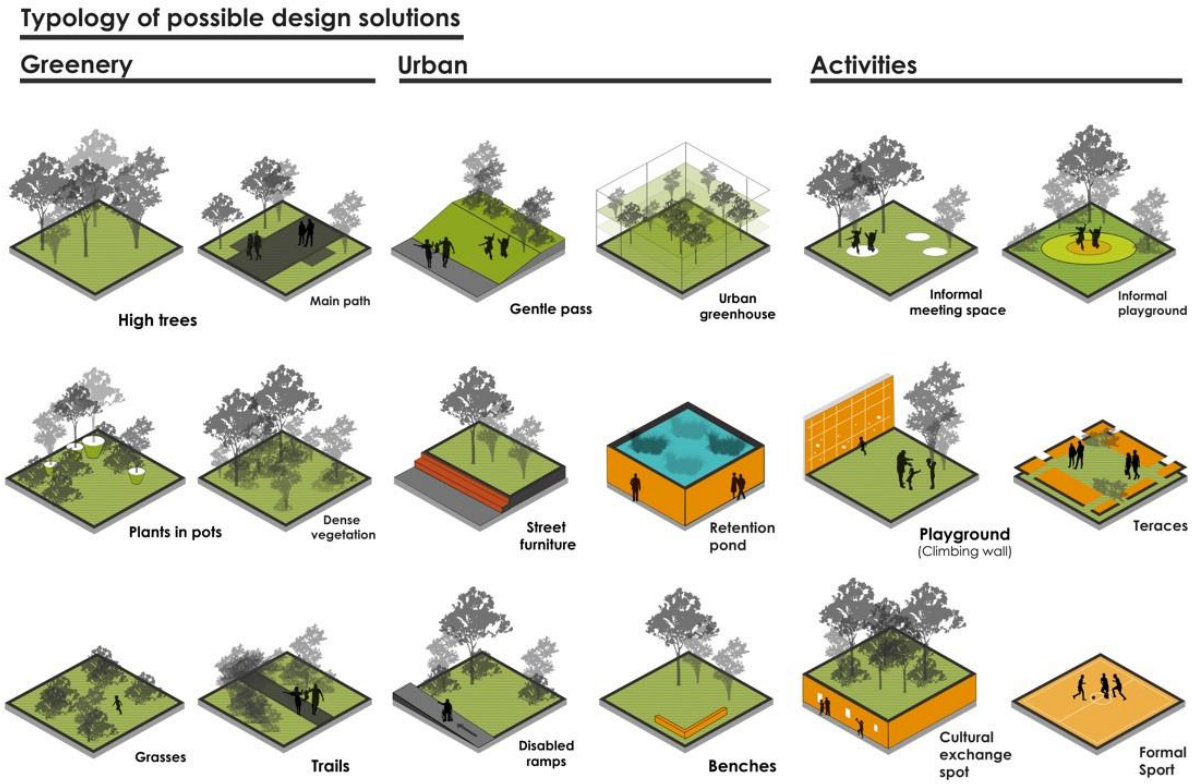


Fig 40. Typology of landscape design elements. Scheme by the author

The developed elements are divided into three groups (Fig.40).

The first group is the design elements exclusively related to the implementation of greenery. It contains variations of possible groups of plants and their combination with pedestrian alleys, which can be used in a given area, according to needs. The second group is urban design elements that create comfortable conditions for a person's stay, but also require interaction with the first group for full effect. The third group - elements that can be used for more active use by residents and children, because the functionality of the space also plays an important role and the more popular the object, the more valuable it is.

Thus, the interaction of these three groups according to the needs of a particular area, creates a multifunctional space, which primarily allows the correct use of territory, reduces the impact of climate change on its scale, and creates new active spaces for residents.

3.3.3 Stormwater management

Developing a system for additional drainage control is one of the most important in combating climate change. As one of the consequences is heavy downpours that can flood densely paved urban areas. Stormwater management is the control and use of storm-water runoff. It includes maintaining stormwater systems, planning for runoff, and regulating the storage, collection, and movement of stormwater. Stormwater management also takes drainage into account when designing cities and housing. Stormwater management aims protect the environment; reduce

demand on public stormwater drainage systems; reduce flooding to protect people and property; and creating healthier, more sustainable communities. Effective stormwater management ensure social, environmental, and economic advantages to local communities. If stormwater management is done well, streams, rivers and lakes become cleaner; flood risks are reduced; reduction of flood costs; and the quality of life of the community is improving (Holm et al., 2014).

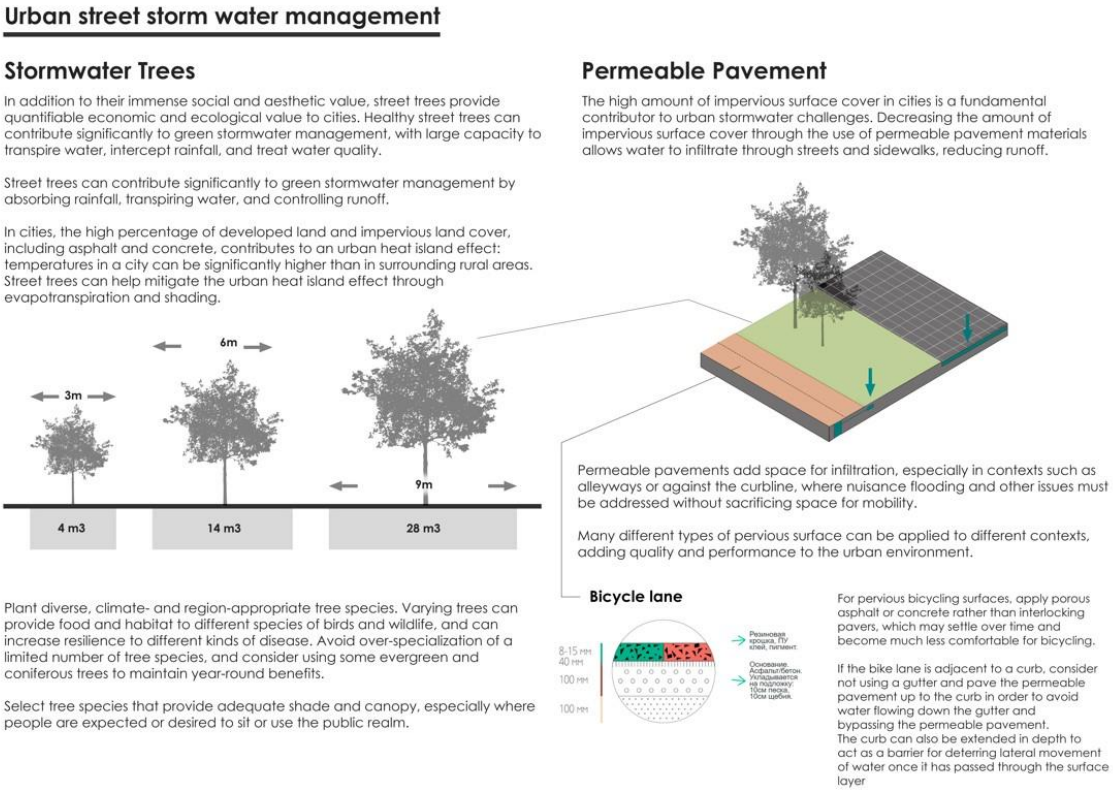


Fig 41. Urban street stormwater management. Scheme by the author

During the development of the landscape design project, a drainage system will be provided, and the water will be collected in certain tanks and later used for irrigation of greenery.

3.4 Implememntation of developed typology of landscape design solutions

The technology of implementation of typological functions is clearly related to the scale of a particular site and its possible potential for development and use.

Small-scale areas can usually contain 1-2 typological functions. This is due to the fact that the potential for a possible outcome is not significant. According to the analysis of existing sites of this type, they are mainly not active and not used by the city residents. The best combination for these facilities is the use of landscaping with certain urban accessories, such as benches or city greenhouses. This combination creates the necessary adaptive potential to combat climate change, as well as makes the site active.

Areas of medium scale are more complex. They can combine from 3 to 5 functions of different typological groups. At the sites it is necessary to analyze the functional areas and ways of use, to form a correct design solution. In such areas, all three typological groups should be used and

properly combined to actively involve city residents. Typological elements can be adapted to the needs, it can be used as elements for organic design and for a simpler rectilinear.

The approach to large-scale sites is more comprehensive. Such sites require a detailed analysis of more complex systems, such as infrastructure and development master plans. Accordingly, the concept of site development is formed. Such sites can contain a combination of small and medium scale to use the relevant aspects and be completely separate objects.

The main task of typological elements is to simplify the search for solutions, as well as the formation of a space that will have sufficient capacity to combat the effects of climate change.

3.4.1 Small, medium and large-scale design proposal concept

Two small-scale plots, two medium-scale plots and one large-scale plot were selected for potential design concept proposals. It was decided to develop small and medium design in two variations - organic design and design using rectilinear elements. This decision was made in order to show the possibility of using typological elements in different design concepts.

The concept of small-scale development is primarily aimed at forming sufficient drainage capacity, the use of appropriate materials and systems, followed by the formation of places for temporary recreation and leisure of city residents, as small-scale areas are most comfortable. For this purpose, urban fittings are actively used, which are integrated into the environment and combined with the developed green structure.

The concept for medium-sized areas is formed in the direction of functional landscaping which will have a significant positive effect in combating the effects of climate change. Existing landscaping in such areas, mainly trees, is not destroyed and in turn is integrated into the new design proposal, this is one of the important aspects of non-interference in the existing environment. Another important aspect is to consider the necessary drainage capacity of the site, the use of water-permeable materials to cover the tracks, as well as the formation of a comprehensive drainage system that will not only eliminate excess rainfall but also create water reserves for irrigation in dry periods. The design also includes the need to create not only a functional but also a comfortable space for visitors, which is also a priority, because they will allow such a design to function and maintain it in good condition. The design should be a functional magnet for a better representation of the city and its level of development.

A large-scale object is formed only at the conceptual level, in this case it does not have a clearly defined planning or legal basis. According to the previous description, the proposal is a significant infrastructural intervention in the existing urban environment. In this case, the concept is formed in accordance with the analysis. The main purpose of such an intervention is to significantly increase landscaping as well as address aspects that contribute to climate change, such as heavy traffic, insufficient drainage capacity, and low landscaping. Eliminating these problems as well as introducing adaptive design elements over a large area will not only have a local effect but will also affect the overall sustainability of the urban environment.

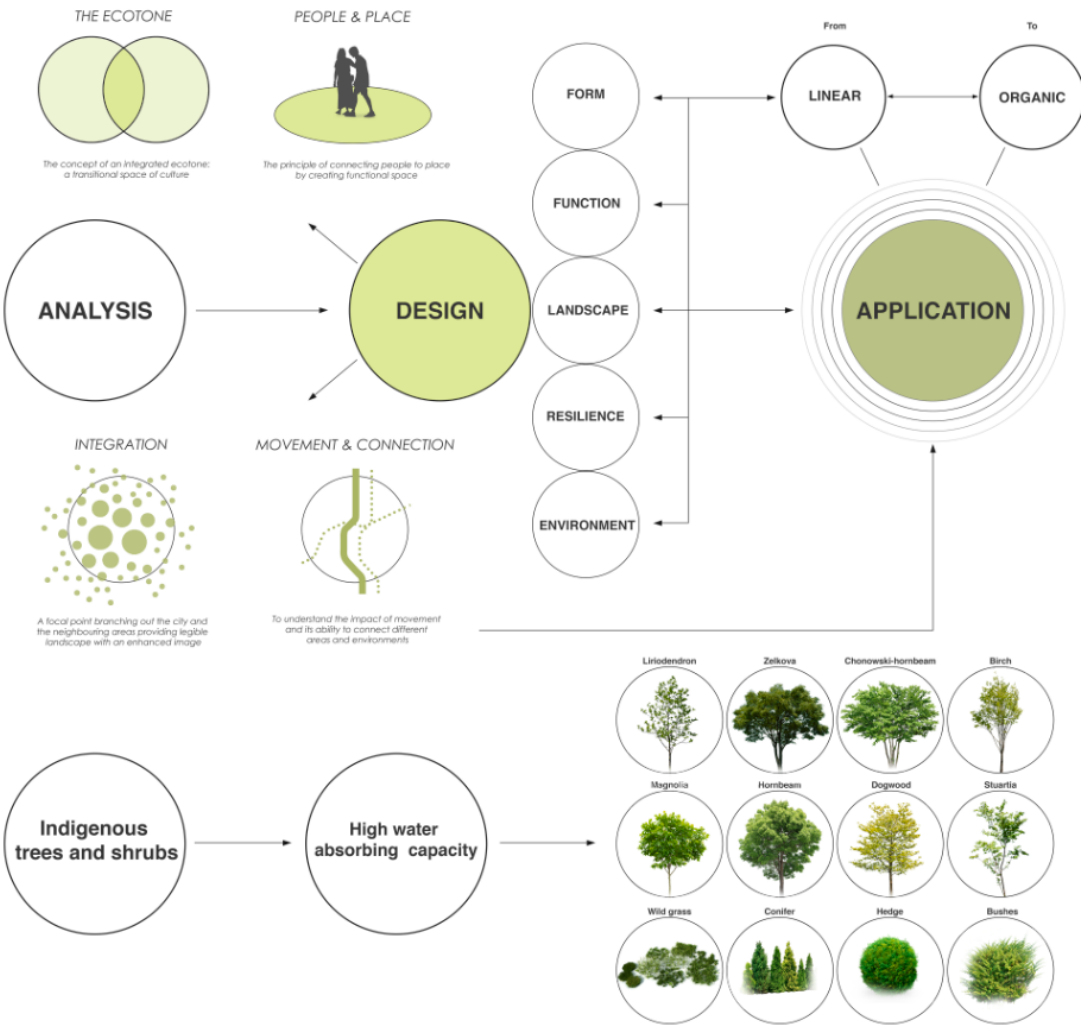


Fig 42. Typical concept of square organization

3.4.2 Small scale design proposal example

Proposal 1

The plot is located at the corner of Podziou and Solutes streets and is formed by perimeter buildings around. Currently, the site does not have a specific function, but has a sufficient amount of existing landscaping.

The design proposal is formed of two typological elements in combination with organic forms. The common area was divided into several zones for the formation of pedestrian paths through it. The first typological element is the use of greenery as usual and the installation of vertical landscaping, which is attached to a special frame to preserve the facade of the building and in the middle of which is built internal watering, which makes plant care much easier. Other greenery is limited to the use of grass in most areas and the preservation of existing trees in combination with several new plantings. The second typological function is the use of urban accessories for recreation. In the center of the site, it is proposed to place accessories for organic recreation with an internal space for greenery. This element allows you to spend short time in this area for recreation or meetings. A drainage tank has been installed at this site to collect water, which will then be used for irrigation of vertical landscaping.

Fig 43. Scheme of small scale design proposal 1

Fig 44. Visualization of small scale design proposal 1

Proposal 2

The plot is formed by perimeter buildings on three sides on Podziou Street, which forms a closed comfortable space for a small group of people but is minimal for the introduction of a significant number of greenery. Currently, the site is more private than public and has no functional significance.

Accordingly, an approach was formed in which the main area was filled with accessories for recreation in combination with greenery. One of the important aspects was the preservation of existing trees on the site as planting new ones could negatively affect the perception of space.

So, the main area is filled with a wooden recreation element using rectilinear shapes and rounded sharp edges to minimize possible injuries and a better visual appearance. In the middle of this element, existing trees are integrated in combination with grass.

The coverage of the site is partially formed of porous concrete slabs that have the ability to pass water, which increases the drainage area.

A small island was also formed using a lawn to increase the functionality of the site as well as a better visual appearance.

Fig 45. Scheme of small scale design proposal 2

Fig 46. Visualization of small-scale design proposal 2

3.4.3 Medium scale design proposal example

Proposal 1

The 857 m2 plot is located at the intersection of Podziou and Silutes Streets and is a rectangular area. The current condition of the site was classified as partially satisfactory, as the level of landscaping meets certain needs, but has a low capacity to combat climate change.

The design proposal was made in an organic version and formed as a reflection of the authentic natural landscape in Lithuania. In general, the area is covered with small green hills, which are covered with wild grass and have significant drainage capacity. The footpath is covered with a special coating that is organic and also allows drainage and is durable for use. A small ditch was also formed, which resembles a river in shape and will be filled with water during heavy rains.

Existing trees on the site have been preserved and integrated into the new design. The vast majority of greenery, such as trees and shrubs, were not additionally used in the design as this could have a negative impact on the perception of the environment.

The design used urban fittings of organic shape and made of porous concrete, which has the ability to pass water. There is also a small playground for families with children who can use the park as a recreational facility. A large number of hills are also a kind of urban fittings because in the warm seasons are suitable for sitting on them.

The purpose of this design was to create both a functional and recreational environment, as the combination of these two aspects allows both to influence the local microclimate and creates the necessary conditions for active use by city residents.

Fig 47. Site plan of medium scale design proposal 1

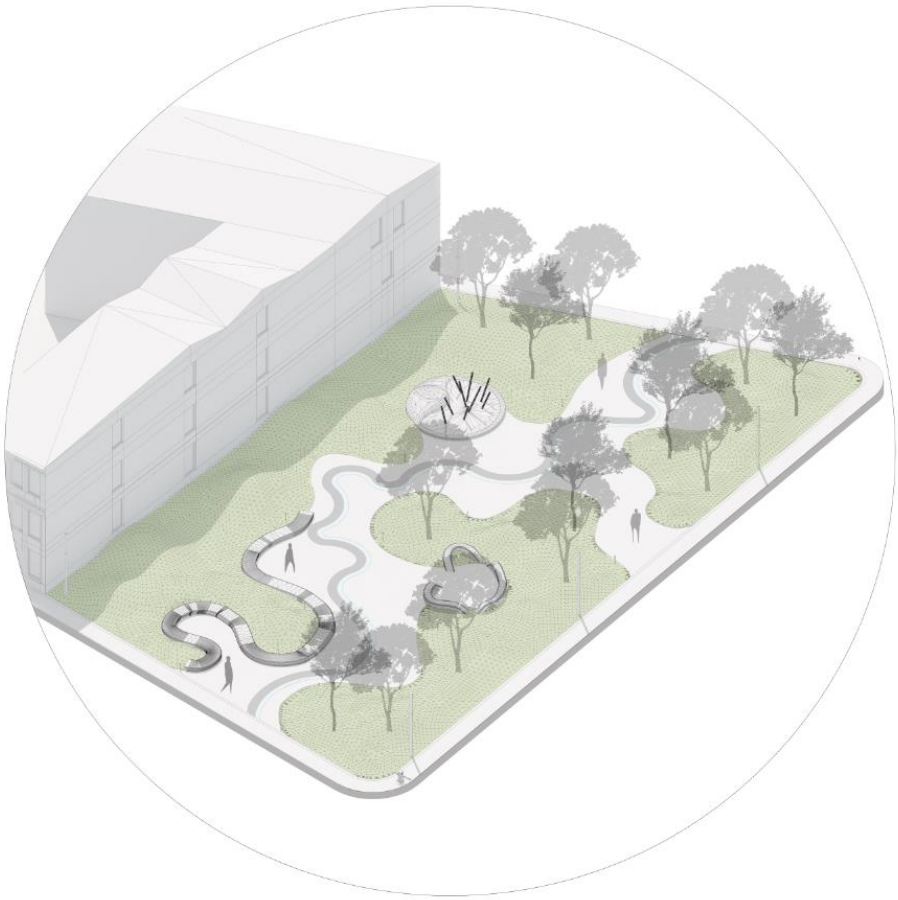


Fig 48. Scheme of medium scale design proposal 1

Fig 49. Visualization of medium design scale proposal 1

Proposal 2

The 1238 m2 plot is located at the intersection of Smaliniku and Podziou streets. The current condition of the site is extremely unsatisfactory, the absolute lack of greenery and use as a natural parking lot has a negative impact on the overall perception of the environment. Poor condition of the cover in the rainy season creates a high level of pollution.

Therefore, a number of solutions were formed to solve these problems. In accordance with modern urban trends, it was decided to completely eliminate the possibility of parking cars, as it destroys the historic environment. The design of the site is made in rectilinear forms and visually divided into two parts. The northern part is formed as an integral green space with a minimum amount of paving, this allows you to create the maximum impact on the microclimate and adaptation to climate change. The greenery of the part is wild grass, deciduous trees and shrubs that are suitable for the region.

The southern part is formed as a public space without significant use of vertical greenery. This decision was made as a result of previous studies, which show that the vast majority of this part is used as a transit route. Extensive use of green cobblestones and certain areas creates an additional drainage effect and has a positive visual impact. Accessories are standard elements such as benches or boxes for sitting in large numbers, for temporary recreation, because there are a large number of offices and public facilities nearby.

The aim of this design was to create an adaptive space that will increase the stability of the urban structure and eliminate previously identified problems.

Fig 50. Site plan of medium scale design proposal 2

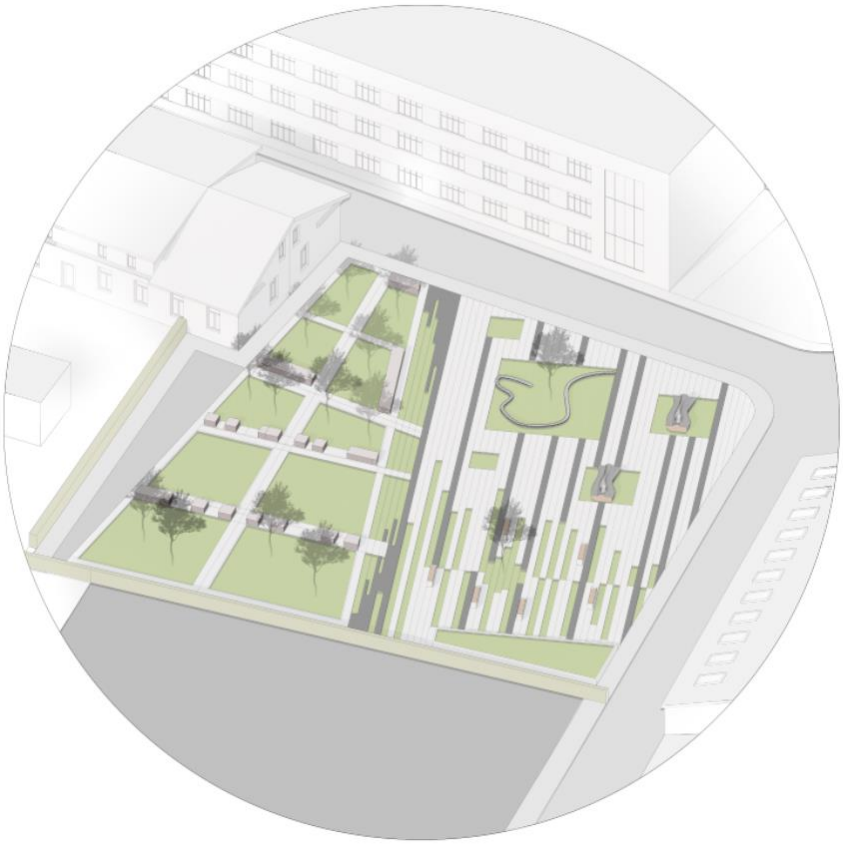


Fig 51. Scheme of medium scale design proposal 2

Fig 52. Visualization of medium scale design proposal 2

3.4.4 Large scale design proposal example

A section of the road on King Mindaugas Street was chosen for this design. It is part of the highway between the river Nemunas and the historic part of the city. Currently, it is actively used by transport, and therefore its organization will need to significantly change the existing infrastructure.

The general concept is to create a green space that will have a significant connection with other existing green areas and create a more global impact on the level of sustainability of the city. The first solution is to narrow the street from 4 to 2 lanes, which allows significantly expand the useful area and minimize the negative impact of vehicles. The next step will be the formation of a better pedestrian space that will allow the least resistance to move between different parts of the territory. In terms of landscaping, it is proposed to form a green coastal alley with lots of urban accessories to attract as many locals as possible.

3.5 Evaluation of experimental design results

In general, these design proposals can be evaluated only during their actual implementation in the urban structure. This is the only way to deal with the unpredictable things about care, functioning and the overall impact on adaptation to climate change.

In my opinion, the concept of gradual expansion is the most optimal because you can implement several test sites where you can get practical data and eliminate certain shortcomings in the design of subsequent sites. Also, the approach aimed at the development of existing green areas, instead of finding new areas, provides significant advantages in the historical environment, as it minimizes the impact on its perception.

The concept of implementing landscape design to combat climate change was formed for possible use not only in Kaunas but also in other cities. It is adaptive and can be modified in some way to the appropriate conditions.

A typological approach to the formation of the functions of green areas, allows you to have already formed a range of measures to combat climate change in accordance with its potential consequences. That is, having such a set, we can quickly create and implement appropriate functions in vulnerable areas and create an attractive design.

The assessment of the concept developed so far is quite indirect. An important aspect in such design is the study of modern technological trends and methods of combating climate change. It can be determined with confidence that the range of typological elements could be significantly expanded after additional research and would be more flexible to solve specific problems. In general, this study approach for addressing adaptation to climate change can be called a flexible approach that varies in different situations. To my mind, in the modern world this is the only way to keep up with trends and consequences, adaptability and gradualness are extremely important elements in the formation of large-scale urban reorganization.

Conclusions

1. Literature and analysis have demonstrated that concentration of large populations in cities, features of the local microclimate that may stress some of the negative effects of climate change, changes in the predominantly paved surfaces of the city, high-rise buildings, public transport network and well-developed infrastructure make the cities much more vulnerable to the effects of climate change than other areas. The main negative effects of climate change that may occur in cities include: heat stress; flooding; reduction of areas and violation of the species composition of urban green areas; extreme natural hydrometeorological phenomena; reduction of quantity and deterioration of drinking water quality; increase in the number of infectious diseases and allergic manifestations; disruption of the normal functioning of the city's energy systems.Analyzed best practice landscape architecture examples – urban park for flood management and biodiversity increase, climate tile, vegetated street furniture – demonstrate the possibilities to use landscape architecture solutions to adapt the effects of climate change in urban environment.

2. The hypothetical model based in the results of theoretical research formation of a systematic approach, taking into account all the climatic, infrastructural features and financial capabilities of the territory that would allow to organize the most effective adaptation measures with minimal demonstrations of weaknesses. Given the climate change situation and considering new development plans developed for individual regions and municipalities, adaptation plans need to be constantly reviewed and updated. After the implementation of adaptation measures, their effectiveness must be systematically monitored and based on the obtained evaluation results, new or additional measures should be planned. Climate change adaptation activities using landscape architecture can be divided into landscape design and landscape planning. Landscape design focuses on local uses appropriate local measures such as the formation of small parks, the use of modern building materials, green roofs and vertical landscaping. Landscape planning forms a general approach to solving the problem of the whole city or district through such measures as: the formation of an adaptive system for the prevention of climate change or the formation of large-scale projects.

3. The empirical research involving different scales and methods confirmed the importance of both landscape planning and landscape design measures in adapting the urban environment to the the effects of climate change. The fractal analysis, analysis of documents, and sustainability compass method had revealed the importance of green infrastructure and water bodies system for the urban sustainability and for the distribution of adaptive landscape planning and design measures. The sociological survey has demonstrated that contemporary landscape architecture trends, which can be identified as ecological landscape architecture, based on native plant species, perennials and more natural outlook, become increasingly socially acceptable and can be integrated into streets, riversides and other public spaces design.

4. Conceptual model developed after the empirical reaesrch maintains that the introduction of landscape design and landscape planning measures creates significant potential for the development of the city's sustainability, has a positive impact on its residents and has financial potential as the method of avoiding financial losses from events caused by climate change.The existing level of urban sustainability and methods of its assessment are one of the most important factors for the formation of opportunities for the implementation of quality adaptive measures in the urban area with the help of landscape design and planning. For high-quality implementation of adaptive measures, it is necessary to have a full range of necessary information related to the city development strategy, its structure, existing problems and preferences of the residents of the city.

5. The analysis of the city of Kaunas showed one of the most vulnerable areas of the city, which is also its historical center and has significant cultural value. The purpose of the experimental project was to show the possibilities of implementing adaptive landscape design measures in the historic area of the city, because its dense urban fabric, historical value, vulnerability to the effects of climate change and the necessity to improve the quality of live there. Experimental design approach logically moves from the analysis of the city, which leads to the definition of a specific area of implementation of measures and ends with the development of typological elements (greenery, urban, and activities), multi-scale approach (small, medium, large scale) and ways to apply them in particular location. Experimental design has demonstrated that landscape design is very flexible tool that can be used and intergrated into the urban structure. Hovewer, on the other hand, it is not enough to simply create a green space, it must be multifunctional and technological to meet standars and requirements for the prevention of climate change.

6. Green infrastructure has a huge potential for making cities more resilient and adapting them to the extremities induced by climate change. Green infrastructure is capable both providing a range of ecosystem services and creating high quality sustainable public spaces for urban populations even in valuable historic areas. The research has demonstrated that sustainable landscape architecture solutions - landscape planning and design measures including typological modular design combined with multi-scale approach – have potential to contribute to adaptation of urban environments to climate change.

List of reference

1. Ackerman, A., Cave, J., Lin, C. -., & Stillwell, K. (2019). *Computational modeling for climate change: Simulating and visualizing a resilient landscape architecture design approach.* International Journal of Architectural Computing, 17(2), 125-147.
2. Alizadeh, B., & Hitchmough, J. (2018*). A review of urban landscape adaptation to the challenge of climate change.* Sheffield, UK: Department of Landscape, The University of Sheffield. Retrieved from: https://www.emerald.com/insight/content/doi/10.1108/IJCCSM-10-2017-0179/full/html
3. Alizadeh, B., & Hitchmough, J. (2019). *A review of urban landscape adaptation to the challenge of climate change.* International Journal of Climate Change Strategies and Management, 11(2), 178-194.

4. Baldwin, E. (2018). *Climate Tile Designed to Catch and Redirect Excess Rainwater from Climate Change.* Retrieved from: https://www.archdaily.com/902399/climate-tile-designed-to-catch-and-redirect-excess-rainwater-from-climate-change?
5. Baldwin, E. (2020). *Mask Architects Design Cooling station for Abu Dhabi`s Urban Hear Island.* Retrieved from: https://www.archdaily.com/949459/mask-architects-design-cooling-stations-for-abu-dhabis-island?ad_source=search&ad_medium=search_result_all
6. Bennett, K. E. (2014). Beautiful landscapes in drag, the material performance of hypernature. *Journal of Landscape Architecture, 9*(3), 42-53. Retrieved from www.scopus.com

7. Bizikova, L., Cohen, S., Burch, S., Robinson, J. (2010). *Linking sustainable development with climate change adaptation and mitigation.* Retrieved from: https://www.researchgate.net/publication/285899307_Linking_sustainable_development_with_climate_change_adaptation_and_mitigation
8. Boeri, A., Gianfrate, V., & Longo, D. (2016). *Green buildings and design for adaptation: Strategies for renovation of the built environment*. International Journal of Energy Production and Management, 1(2), 172-191.
9. Buondonno, E. (2021). *Climate changings: New paradigms of contemporary architecture*. Retrieved from www.scopus.com

10. Business Green. (2019). *Addressing the climate change challenge with sustainable procurement.* Retrieved from: https://www.factorco2.com/en/addressing-the-climate-change-challenge-with-sustainable-procurement/new/6255
11. Ceylan, S. (2019). *An overview and a future projection on the architectural design of artificial environments*. International Journal of Architectonic, Spatial, and Environmental Design, 13(3), 31-49.
12. Crichton, D., Fergus, N. (2009). *Adapting buildings and cities for climate change: A 21st Century Survival Guide.* Second edition. Elsevier Ltd. Retrieved from: http://library.uniteddiversity.coop/Ecological_Building/Adapting_Buildings_and_Cities_for_Climate_Change.pdf
13. Duarte, D. H. S., & Gonçalves, F. L. T. (2018). *The role of planning, urban and building design for climate adaptation in the microscale: An interdisciplinary research experience empowering architectural education.* Paper presented at the PLEA 2018 - Smart and Healthy

within the Two-Degree Limit: Proceedings of the 34th International Conference on Passive and Low Energy Architecture, 892-897. Retrieved from www.scopus.com
14. Fecheyr-Lippens, D., & Bhiwapurkar, P. (2017). *Applying biomimicry to design building envelopes that lower energy consumption in a hot-humid climate.* Architectural Science Review, 60(5), 360-370.
15. Gallucci, M. (2015). *Six of the most extensive climate adaptation plans.* Retrieved from: https://insideclimatenews.org/news/20062013/6-worlds-most-extensive-climate-adaptation-plans/
16. Gradzinski, P. (2019). *Resilience as a sustainable design process in the world climate change.* Paper presented at the IOP Conference Series: Materials Science and Engineering, 471(9). Retrieved from www.scopus.com
17. Guminska, A. (2019). *Qualitative research of contemporary architecture and space of european cities in the aspect of correlation: The principles of a sustainable environment, the perception of space and technological solutions of objects.* Paper presented at the IOP Conference Series: Materials Science and Engineering, 471(10). Retrieved from www.scopus.com
18. Hunter, M. (2011). *Using ecological theory to guide urban planting design: An adaptation strategy for climate change*. Landscape Journal, 30(2), 173-193.

19. Yohe, G.W., R.D. Lasco, Q.K. Ahmad, N.W. Arnell, S.J. Cohen, C. Hope, A.C. Janetos and R.T. Perez, 2007: Perspectives on climate change and sustainability. *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge, UK, 811-841.
20. IPCC. (2007). *Climate Change: Mitigation of Climate Change.* Retrieved from: https://www.ipcc.ch/site/assets/uploads/2018/03/ar4_wg3_full_report-1.pdf

21. Jakob, M., Steckel, J. (2016). *Implications of climate change mitigation for sustainable development.* Environmental Research Letter, 11. Retrieved from: https://iopscience.iop.org/article/10.1088/1748-9326/11/10/104010/pdf
22. Lenzholzer, S., & Brown, R. D. (2013). Climate-responsive landscape architecture design education. *Journal of Cleaner Production, 61,* 89-99.

23. López, A. S., López, D. R., Caballé, G., Siffredi, G. L., & Marchelli, P. (2020). *Local adaptation along a sharp rainfall gradient occurs in a native patagonian grass, festuca pallescens, regardless of extensive gene flow.* Environmental and Experimental Botany, 171. Retrieved from www.scopus.com
24. Mairs, J. (2016). *Sunken pools and planting proposed to ease flooding in Copenhagen neighbourhood.* Retrieved from: https://www.dezeen.com/2016/07/12/hans-tavsens-park-korsgade-sla-copenhagen-denmark-flooding-urban-planning/
25. Meseneva, N. V. (2020). *Current trends in urban design.* Paper presented at the IOP Conference Series: Materials Science and Engineering, 753(2). Retrieved from www.scopus.com
26. Monge-Barrio, A., & Sánchez-Ostiz Gutiérrez, A. (2018). *Climate conditions and future scenarios in southern Europe*. Retrieved from www.scopus.com
27. New Jersey Climate Adaptation Alliance (NJCAA). (2014). *The Role of Buildings in Climate Adaptation. Climate Change Preparedness in New Jersey.* Edited by Jennifer Senick. Retrieved from: https://njadapt.rutgers.edu/docman-lister/resource-pdfs/111-green-bulding/file

28. Noges, T., Noges, P., Cardoso, C. (2010). *Climate change adaptation and mitigation strategies already in practise based on the 1st River Basin Management Plans of EU Member States.* Luxembourg: Publications Office of European Union.

29. Noran, O. (2019). *An adaptive architecture for long term energy programme management.* Paper presented at the E3S Web of Conferences, 111. Retrieved from www.scopus.com
30. OECD. (2008). *Climate change mitigation: what we do?* Retrieved October 1, 2020, from: https://www.oecd.org/environment/cc/41751042.pdf

31. Pedersen, M. (2008). *Bioinspired architectural design to adapt to climate change.* Wellington, New Zeland: Victoria University of Wellington. Retrieved from: https://www.researchgate.net/publication/261477300_Bioinspired_architectural_design_to_adapt_to_climate_change
32. Ravenscroft, T. (2020). *On-A proposes covering Barcelona`s Nou Camp stadium with Nou Parc.* Retrieved from: https://www.dezeen.com/2020/08/26/on-a-architecture-barcelona-nou-camp-stadium-nou-parc/
33. Shaw, R., Colley, M., and Connell, R. (2007). Climate change adaptation by design: a guide for sustainable communities. TCPA, London. Retrieved from: https://www.preventionweb.net/files/7780_20070523CCAlowres1.pdf
34. Sijakovic, M., & Peric, A. (2020). *Sustainable architectural design: Towards climate change mitigation.* Archnet-IJAR. Retrieved from www.scopus.com
35. *South Bay Sponge: Nature, technology and resiliency in the South Bay.* Retrieved from: http://www.resilientbayarea.org/south-bay-sponge
36. TERI. (2010). *Climate Change Mitigation and Sustainable Development.* Retrieved from: https://sustainabledevelopment.un.org/content/documents/1489mitigation_paper.pdf
37. The Landscape Institute (LI). (2008). *Landscape architecture and the challenge of climate change*. London, England. Retrieved from www.scopus.com
38. Turner, T. (2020). C*limate change mitigation through landscape planning.* Retrieved from: http://www.landscapearchitecture.org.uk/climate-change-mitigation-through-landscape-planning/
39. UNFCCC. (2007). *Climate change: impacts, vulnerabilities and adaptation in developing countries.* Retrieved from: https://unfccc.int/resource/docs/publications/impacts.pdf
40. USGCRP. (2016). *The impact of Climate Change on Human Health in the United States:A Scientific Assessment.* Retrieved from: https://health2016.globalchange.gov/

41. Xuepeishan, Chen. (2016). *An Analysis of Climate Impact on Landscape Design.* New castle, England: School of Architecture, Planning & Landscape, Newcastle University. Retrieved from: https://www.researchgate.net/publication/305642355_An_Analysis_of_Climate_Impact_on_Landscape_Design
42. Zaleckis, K., Kamičaitytė –Virbašienė, J.(2012). Evaluation of the Potential of Urban Structures for the Modeling of Sustainable Development: Kaunas Case. Kaunas University of Technology, Department of Architecture and Land Management.
43. Dumbrauskas, A., Vyčienė, G. (2018). GIS-based Flash Flood Risk Estimation in Urban Areas. Kaunas City Case Study. Aleksandras Stulginskis University.
44. Intergovernmental Panel on Climate Change (IPCC). Climate Change 2014; Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change; Core Writing Team, Pachauri, R.K., Meyer, L.A., Eds.; IPCC: Geneva, Switzerland, 2014; p. 151

45. COM. The European Strategy on Adaptation to Climate Change; European Commission: Brussels, Belgium, 2013; p. 216
46. Jim, C.Y. Green spaces preservation and allocation for sustainable greening of compact cities. Cities 2004, 21, 311–320.
47. Alijošiūtė, A.; Gineitienė, D. 2001. Implementation of sustainable development in municipalities: Polish and Lithuanian experience. Kaunas: ECAT.
48. Čepinskis, J.; Smilga, E.; Žirgutis, V. 2002. Strategic management of sustainable development, Organiza-tional Management: Systematic Research 22:55–67.
49. Kaunas City Municipality Council.(Strategic development plan of kaunas city municipality up to 2022. http://en.kaunas.lt/wp-content/uploads/sites/10/2015/11/STRATEGIC-DEVELOPMENT-PLAN-OF-KAUNAS-CITY-MUNICIPALITY-UP-TO-2022.pdf
50. Ivano-Frankivsk City Municipality.(2018). City development strategy Ivano-Frankivsk for the period until 2028. https://www.mvk.if.ua/uploads/files/44957-1.pdf
51. Lo, A.Y.; Jim, C.Y. Willingness of residents to pay and motives for conservation of urban green spaces in the compact city of Hong Kong. Urban. Urban Green. 2010, 9, 113–120.
52. Gómez-Baggethun, E.; Barton, D.N. Classifying and valuing ecosystem services for urban planning. Ecol. Econ. 2013, 86, 235–245.
53. Cheng, J. (2004). The role of green structure in development of sustainable city. https://www.yumpu.com/en/document/read/26297706/the-role-of-green-structures-in-development-of-the-sustainable-city
54. Werguin, A.C.; Duhem, B.; Lindholm, G.; Oppermann, B.; Pauleit, S.; Tjallingi, S. (Eds.) Green Structure and Urban Planning; Final Report, COST Action, No. C11; Office for Official Publications of the European Communities: Luxembourg, 2005.
55. Aplinkos apsaugos agentūra, 2020. https://potvyniai.aplinka.lt/map

Appendices

Appendix 1. Sociological survey questionary

AGE CATEGORY?

- ○ 18 - 24
- ○ 24 - 35
- ○ 35 - 50
- ○ 50 +

YOUR CITY?

- ○ Ivano-Frankivsk
- ○ Kaunas
- ○ Lviv
- ○ Vilnius
- ○ Інше...

DO YOU HAVE RELATION TO THE ARCHITECTURE?

- ○ Yes
- ○ No

DO YOU NOTICE SOME PROBLEMS WITH FLOODS OR TEMPERATURE INCREASING IN YOUR CITY?

- ○ YES
- ○ NO

IS IT ENOUGH GREENERY AND PARKS IN URBAN AREA INTO YOUR CITY?

- ○ Yes, it is enough
- ○ Yes, but it need more greenery in some districts
- ○ No, it is too small amount

HOW MANY TIMES PER WEEK YOU VISIT GREEN AREAS IN THE CITY?

- ◯ I don`t visit green areas
- ◯ 1-2 times per week
- ◯ 3-4 times per week
- ◯ 5+ times per week

DO YOU USE RIVER SIDES FOR WALKING AND RELAX?

- ◯ YES
- ◯ NO

IS IT SOME PROBLEMS CONNECTED WITH CLIMATE CHANGES INTO YOUR DAILY LIVE? *

Текст запитання з короткими відповідями

WHICH KIND OF TRANSPORT DO YOU USE?

- ☐ Public transport
- ☐ Personal car
- ☐ Bicycle
- ☐ Інше...

DO YOU FEEL YOUR INFLUENCE ON THE SURROUNDING ENVIRONMENT AND LOCAL CLIMATE?

- ◯ Yes, I feel
- ◯ No, but I think I am creating some influence
- ◯ No, I don`t feel

ARE YOU INTERESTED IN CONTRIBUTING TO SUSTAINABILITY OF YOUR CITY BY YOUR PERSONAL BEHAVIOUR?

- ◯ Yes, I want to live into the sustainable city
- ◯ No, but I appreciate sustainability
- ◯ No, I don`t care about sustainability

HOW YOU EVALUATE YOUR OWN INFLUENCE ON CITY SUSTAINABILITY?

- ◯ Excellent
- ◯ Good
- ◯ Normal
- ◯ Bad
- ◯ Інше...

HOW YOU EVALUATE CITY FINANCIAL POTENTIAL FOR DEVELOPING URBAN AND LANDSCAPE PLANNING STRUCTURE?

- ◯ Excellent
- ◯ Good
- ◯ Normal
- ◯ Bad
- ◯ It have any finances for developing

WHICH KIND OF GREENERY IMPLEMENTATION ON THE STREET YOU PREFER?

- ◯ 1. I prefer a slight implementation of greenery on the streets
- ◯ 2. I prefer green plantings that do not create obstacles for carrying and are maximally integrated into the s...
- ◯ 3. I have a negative attitude to the greenery implementation on the streets
- ◯ 4. The street should be covered with greenery as much as possible
- ◯ Інше...