CZECH UNIVERSITY OF LIFE SCIENCES

Faculty of Environmental Sciences

Department of landscape and urban planning

Implementing green infrastructure corridors in city's left-over spaces to mitigate urban heat: The case of Prague, The Czech Republic

Diploma Thesis

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CZECH UNIVERSITY OF LIFE SCIENCES

FACULTY OF ENVIRONMENTAL SCIENCES

DIPLOMA THESIS ASSIGNMENT

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LANDSCAPE ENGINEERING
LANDSCAPE PLANNING

Thesis title:

Implementing green infrastructure corridors in city's leftover spaces to mitgate urban heat: The case of Prague, The Czech Republic

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Objectives of thesis:

This master's thesis aims to demonstrate a solution for urban heating by defining new green infrastructure (GI) corridors within leftover spaces of Prague city. Hence, the establishment of this new layout not only is essential for the ecosystem and biodiversity but also will cause a continuous connection between urban and pre-urban GI. Due to the vase scale of vacant fields in Prague, it is one good potential to turn them into green parcels, in which feasible possibilities of human activity are also doable. This research implies some fundamental value of infrastructure (Natural, recreational, sustainable, and resilient values), which represent the functionality of the landscape. Although the presence of various parcels will not provide us a thorough prescription, the aim is to scrutinize various land uses, design, and implementation of specific GI. This thesis will conclude with some new designs and information data achievements that will help users in such a similar case study.

Methodology:

This thesis implements a combination of mixed research methodologies and strategies, which are complementary. As the main body of this master's thesis is based on objective-oriented approaches and case studies; thus, formulating the theoretical base for discussion on concepts of green infrastructure corridors, urban heating, and lefotver spaces are the backbones of the implemented thesis approaches. Moreover, exploration of previous researches on this specific topic in Prague city is also aplicable. Consequently, field surveying and analyzing the data via Esri ArcGIS and computer aided design (CAD) are the main driving force alongside the methods mentioned earlier applicable in this research area.

The proposed extent of the thesis:

70 Pages

Keywords:

Green infrastructure, Urban heat, Island heat, Leftover spaces, Prague city

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Recommended information sources

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DIPLOMA THESIS AUTHOR'S DECLARATION

I hereby declare that I have independently elaborated the diploma/final thesis with the topic of:
Implementing green-blue corridors in city's undeveloped open spaces to enhance landscape interconnectivity: The case of Prague, The Czech Republic, and that I have cited all the information sources that I used in the thesis and that are also listed at the end of the thesis in the list of used information sources. I am aware that my diploma/final thesis is subject to Act No. 121/2000 Coll., on copyright, on rights related to copyright and on amendment of some acts, as amended by later regulations, particularly the provisions of Section 35(3) of the act on the use of the thesis. I am aware that by submitting the diploma/final thesis I agree with its publication under Act No. 111/1998 Coll., on universities and on the change and amendments of some acts, as amended, regardless of the result of its defence. With my own signature, I also declare that the electronic version is identical to the printed version and the data stated in the thesis has been processed in relation to the GDPR.

Date

Masoud Barikani

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ABSTRACT

This master's thesis aims to demonstrate a solution for enhancing the landscape interconnectivity quality by defining new green-blue infrastructure corridors within fragmented leftover spaces of Prague city. Hence, the establishment of this new layout, not only is essential for the ecosystem and biodiversity but also will manifest a continuous connection between urban and pre-urban vicinities to a broader extent.

Due to the vast scale of fragmented leftover spaces in Prague, there is potential to turn them into green-blue parcels, where we can hope to observe varying recreational human activities alongside other achievements such as resiliency, sustainability, and biological reclamation and connectivity.

This research implies some fundamental values of infrastructure (Natural, recreational, sustainable, and resilient values), which represent the functionality of the landscape within an urban area.

Key words: Green-blue corridors, leftover spaces, Landscape Interconnectivity, Fragmented parcels, Prague city

ABSTRAKT

Tato diplomová práce si klade za cíl demonstrovat řešení pro zvýšení kvality propojitelnosti krajiny definováním nových zeleno-modrých infrastrukturních koridorů v rámci roztříštěných zbytkových prostorů Prahy. Vytvoření tohoto nového uspořádání je tedy nejen zásadní pro ekosystém a biologickou rozmanitost, ale také v širším rozsahu projeví nepřetržité propojení mezi městskými a předměstskými okolím. Vzhledem k obrovskému rozsahu roztříštěných zbytkových prostorů v Praze existuje potenciál proměnit je v zeleno-modré parcely, kde můžeme doufat, že budeme sledovat různé rekreační lidské aktivity spolu s dalšími úspěchy, jako je odolnost, udržitelnost a biologická rekultivace a konektivita. Tento výzkum implikuje některé základní hodnoty infrastruktury (přírodní, rekreační, udržitelné a odolné hodnoty), které představují funkčnost krajiny v městské oblasti.

Klíčová slova: zeleno-modré koridory, zbytková místa, propojenost krajiny, fragmentované parcely, město Praha

CONTENTS

1. Introduction

Nowadays, our cities are almost occupied with various buildings that disconnect the interconnectivity between green parcels such as parks or artificial forests, whether inside the urban area or pre-urban; Furthermore, the exponential growth of urban areas causes significant fragmentation and puts a strain on environmental services. This fragmentation within an urban area can be fixed via implementing natural corridors as known as green-blue infrastructure (GBI).

Green corridors serve many essential functions, ranging from providing critical ecological connectivity between larger patches or bio-centers in the case of TSES.

These corridors can and are used as greenways linear parks and can increase the interconnectivity between parcels of undeveloped land within urban areas, providing the same services in the peri-urban fringe; moreover, they will provide better ecological and ecosystem services link undeveloped open spaces where integrated connectivity is absent.

These undeveloped spaces sometimes referred to as undeveloped open spaces, provide an excellent potential to function as a corridor to reconnect fractured or fragmented landscapes within a broad urban area. According to Bolund and Hunhammer's research (1999) on ecosystem services in urban areas, implementing green spaces will have significant changes like reducing inhomogeneity of air, water, noise pollution, reducing urban heat island, increasing recreational activity, and local climate regulations (Bolund and Hunhammer, 1999; Zhange et al., 2019).

Green space and its associated corridors also provide essential and necessary shelter for various terrestrial, avian, and aquatic species and are vital to maintaining biodiversity in creating urbanized areas. Water storages, fish-ponds, constructed wetlands, and rivers are significant elements within an urban area that can be considered as artificial blue parcels.

Different types of functions relate to blue parcels: recreational activities, conveying surface water runoff, providing new shelter for various types of species, and serving as a great carbon sink. Most of the comprehensive master and spatial planning for delineating these types of bio corridors (TSES) need thorough strategies to ensure ecosystem services are in the best use for all aspects of living in an urban area.

Historically, the majority of competitions held by authorities were in the case of architecturally stimulating projects while limiting the urban evolution resources. Also, there was a belief that developing eco-friendly corridors are unrealistic and exaggerating. However, much damage has been done to ecological connectivity in developed, urbanized areas.

Therefore, urban sprawl resulting from mass buildings' construction will cause exponential fragmentation, and due to that, the disconnection of green-blue landscape services is one significant consequence.

This thesis aims to investigate a part of this fragmented area within Prague, Czech Republic and focuses mainly on the lack of such designs within an urban area and its associated side effects.

According to the Husqvarna Urban Green Space Index (HUGSI), which aims to quantify and analyze urban green spaces through the use of geospatial data from satellite images, Prague is ranked 13th out of 155 cities assessed with almost 180 m2 of green spaces per inhabitant (HUGSI, 2021).

Although the vast majority of these green spaces exist in the city, the absense of meaningful connections between them is one major issue that will be the primary task of this thesis.

Moreover, some successful case studies will scrutinize, and by keeping an eye on the detailed design master plan and the achievements in mentioned cases, and replication of those ideas in the case study, which is Prague will go to some deductions and designing.

A wide range of achievements that will be a feasible companion of green-blue corridors such as natural, recreational, sustainable, resilient values, urban heat control, reduction of air, water, and noise pollution will take into account within the new design idea and analyses of pre-exist data.

2. Objectives

This master's thesis aims to demonstrate a solution for enhancing the landscape interconnectivity quality by defining new green-blue infrastructure corridors within fragmented open spaces in Prague.

Hence, the establishment of this new layout, not only is essential for providing ecosystem services and biodiversity but also will manifest a continuous connection between urban and pre-urban vicinities to a broader extent.

Due to the vast scale of fragmented undeveloped open spaces in Prague, there is potential to turn them into green-blue parcels, where it brings hope to observe varying recreational human activities alongside other achievements such as resiliency, sustainability, and biological reclamation and connectivity.

This research implies some fundamental values of infrastructure (natural, recreational, sustainable, and resilient values), which represent the functionality of the landscape within an urban area.

Design in this context refers to designing in a inter-disciplinary aspect comprised of architecture, landscape architecture, urban planning, and analysis of multi-spectrum of data that can be distinguished as climatic data, anthropocentric synergies with the affected case study, and the technology influences. Therefore, due to the natural basis of this research based on objective-oriented goals, it is not enough to narrow it down to one thorough research hypothesis or single proposition. Moreover, developing systems that may include modeling and making a space or an infrastructure may involve the design and analysis.

This research hypothesis does not aim to prove or disapprove an existing theory or design of such a similar multi-disciplinary field of study as a worldwide standard. Rather, it is a proposition considering the various aspects that may interfere with the case of interest and how green-blue corridors and infrastructure can be implemented to fulfill the optimum standard.

In this framework, the goals are green-blue infrastructure, resiliency, and sustainability, while data analysis and design in all mentioned scales are the means.

The analysis refers to a wide range of computer-aided design (CAD) software, recalibration of various data layers in ArcGIS, and field surveying. The measurements of efficiency and performance criteria such as functional, environmental, structural, and human intervention, as well as the scale, may vary from case to case.

With the above-mentioned research hypothesis, the proposition is to explore and incorporate data analysis, design alternatives in various scales and types, new strategies, and develop innovative and creative methods and design alternatives.

Similarly, this study focuses on various aspects of green-blue corridors implementation and leads to the following research questions:

How can green-blue corridors reduce heat, air, noise, and climate pollution?

How can a new green-blue infrastructure corridor connect various parcels within an urban area and pre-urban ones?

The general purpose of this master's thesis will be:

To concrete the importance of green-blue corridors and related infrastructure for a fragmented urban area and enhance interconnectivity between urban and pre-urban vicinities.

To demonstrate this using a piece of Prague as a case study of the fragmented parcels, then for the solution, propose a detailed design for the mentioned site.

3. Literature review

3.1 Theoretical foundation

Exponential urbanization and urban sprawl within a metropolitan area will negatively affect ecosystem and environmental services. Moreover, open spaces suffer from a lack of vegetation and fragmentation where various parcels, for instance, buildings, infrastructure, and various functions, contribute to exacerbating this phenomenon.

Global warming is a possible threatening phenomenon that will happen, and nowadays, there are a vast majority of policies envisioned for this. In addition, it is a threat to the resiliency and sustainability of our cities, mainly those that locate near coasts or seashores.

Another defect that can be mentioned as the consequence of urban sprawl is increasing the surface stormwater run-off. It autonomously will cause problems related to the water system regime, such as water pollution, increased water discharge, lower oxygen, high nutrient risk, and numerous other results. Consequently, it will exacerbate aquatic biota livability and a loss of continuous chain reaction of ecosystem services. Thereby, urban green-blue corridors or infrastructure is a must-do to mitigate numerous mentioned problems.

It also includes autonomously processes that guarantee collateral advantages to grow resiliency and sustainability in a wide range of climatic parameters (Gentle et al., 2007; Leary, 2012; Middlemann and Middelmann, 2007). Thus, by implementing the green-blue corridors and infrastructure, several ecological benefits such as revitalization of ecosystem and environment, recreational activities, and aesthetic approaches can be achieved at the local, regional, and national levels.

To a broader extent, the interconnectivity of green-blue corridors is a multi-disciplinary approach from minor scale design to mega-scale one with the companionship of chronological analyses on different climatic parameters, literature review of similar cases, questionnaires, and interviews in cases related to human recreational activity.

3.2 Literature Review introduction

The literature review in this thesis is spread throughout the entire text at various levels.

Firstly, a background of theoretical and historical references are briefly provided with definitions of green-blue corridors, undeveloped open spaces, landscape interconnectivity, fragmented parcels, resiliency, and sustainability.

The second level of the literature review is the introduction to some cases of interest. Also, it will be accompanied by analyses of successful case studies and multi-disciplinary design in the field of methodologies and mentioned parameters.

Consequently, this research focuses on the possibilities of implementing green-blue corridors in Prague city, from CTU university till skirt of *Stromovka Park* as shown in the below picture; thereby, the primary perspective of GBI implementation is extensively considered in urban scale terminology.

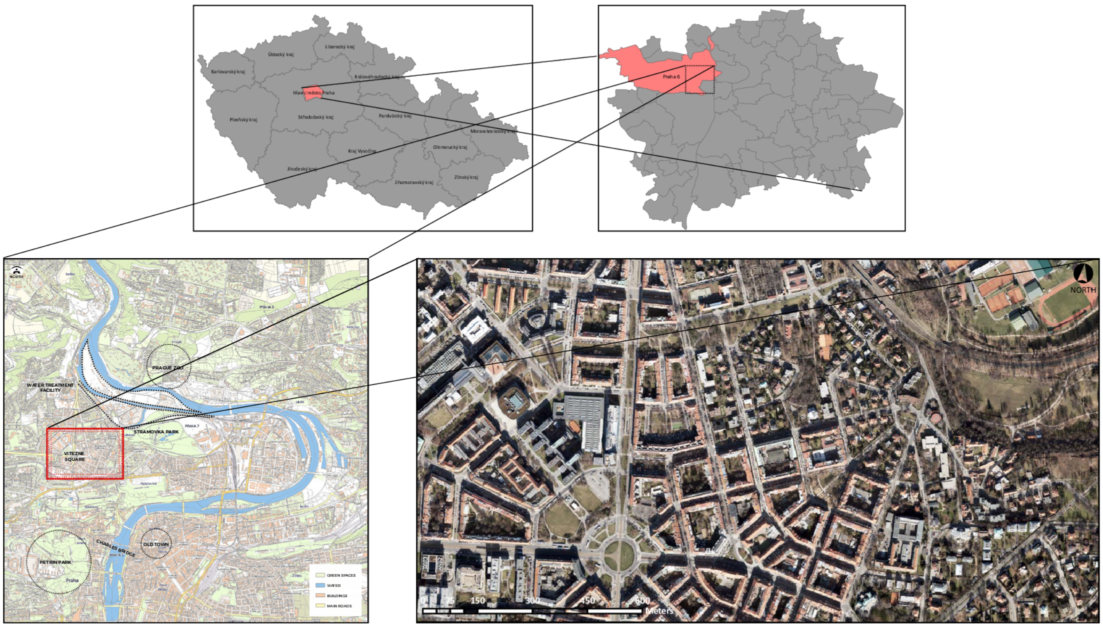

Figure 3.1: Case of interest, Prague, The Czech Republic (Geoportal Praha, 2021)

3.2.1 Green corridors definition

There are always two primary key elements that define greenways as tangible terminology: A thorough understanding of natural and cultural features and perspective influence.

Green infrastructure terminology has been utilized by various disciplines related to conservation, enhancement, design, and implementation of planning. Thereby, it is feasible to specify some features that have common approaches in terms of use: Connectivity, multifunctionality, and intelligent conservation. Furthermore, there is a vast majority of studies in which protection and development is the primary point of their determination (EEA, 2011). Furthermore, there is a vast majority of services that will acquire upon this establishment: Critical filtering zone, absorbent of contaminants of surface run-off, cleansing and replenishment of air with trees, shrubs, and cover vegetation, recreational activities, accessible alternatives, outdoor activities, the safety of nonmotorized vehicles, lessening the dependence of automobile, cultural heritage, the joint-use partnership of infrastructures, rural character, visual relief, preserving of farmland, community amenities with an economic value, enhancement of the quality of life, and finally revitalization of firmer town centers (Schwarz et al., 1993).

A green corridor, also known as a wildlife corridor, biological corridor, or habitat corridor, is a strip of land established to enable the movement, bridging of habitat populations separated by human-induced activities such as urbanization or other activities. As mentioned before, based on the definition of the European Environment Agency (EEA), there are two primary concepts for green infrastructure with respect to their scales: (a) urban scale and (b) landscape scale.

3.2.2 Multi-disciplinary approach and issues upon defining GBI

As mentioned before, the various perspective of green-blue infrastructure can be defined from urban and landscape points of view. Table 3.2.1 demonstrates an extensive comparison and description of various approaches based on the GBI with regard to the European Environmental Agency Technical Report (EEA, 2011; Pachapski, 2021).

Green Infrastructure Characteristics	Urban scale	Landscape scale
Short description	- Development and protection of a network of multi-functional green space in urban environments	- Development and protection of connections between valuable habitats in wider landscape scale
Matrix / obstacles	- Urban built-up environment	- Intensively farmed land - Built-up areas - Grey infrastructure
Key associated benefits (as highlighted in the literature)	- Urban heat island mitigation - Water run-off management - Water retention (flood prevention) - Recreation - Visual pleasure, sense of nature and open space - Wildlife habitats	- Species migration - Water retention (water recharge and flood prevention) — to a lesser extent

Most common structures	Parks, tree-lined avenues, green roofs, agricultural land and woodland inside towns, etc.	- Habitats (in the EU, more specifically the Natura 2000 sites) and corridors - Rivers and streams, hedges, etc. - Overlap with term 'ecological network'
Examples of disciplines using the term	- Urban planning - Landscape architecture - Environmental management	- Species conservation - Spatial planning - Environmental management
Key topic / policy links	- Quality of life in cities - Biodiversity protection - Climate change compliance - Climate change reduction	- Biodiversity conservation - Climate change compliance

Table 3.2.1: Comparison of GBI at Urban and landscape scales (EEA,2011)

Thereby, as a case of interest, urban scale is the main category that most of the definitions and analysis in this dissertation will look forward to.

The primary concept of GBI mainly refers to conservation as a vital element that benefits go to landscape scale; However, planning, implementing, and managing the existing GBI may use conservation support as well as recreational activities and other social values (Benedict and McMahon, 2006).

Furthermore, there are wide ranges of definitions of GBI in the present literature of researchers and organizations that creates complications in the case of scales and apprehensions.

Reference	Explanation	Scale of application
Benedict and McMahon (2006)	Green infrastructure is an interconnected network of natural areas and other open spaces that conserves natural ecosystem values and functions, sustains clean air and water, and provides a wide array of benefits to people and wildlife	Landscape
European Environment Agency (2011)	Green infrastructure is a concept addressing the connectivity of ecosystems, their protection and the provision of ecosystem services, while also addressing mitigation and adaptation to climate change. Green infrastructure helps ensure the sustainable provision of ecosystem goods and ervices while increasing the resilience of ecosystems.	Landscape

Landscape Institute (2009)	Green infrastructure is an approach to land use, underpinned by the concept of ecosystem services. Green assets such as parks, coastlines or embankments have generally been thought of in terms of their single functions — the approach that recognises their vast range of functions and their interconnectivity is called green infrastructure.	Landscape / Multi-scale
Tzoulas et al. (2007)	The concept of Green Infrastructure can be considered to comprise all natural, semi-natural and artificial networks of multifunctional ecological systems within, around and between urban areas, at all spatial scales.	Multi-scale
European Commission (2013)	Green Infrastructure can be broadly defined as a strategically planned network of high quality natural and semi-natural areas with other environmental features, which is designed and managed to deliver a wide range of ecosystem services and protect biodiversity in both rural and urban settings.	Multi-scale
Forest Research (2010)	Green infrastructure refers to the combined structure, position, connectivity and types of green spaces which together enable delivery of multiple benefits as goods and services. It is important to consider green infrastructure holistically and at landscape as well as individual site scale.	Multi-scale
Natural England (2010)	Green infrastructure is a strategically planned and delivered network of high-quality green spaces and other environmental features. It should be designed and managed as a multifunctional resource capable of delivering those ecological services and quality of life benefits required by the communities it serves and needed to underpin sustainability. Green infrastructure includes established green spaces and new sites and should thread through and surround the built environment and connect the urban area to its wider rural hinterland.	Urban

Ahern (2007)	Green infrastructure is a concept that is principally structured by a hybrid hydrological/drainage network, complementing and linking relict green areas with built infrastructure that provides ecological functions. Green infrastructure plans apply key principles of landscape ecology to urban environments.	Urban
Sandström (2002)	Green infrastructure' concept is introduced in order to emphasize the multiple purposes of green space (including ground and surface water). In current efforts to achieve sustainable urban development, 'green infrastructure' has the same dignity as 'technological infrastructure' has had in traditional urban planning.	Urban
EEAC (2009)	Green infrastructure is the actions to build connectivity nature protection networks as well as the actions to incorporate multifunctional green spaces in urban environment.	Urban

Table 3.2.2: Examples of GBI definitions (Pachapski, 2021)

To highlight the correlation between green-blue corridors and ecosystem services, the technical report of the European Environment Agency indicates that the research illustrates the synergy test between the them (EEA, 2011).

The Landscape Institute also supports the concept of ecosystem services in terms of the multifunctional nature of green infrastructure assets (Landscape Institute, 2009).

The definition of the Green Infrastructure Guidance by Natural England generally recognizes green infrastructure on an urban level, simultaneously highlighting ecosystem services and advantages which relate to the life quality that green spaces provide to societies (Natural England, 2010).

Many research emphasize the importance of considering green infrastructure on various scales (Tzoulas et al., 2007; Forest Research, 2010; European Commission, 2013).

Some of green-blue infrastructure defintions mention it as a continuous network as an essential attribute, whether as a conceptual or practical approach. High quality of green spaces and greenery, and well strategic plan of green infrastructure networks is another definition which put it at the importance (Natural England, 2010; European Commission, 2013).

The green-blue infrastructure definitions mounted by Sandström (2002) and Ahern (2007) generally indicate an urban scale, emphasizing greenery' corelation with hydrological elements, specially drainage system, ground, and surface water.

Furthermore, Sandström (2002) asserts that green infrastructure has the same status as technological infrastructure has had in urban planning.

Although research by Sandström (2002) highlights green infrastructure planning in the urban areas of Sweden, such a statement has been repeatedly used in American science since the mid-1990s, when the term was used for the first time.

Geographic analysis of the definitions of green infrastructure notes that in the United States, the concept is often applied to the management of stormwater run-off through natural systems (EEA, 2011). However, some American institutions like the Conservation Fund use the term in its broader meaning, recognizing the benefits of green infrastructure (e.g., Benedict & McMahon, 2006).

An American understanding of green infrastructure as a network of hydrological parts are also typical for Ahern (2007), who mainly adjusts on applying landscape ecology principles to urban green infrastructure, while its spatial properties are the completion climax. The author declares that the key ideas from landscape ecology like multi-scale approach and emphasis on physical and functional connectivity are highly relevant for urban green infrastructure (Ahern, 2007).

3.3 Green- Blue Infrastructure services

Benefits or developments of interest to an individual or a group are referred to as services (Chan et al., 2018).

This section addresses GBI services that can alleviate hydrological extremes, provide water quality improvement, mitigate climate change, reduce urban heat island effect, provide energy-saving, promote carbon sequestration, and improve the overall ecology of cities.

These services are highly interwoven within each other, and one will affect others. Therefore, there are a vast majority of analyses about unified services for GBI implementation that need to take the physical and social advantages to account, and these concepts have been demonstrated by several authors (James et al., 2009; Walker et al., 2014).

3.3.1 Reduce hydrological extremes

One of the main issues that conclude from human-induced activities and interventions are floods and droughts, which are considered as extreme weather events (Intergovernmental Panel on Climate Change (IPCC), 2014). However, there is absolute uncertainty about this phenomenon concerning climate change during extreme events.

Extreme events such as heatwaves, forest fires, floods, and droughts are the most significant human-induced events in relation to natural ecosystems, where significant vulnerability and susceptibility of the climate changes are evident. Alternations in ecosystems, food production, water supply interruption, damage to infrastructure, and human health risks are significant impacts that the climate climaxes impose on the natural and human ecosystem services (Din Dar et al., 2017; Hameed et al., 2017). Moreover, the lack of preparation for climate variations can exacerbate these mentioned impacts in a transboundary border.

One high potential of probability in the context of climate change is the occurrence of floods within urban spaces during high precipitation seasons.

One of the vital objectives of GBI is the improvement of environmental quality by the management of urban floodwater and surface run-off. Strategies such as GBI, including operations for collateral advantages, also increase resilience in a range of expected future climates (Gentle et al., 2007; Middlemann and Middelmann, 2007; Leary, 2012; Din Dar et al., 2021).

Flood protection and excess run-off management are some minor benefits alongside other multitude ones offered by GBI. The surface, subsurface, and aboveground GBI structures and their performance reported by different studies are summarized in (Table 3.3.1). The studies are either based on lessening the runoff or attenuating the peak of hydrological storms. Hence, the rise in the recurrence of climax weather conditions such as floods demands the implementation of GBI to achieve resilience and sustainability in urban areas (Din Dar et al., 2021).

Process	Surface	Above ground	Sub-surface
Infiltration retention	Bio-retention swales, Permeable pavement, Parks and forests, Stormwater trees, Stormwater flow through planters, Regional agriculture, Bioretention cells	Green facades, Green roofs, Trees	Subsurface storage
Detention	Surface detention pounds, Water square	Blue roofs	Subsurface storage tanks
Storage retention	Rainwater harvesting, Retention storage basins, Regional wetland, Seasonal storage	Rainwater tanks	Surface storage

Table 3.3.1: GBI components for flood mitigation (Cruijsen, 2015)

3.3.2 Water quality improvements

Several studies in various locations around the world indicated the capability and efficiency of GBI to improve water quality (Table 3.3.2).

Total phosphorus, total nitrogen, total suspended solids, and run-off volume reduction are achieved with best management practices (BMP) during the implementation of this system to the Crooked Creek watershed.

Among all mentioned parameters, the establishment of grass strips is the most compelling case scenario (Liu et al., 2016).

Another outcome of urban GBI is the plunge of run-off peak, also, elevation of physiochemical characteristics of run-off by deleting heavy metals, nutrients, hydrocarbons, and suspended solids (Davis et al., 2010).

Location	Total run-off reduction	Peak flow	Study
Northearth Ohio, USA	16-53%	80% peak flow reduction	Winston et al., 2018
Edinburgh, UK	40-92%	-	Alsubih et al., 2016
Montreal, Canada	26-98%	21-48%	Vaillancourt et al., 2019
Wheatley, England	Underdrain discharge 67% of Surface run-off volume	Peak flow lag (5 min- 9 h)	Abbot and Comino Mateos, 2003
Ontario, Canda	Underdrain discharge was 57% of surface run-off volume	92% average peak flow reduction Peak flow lag (45 min- 57.5 h)	Drake et al., 2012

Table 3.3.2: Permeable pavement hydrology performance based selected research findings

3.3.3 Climate change

Greenhouse gas emissions and global warming are the features of the earth's climate change (Intergovernmental Panel on Climate Change (IPCC), 2014).

GBI can provide a significant decline such as reduction of a specific impact of climate-changing on urban environments, an effect that known by the heat-island effect.

Air temperature and the majority of surfaces within an urban area have mostly warmer temperatures than urban fringes and non-urban areas.

One reason is the high capacity of heat absorbent by the materials trapped by roads, paved areas, and buildings; hence, this absorbed heat will release during the night, resulting in the rise of temperature (RICS, 2011).

Implementation of GBI enhances the greenery coverage within an urban area; thereby, one consequence of this phenomenon is the reflection of incident radiation into the atmosphere, where the cooling effect is produced by the mentioned parameter.

Incident radiation is the total amount of solar energy that the earth can absorb.

During the process of evapotranspiration, Plants also manipulate some of the incident radiation by making latency of heat's evaporation (Bhat et al., 2017b, 2017c).

Two primary factors can impose directly to urban heat effect reduction: 1. Increase of the green cover 2. Increasing the albedo (reflection of the surface) (Obendorfer et al., 2007).

GBI implementation in an urban area is a long-term solution and cost-effective measure to impact climate change (CABE, 2010; Schaffler and Swilling, 2013). The significant consequences of climate change can be counted as increased intensity and frequency of storms, mean sea-level rise, and extreme temperature and precipitation events (Malik et al., 2018; Milly, 2012).

The average annual summer and winter temperatures are assumed to grow in urban areas by the same mentioned scenario of climate change.

Adaptation of GBI within urban areas can significantly reverse the summer temperature (SURF, 2011). Some possible outcomes of GBI implementation are improved environmental performance and city habitability (Din Dar et al., 2021).

3.3.4 Temperature mitigation

It has been confirmed by many different authors that urban micro-climates have significantly higher wind speeds, higher temperatures, and lower rainfall amounts in association to the natural landscapes or rural areas (Santamouris, 2013).

Consequently, microclimate enhancement of the urban areas may be considered as one of the significant environmental advantages of the GBI, especially urban forests and trees (AILA, 2012). Higher temperatures emerging from urban heat islands varies the urban micro-climate augments the climate variability resulting from global warming, and increases the severity of rainfall occurrences in the mentioned areas (Liu and Niyogi, 2019; Simsek and Odül, 2019).

Plants and trees have been determined to develop the urban microclimate and decrease the Urban Heat Island effect via two main natural processes:

i) cooling effect through shading of urban surfaces

ii) humidification and evapotranspiration effects in the cooling of air.

Improving the area under green cover in a city can significantly impact the daily temperature of the cities. Various researches have assessed the level of cooling in different climate scenarios. For instance, modeling of green cover by Gill et al. (2007) in Manchester (UK) have suggested a possibility of preserving the maximum surface temperature in urban centers and high-density residential areas considerably under the surface temperature levels of 1961-1990 to 2080.

Researches have additionally suggested that a decline of 10% in the green cover through replacement with concrete and impermeable areas may reduce the cooling effect of the vegetation and raise the maximum temperature to nearly 35 ◦C. On the contrary, a 10% rise in green cover by growing tree canopies around the roads can limit the maximum summer temperatures to around 29 ◦C (Gill et al., 2007).

These assessments were done for Manchester City; however, it could be implying other urban areas and cities as well.

Likewise, surface temperature reduction temp was between 1-15 ◦C by constructing green walls and facades in warm temperature environments (P’erez et al., 2014).

3.3.5 Energy savings

The economic growth of a country has a direct relation with energy availability, and therefore all the countries globally are searching for ways to lessen energy demand and consumption (Banking on Green, 2012).

The implementation of green covers has been increasingly perceived as a sustainable and practical solution for diminishing the energy costs for cooling buildings in cities with a temperate climate (Bayram and Ercan, 2012).

Urban GBI plays a vital role in climate variation change by reducing surface and air temperatures. Thermal comfort zone and lower energy consumption are the direct results of temperature reduction. The physical indicators such as room temperature, energy savings, and turbulent flows quantify thermal comfort and lessen energy demand due to GBI selection.

Studies have indicated that vast urban green spaces, green roofs, and roadside trees immensely lessen the cooling and heating demands of the individual buildings by making them more energy-efficient (Banking on Green, 2012).

Heisler (1986) stated that GBI decreases the heating cost by 10-15% and cooling cost by 20-50% for residential areas with trees. Likewise, expanding the area under green cover may diminish the total energy for cooling by 5-10% and by 10% for heating, as achieved from a study in Chicago (USA). Chicago has been a green roof installation movement pionner with half of the building in the city has installed green roofs and therefore, yielding an energy saving of 3600$ annually at the building level (Banking on Green, 2012).

There is difficulty determining the overall benefits of GBIs due to variability in estimating the various benefits and energy costs of the GBI installed at several scales. However, multiple types of research and examples imply significant environmental interests and energy-saving through GBI development (Banking on Green, 2012).

GBIs likely lessen the values of energy requirements and health problems by naturally reducing the optimum temperature of the urban areas. Whilst summing up the earlier discussion and Table 3.3.3, the conclusion of the development in the form of GBI such as green roofs (Table 3.3.3) demonstrates a significant decline of heat input and surface temperature in comparison with the conventional roofs without the greenery coverage.

Location	Thermal Reduction	Study
Reunion Island, Indian ocean	6.7 °c (Roof surface)	Moray et al., (2012)
Tamuna nagar, India	5.1 °c (Indoor air)	Kumar and kaushik, (2005)
New york city, USA	2 °c (Indoor air)	Susca et al., (2006)
Singapore	7.3 °c (Roof surface)	Qin et al., (2013)
Kuala lumpur, Malaysia	1.5 °c (Indoor air)	Kok et al., (2013)
Cascaval, Brazil	4.96 °c (Indoor air)	Cassia et al .,(2018)

Table 3.3.3: Green roof thermal reduction (Din Dar et al., 2017)

3.3.6 Carbon sequestration

A phenomenon called carbon sequestration or carbon storage above the land as the form of biomass is one of the most valuable ecosystem services of GBI. (Davies et al., 2011; Schimel, 1995; Bento et al., 2015; Grimm et al., 2008).

Carbon dioxide long-term fixation and storage by carbon sequestration designate as the structure of organic material in soil and long-lived plants (Din Dar et al., 2020: Lal, 2009). Vegetative soil is very good at absorbing and storing atmospheric carbon (Baes et al., 1977).

The *Water Sensitive Urban Design* (WSUD) systems and vegetation because of this possibility can serve as a crucial tool for moderating their carbon footprint directly or indirectly (Lal, 2004; Litynski et al., 2008; Griggs and Noguer, 2002).

GBI in urban areas can significantly reduce CO2 from the atmosphere in the daytime within the photosynthesis cycle. Another possibility of CO2 removal is its trapping during biomass production and in the underground soil, which significantly will have lessened the effects of climate change (Velasco and Roth, 2010).

The presence of evergreens plants such as Mangifera indica, virens, and macrocarpa in urban GBI may be a primary reason for high carbon sequestration in some cities like Guangzhou.

Another possibility of high carbon sequestration rates is the plantation of juvenile plants with the capability of high growth. Hence from the above discussion, it can be inferred that the growing season of the plants and the total area under the coverage of greenery spaces determine the annual carbon sequestration rates in urban areas.

3.3.7 Urban Ecology

The urban area can be defined as an area that is densely populated by humans and occupied by buildings. A thorough and historical definition of a city is the place where its core is highly populated, and by distance from the center of it to its edge, the mentioned parameter declines.

In the terminology of urban planning, urban fringes are the areas where quite distinctive characters can be distinguished between urban and rural environments. Furthermore, the definition of the urban gradient is a cross-section that passes from the core of a city, where it continues its path through suburbs and rural outskirts (Bryant, 2006).

Until today, There are not many studies in cities executed by ecologists; However, the majority of these types of research happened in pristine and wilderness areas where the human impact is at its minimal level.

The situation within urban areas due to urbanization and consequently alteration of land-uses and occupancy always vary, and one is the loss of native species in urban areas. Urban areas can no longer be neglected. By publishing the journal of Urban Ecosystem in 1997, urban ecology researches had a new sign of illuminance. With approximately 3 million acres being converted to various land uses annually between

1992 to 1997 in the United States, the rate of land development almost doubled during a 10-year period (Environmental Protection Agency, 2000).

Alteration of a piece of land from non-agricultural or undeveloped uses to a refined use as residential, commercial, and industrial is the definition of land consumption (Bryant, 2006). Another phenomenon that needs to be cleared from the aspect of terminology is urban sprawl.

By referring to that, urban sprawl is the excessive land consumption rate compared to the population increase rate on a metropolitan scale.

There is not much world's population that senses the correlation between cities and biodiversity due to the back and forth from the countryside into cities (United Nations et al., 2000).

Due to the living of the most world's population inside cities, some studies named it "first urban century" (Hall et al., 2000).

One crucial strategy to approach the impacts of urbanization is to find better accommodation alternative developments in an ecologically sensitive manner.

In one study conducted by Grimm et al. in 2000, the importance of the correlation between urban areas and the global environment was emphasized as follow: 78% of greenhouse gas emission are produced by urban areas which occupy only 2% of Earth's land cover, and global climate change is the result of it. Urban cores and areas also play an essential role by remodeling the global biogeochemical cycles and changes in biodiversity due to habitat fragmentation and the results that derive from the following phenomenon (Grimm et al., 2000).

Furthermore, there are two differences in this study between "ecology" and "ecology of cities."

These days, most researches and studies are primarily conducted around the ecology of cities where the city analyzes as an ecosystem instead of a city as a defect on the natural landscape (Grimm et al., 2000; Lord et al., 2003).

A series of natural scientists and social ones address the urban long-term ecological research (LTER) as a measuring method to observe and evaluate the ecological changes in a minimum period of 30 years.

Furthermore, there is an extensive alteration in cities without considering the ecological relationship with LTER methods. To a broader extent, knowledge of urban studies is constituted by longlisted authorities in charge as researchers, government agencies, and grassroots organizations who need to fulfill research and land-use decision-making.

3.3.8 Urbanization impacts on biodiversity

The physical environment, flora, and fauna inside the cities have been mentioned in numerous studies. Also, four primary parameters have impacts on the cities increasing temperature as the side effects of urbanization: Urban heat island effect, increased run-off due to impervious surfaces, lower level of native species and a higher level of alien species, and a higher level of carbon dioxide (Whitford et al., 2001; Douglas, 1983; Bridgeman et al., 1995).

Variability of soil temperature and moisture levels, solar radiation, humidity, wind speed, and direction can be considered the spatial variability of the physical environment of cities (Gilbert, 1989).

Most of the soil's characteristic parameters are highly polluted and changed by previous land-uses. The physical changes in soil characteristics can be measured and quantified on an urban gradient scale. The mentioned parameters comprised road density, air and soil pollution, heat island effect, average annual rainfall, soil compaction, soil alkalinity, impervious surface coverage, and energy and material consumption, which were imported for humans.

The urbanization impact will remain longer compared to the other types of disturbance imposed on the built environment due to its permanence essence (McKinney, 2002).

One of the significant consequences of alteration of the landscape of cities is the changeover of habitats for plants and animal species. Fragmentation of the natural landscape and habitat is the definite impact of the development of farmlands, artificial forests, and pastures in suburbs and exurbs.

A study that has been held in Brussel over a 60- year time period concrete the

previously mentioned pieces of evidence that some plant species completely disturbed or the abundance of them were affected due to human activities, concluded to a decline or disappearance, in addition to the appearance of alien species due to their resistance nature against nitrogen, light, drought, heat, and alkaline soils (Godefroid, 2001).

Therefore, all the endeavors of the urban authorities should be pointed to the best management of urban biodiversity in order to minimize and mitigate the mentioned impacts, protection and connection of habitats, and restoration of damaged natural areas to get the best ecosystem services out of them (Bryant and Randolph, 2002).

Despite the impacts of urbanization, even landscapes adjacent to the urban core demonstrate a high-level heterogeneity that is the consequence of a wide variety of habitat gaps for species to exploit (Bradshaw, 1999). Habitat biodiversity and life-support conditions are significantly altered in the urban-rural gradient scale. Consequently, Green-blue infrastructures can be designed to respond to the variable conditions mentioned above.

3.4 Intangible benefits

GBI offers a wide range of ecosystem services that are somehow intangible and invisible; however, it has a long-term contribution to the ecosystem. Some of these advantages are hard to measure and quantify, but their impacts on both environment and society are quite obvious. Some of the intangible advantages comprised of GBI implementation and attempted to be measured are discussed as the rest of the discussion (Din Dar et al., 2021).

3.4.1 Habitat improvement

One of the crucial occurrences by implementing GBI in urban areas is increasing vegetation, which promotes a vast alteration of flora and fauna.

It can be said that habitat improvement and green spaces have an autonomous way of chain reaction to each other; the more greenery, the more habitat.

This phenomenon will have better performance when GBI components such as rain gardens contain native species as the vegetation.

There are two main advantages of habitat development in green spaces: First, a dwelling space and food for migratory birds, insects, and other tiny organisms. Second, a habitat nursery for species that need a shelter for initial degrees of growth. Another potential of GBI implementation within an urban area is the economic outcome of the adjacent territory based on the goods harvested at the habitat. GBI offers an exciting ecosystem service upon building comfort based on noise reduction. There are some significant sources of noise pollution inside the cities that exceed the bearable limits and can be detrimental to human health. The establishment of porous pavements is one technique that reduces the noise level up to 10 dB (Olek et al., 2003; Gerharz, 1999).

Another implementation that can reduce the noise level and sound transmission by 2-13 dB is the usage of green roofs (Connelly and Hodgson, 2008).

In this similar case, one research mentions the property value reduction upon increasing decibel sound level between 0.86% and 0.55% average, primarily for aircraft and road noise (Navrud and Bergland, 2004).

GBI is an exciting concept in urban areas which affiliated with urban comfort. The green urban network connects various big green parcels within an urban area and conforms to elements such as natural infrastructure, plants, trees, and links to open spaces and greeneries.

Some of the advantages that can be achieved via the implementation of GBI are habitat improvement, mobility networks, social interactions, reduction of noise level, and cooling effect yield against urban heat island effect.

Some of the cities that have already implemented GBI, mostly in existing parking lanes and spaces and buildings, retrofitted this technique to manifest habitat of wildlife, shading effect, and pedestrian safety; Montreal (Canada) and Mexico are between them that in case of study part, there will be some examples of what has been done there.

3.4.2 Recreation and aesthetic

Recreational activities within an urban area, such as jogging, picnicking, observing nature, etc., are some outcomes of GBI implementation. Implementation of GBI directly impacts the growth of recreational activities and everyday usage of the space. Daily excursions also is another value that can be addressed to GBIs. An increased rate of 350 million recreational trips over a 40-year period was counted in Philadelphia, Pennsylvania for one established project with the name of Green City Clean Waters plan in order to control stormwater control. Based on the reports, these trips' total monetized income value in 2009 might be more than $520 million (Stratus, 2009).

Another positive income of GBI implementation is the impact on human health, where the studies demonstrate a correlation between the two mentioned elements and how the medical expenses decline in relation to physical activities that happen the GBIs (Pratt et al., 2000).

Another achievement of GBI implementation within urban areas is aesthetic value. Cities with ample green cover are basically beautiful and aesthetically pleasing. Like recreational activity, urban greening is also directly correlated with property value.

The correlation association between urban greening and property values demonstrates a positive impact of GBI implementation based on aesthetics. As a general rule, most people who want to buy a property would rather pay more in green spaces and aesthetic approaches that will achieve via greenery. Therefore, the properties which are adjacent to greeneries are considered more valuable. One study reported that street trees decrease the latency market time of a residential property by 1.7 days and raise the property selling value by approximately $9000/ sqm (Donovan and Butry, 2009).

There are some deficiencies in measuring the advantages of improving water quality, air quality, flood control, and energy usage in relation to aesthetic approaches of GBI implementation.

3.4.3 Links between GBI, human, and ecosystem services

As a multi-scalar approach for GBI implementation from site-scale to citywide, there is a magnified perspective to get to our design. Therefore, one integrated approach to turn urban areas more green-friendly is to connect remaining habitat patches, whether inside urban areas or in urban fringes, to pre-exist GBI or implemented ones in order to achieve interconnectivity between them (Lovell and Taylor, 2013).

The priority of alteration within the urban area to GBI is with vacant lands and parcels where the various functions start fragmentation. By changing them to green spaces and recreational facilities, residential neighborhoods start to get connected to each other, and it means the social activity within various parcels (Ernstsonet al., 2009; Heynen et al., 2006; O'Brien et al., 2017).

The site-scale design will help connect ecological and social activities with other necessary elements of GBI, which can be comprised of another critical approach: landscape architecture (Nassauer and Raskin, 2014).

The type of landscape design should specifically have consideration to stormwater management, reduction of the urban heat island, an increase of recreational activities, and more. Hence, this approach to implement GBI is critical to gather the community and stakeholders all together where they can hear each other and provide the best for the users. Moreover, GBI projects must avoid gentrification (Wolch et al., 2014).

3.4.4 Economic consideration, and benefits of GBI

GBI projects during a long-term period will incur various costs, such as maintenance and environmental. Thus, a great detailed design and a thorough approach that take all the consideration into account is vital.

Some most common forms of GBI implementation in new intelligent cities are green roofs, rain gardens, bio-retention cells, and green corridors.

Compared to traditional materials and infrastructure, green roofs and facades are more environmentally friendly, and it is preferable due to their low-cost maintenance value (Bachawati et al., 2016; Chenani et al., 2016; Liu et al., 2016; Peri et al., 2012; Spatari et al., 2011; Vacek et al., 2017; Ottele et al., 2011; Manso et al., 2018).

It is also to say that the placement of the material and plants have direct impacts on urban GBI's performance (Ottele et al., 2011; Manso et al., 2018).

There are various approaches to implement GBI within an urban area. For instance, one strategy considers tree plantations and permeable surfaces to achieve significant environmental advantages, like reducing greenhouse gas emissions and energy saving.

With extent to a more extended period duration, it can be seen that the advantages of GBI are way much higher than the costs that it incurred for implementation (Spatari et al., 2011).

Based on the result of a study on cost-benefit analysis of BGIs on urban stormwater management and utilization conducted in Beijing, China, the annual average advantages of urban GBI were almost 1.91 times higher than the total costs incurred during implementation (Liu et al., 2016).

Also, compared to one single GBI facility, integrated infrastructures comprised a wide range of elements: Underground storage ponds, porous pavement, green spaces with the highest economic feasibility.

One mandatory assignment that should be done for any urban GBI project is to identify a detailed analysis of the environmental performances to be acknowledged as economically beneficial. Also, all of the analysis and strategies should be indispensable to all authorities to construct or dispose of the pieces of information (Din Dar et al., 2021).

3.5 GBI for sustainable development and conservation tool

Various elements lead a city to sustainability, and they are the outcome of equilibrium between economic, socio-culture, and ecological components.

Gathering all the GBI implemented approaches, and the long-listed services, makes an urban area sustainable and resilient. Changing the landscape of an urban area will cause negative impacts on the natural system of a city, such as the hydrological cycle, greenhouse gas emission, biodiversity, and biochemical cycles, which all of the mentioned parameters are derived from urbanization (Grimm et al., 2008). The different combination of gray and green parcels within an urban area will go to an equilibrium where sustainable and resilient urban planning introduces nature to the built environment. One of the primary critical features of

GBI is connectivity, where the majority of the advantages of GBI only be achieved by the interconnectivity of the network facilities (Faggian and Sposito, 2009; Faggian et al., 2012; Kazmierczak and Carter, 2010; Villarreal et al., 2004; Benedict and McMahon, 2006). Also, the implementation of GBIs has various geographical scales (Urban, regional, and watershed), and the establishment method are different from the conventional gray infrastructures. Due to a lack of general awareness, it is hard to implement the GBI as a widespread adoption method; however, the popularity is expected to be aroused contrary to the small number (Thorne et al., 2015).

Based on the experiments carried out on some of the GBIs in the Netherlands during many years, the effect of climate change on floods is that nearly 25% of the land lies below the average sea level, where dykes are required for more than 50% of the country (Snepvangers et al., 2011; Verburg et al., 2012).

Generally, climate change and changing socio-economic evolution result in dramatic land-use patterns.

Furthermore, various alternatives demonstrate in Fig. 3.2 illustrate several possibilities to implement GBI elements in which the functional synergies are heightened (Verburg et al., 2012).

It can be seen in the mentioned figure, part (a), that the various elements that accompany this method will bring improvement in water quality by controlling them based on natural circulation along the watercourses.

The large natural catchment area has the capability to absorb more sediments and nutrients due to heavy run-off; thereby, the water quality breakthrough is the result of it. Moreover, wetlands, whether artificial or natural, will delay the run-off time by filling up and emptying down during a flood event, and consequently, it helps the reduction of flood peaks in low-level lands (Snepvangers et al., 2011).

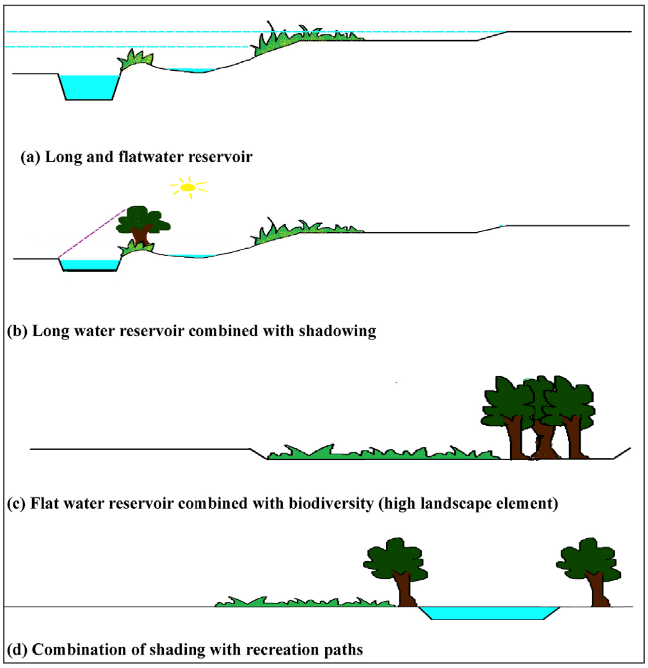

Figure 3.2: possible components of BGI based on a study in the Netherlands (Snepvangers et al., 2011).

4. Methodology

4.1 Introduction

This thesis implements a combination of mixed research methodologies and strategies, which are complementary. The main body of this master's thesis is based on objective-oriented approaches and previous successful case studies; thus, formulating the theoretical base for discussion on concepts of green-blue infrastructure, landscape interconnectivity, and undeveloped open spaces are the backbones of the implemented thesis approaches. Moreover, exploration of previous research and existing data to compare and analyze various ecosystem services on this specific topic in Prague city is also applicable. Furthermore, a questionnaire was provided by the author of this thesis to find the best location to establish the GBIs in the adjacent study area. Consequently, Field surveying and analyzing the data via Esri ArcGis and Computer-aided design software (CAD) is the main driving force alongside the methods mentioned above apply in this research area. Therefore, compulsory interaction here is to identify the ecosystem services of each of these case studies, which will shape the backbone of this master's thesis. The next part of the methodology identifies the various case studies in different countries.

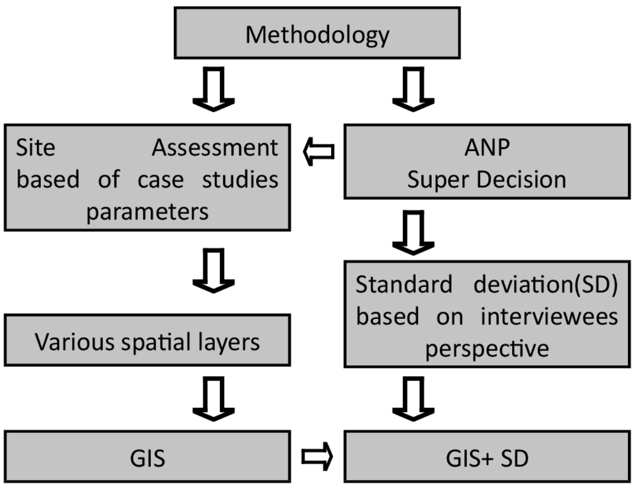

Figure 4.1: Framework of methodology

4.2 Case studies

4.2.1 Copenhagen, Denmark, Finger Plan, Urban green wedges

This master plan, as they called it Finger plan, is an iconic status model for urban development that was first established and drawn in 1947.

The city has been organized based on an overall regional structure where urban development is concentrated along city fingers linked to the railway system and radial road networks and where the city fingers are separated by green wedges, which are kept exempt from urban development.

This master plan has ensured free access to recreational areas for the whole citizens of Copenhagen, also easy access to central parts of the city. In the finger plan, all urban developments should generally occur in the core and peripheral urban regions associated with traffic infrastructure comprised of railway services and road networks where green wedges should be maintained for the city's finger as recreational or agriculture activity. The Finger plan has also helped prevent urban sprawl by maintaining regional outdoor recreational areas accessible to all residents.

Green wedges between city fingers have played the primary role in order to ensure all citizens have close accessibility to the city's green spaces close to the center via these parcels since 1947.

As far as the city is widening through its fingers direction, green wedges have also done the same; today, they comprise core and peripheral green wedges. Furthermore, the Finger Plan includes "green urban wedges." The green urban wedges are areas of regional significance for outdoor activities within the core urban municipalities.

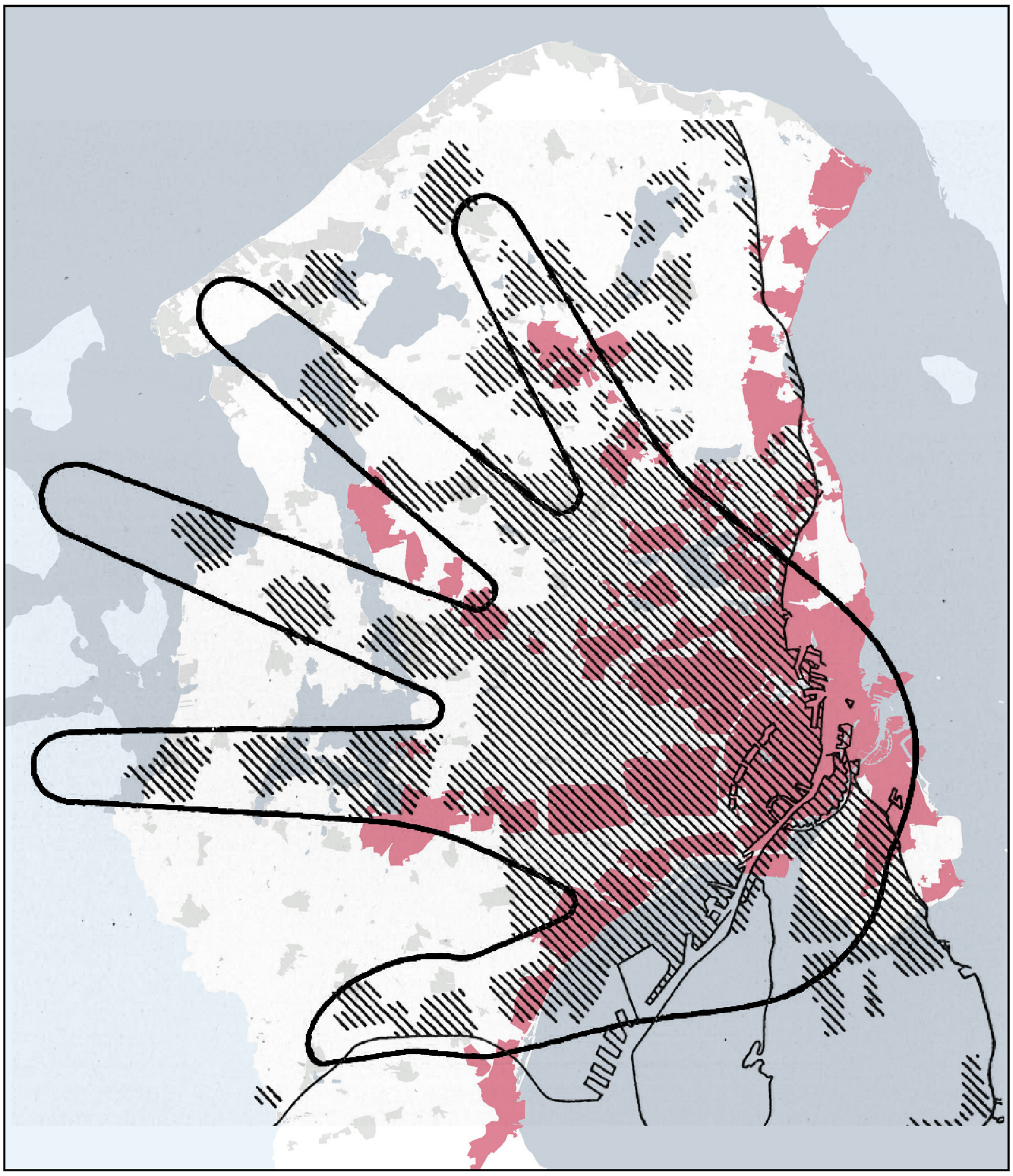

Figure 4.2: Finger Plan affected territory, Sketch from the first Finger Plan created by the Regional Planning Office in 1947 (Ministry of the Environment, Denmark, 2015)

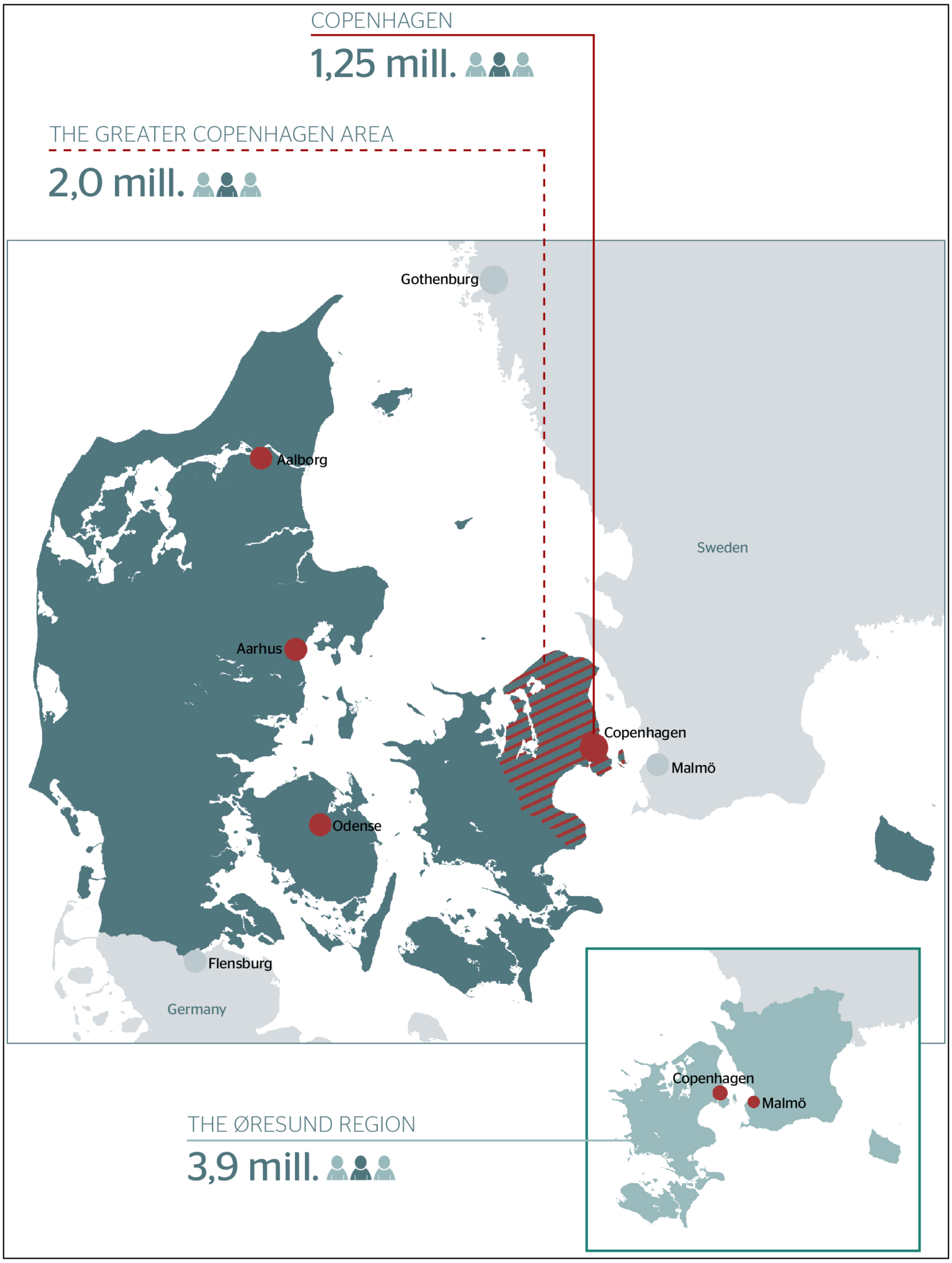

Figure 4.3: Denmark's location (Ministry of the Environment, Denmark, 2015)

Green urban wedges in the municipal plan are also designated as green parcels. The primary purpose of these green wedges is general outdoor activity and recreational functions, which means that the people are the primary target and priority for this. Construction of more summer cottages, residential facilities, commercial and urban development are totally forbidden and exempted inside the wedges. There are only a few small-scale buildings and construction such as villages located in the wedges which adapted to the landscape, nature, and cultural values of the place. Other mandatory parts of construction exemption from the installation are preventions of wind turbines and solar panels; however, agricultural use is possible because they are part of a varied landscape. Additionally, the introduction of intensive livestock farming needs to assess the results for recreational interests. The Finger Plan includes the possibility that, in those parts of the green wedges not covered by areas reserved for transport corridors, facilities for climate change adaptation could be established provided that recreational and nature-related conditions were strengthened to the broadest extent possible. Local considerations may entail alternative solutions, which may not impair the natural and recreational values of the area. For example, these could be rainwater retention basins and canals, contributing to recreational value. A temporary storage system for rainwater within the green wedges could act as a temporary infiltration plant, thereby safeguarding future groundwater resources. The mindset behind the peripheral green wedges is that the green structure must be developed in line with the expansion and delimitation of the city fingers (Ministry of the Environment, Denmark, 2015).

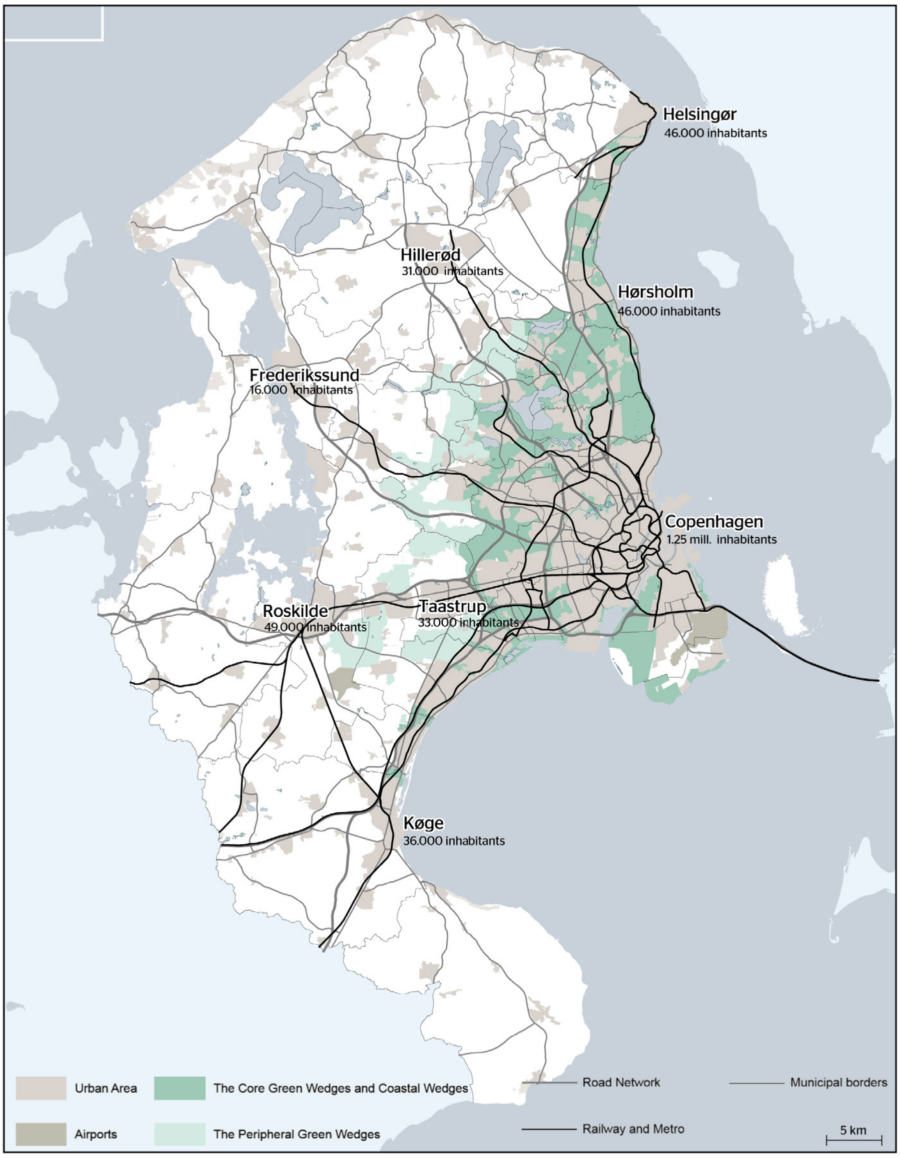

Figure 4.4: The wedge green cover (Ministry of the Environment, Denmark, 2015)

The green urban wedges aim to ensure large, green areas in the core urban region (the palm of the hand) in the form of predominantly publicly available regional outdoor areas for the entire population of Greater Copenhagen. The green urban wedges are of regional importance as they include the most attractive and popular parks and significant green areas etc., which, together with green paths, may form part of an overall green structure in the central part of the big city. The green urban wedges are part of the Finger Plan's urban area and urban zone as they are integrated into dense, urban surroundings and often have urban recreational facilities. This contrasts with the green wedges outside the core urban region between the city fingers. All areas in the green urban wedges were already designated as green areas in the individual municipal plans prior to their inclusion in the Finger Plan. The majority of the green urban wedges are covered by conservation orders stipulating land development and use provisions. The Finger Plan does not disregard provisions in existing conservation orders or local development plans (Ministry of the Environment, Denmark, 2015).

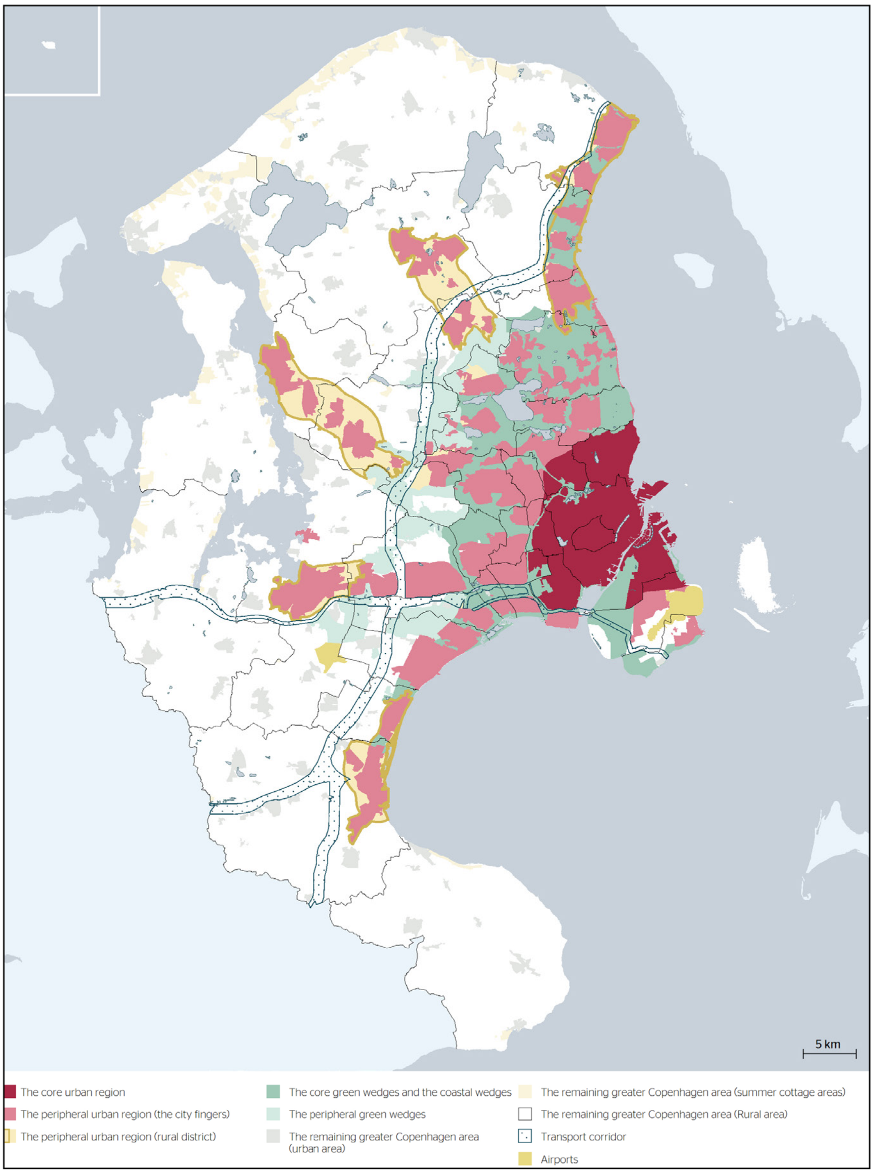

Figure 4.5: The geographical area (Ministry of the Environment, Denmark, 2015)

Figure 4.6: Different photos showing GBIs in Copenhagen, Denmark, 2021

4.2.2 Cheonggyecheon Stream Restoration Project, Seoul, South Korea, Challenges, Solutions

The Cheonggyecheon Creek revitalization project in downtown Seoul triumphs over urban renewal. The city's heart is now a green riverside park complemented by better public transport, providing citizens with a better living environment. Before the restoration, Cheonggyecheon was a dilapidated road and highway with more than 168,000 residents driving by every day.

However, instead of investing millions of dollars in upgrading this congestion and pollution-causing juggernaut, the city government decided to demolish it in a historic decision. Then Mayor Lee Myung-bak, who eventually became President of the Republic of Korea, spearheaded the project. Rumored to have contributed to its political victory, the restoration transformed Seoul into a sustainability-minded global metropolis. Cheonggyecheon was once a historic stream steeped in history. It was cutting through Seoul, Cheonggyecheon, which translates to a clear stream in the valley. A victim of urbanization in the mid-20th century, the river bank was lined with shacks, and sanitation was a problem. To solve this problem, the river was covered with concrete and turned into a 6 km causeway in the late 1950s. In 1971, Cheonggyecheon had a high highway 5.8 km from 6Lans to host the growing vehicular traffic of the capital. For a while, this infrastructure served its purpose.

Seoul has become a dynamic city with its extensive shopping center in the Cheonggyecheon district. However, in 2000 the highway reached its point of obsolescence. Engineers from the Korea Civil Engineering Society estimated that the repair would cost $95 million (Seuol metropolitan facilities management corporation, 2010).

The Korean civil engineering company engineers found the highway not to have structural integrity in 2000. prior study of this evaluation, only small cars have been allowed to pass since 1997. Carbon monoxide development around the central business district soon ceased, population and employment declined, and part of the company headquarters moved to Gangnam. It turned into a Cheonggyecheon spiral losing its competitiveness. Although it provides access and connects the north and south sides of the city, the elevated highway has also cut through neighborhoods and, over time, segmented communities. Likewise, locals considered the old highway an eyesore. The removal of the highway was seen as a drastic move, and few locals embraced the idea at first. Residents and some transportation experts believed it could worsen traffic jams and congestion in the city. Businesses also opposed the project, citing access and removing consumer foot traffic. Noise and dust from construction activities would also hamper business operations. Thus, building healthily and quickly has become an additional challenge for the town hall and how to recycle the waste generated by the demolition. Restoration of constant flowing streams Water was also an issue as the water supply was spotty in Cheonggyecheon except for rains during the summer season (Seoul Metropolitan Facilities Management Corporation, 2010) (Seuol metropolitan facilities management corporation, 2010).

Figure 4.7: Conceptual site plan (Research center director of Seoul development institure, 2002).

The severe health and safety risks supported the logic of dismantling the old road and the elevated highway. The value of an environmentally friendly and livable city has been increased in its place. Thus, Mayor MyungBak Lee proposed a paradigm shift in urban management: a Seoul for people, not cars. A lower budget was also needed with the revitalization project, and there would be no costly maintenance costs. Removing the freeway and the many vehicles that cross it has improved air quality and noise levels in the city. With its abundant biodiversity, the new seafront has enhanced this new section. The resulting serene stretch also helped reduce Seoul's urban heat island effect. Temperatures have cooled in the corridor, and even the wind speed has increased. More importantly, modernizing public transport and prioritizing its use over-reliance on cars has helped reduce pollution. The city government has discouraged the driving of private vehicles in the city center and has essentially streamlined its bus services. It has also integrated buses and trains to travel more smoothly. In addition, it has invested in Intelligent Transport Systems (ITS) to manage traffic routes and operations and introduced an innovative card system, which will allow the public to transfer and pay between different modes of transport quickly. The result was an increase in the number of buses and metro passengers. The city government has engaged stakeholders through extensive consultations for a practical shift in the urban paradigm. They explained the value behind restoring the Cheonggyecheon stream over investing in an expressway, citing how it will address. Security and mobility demand issues;

restoring history and culture through the preservation of relics and beautifying streets revitalizing businesses. In particular, the government provided financial support and subsidies to entrepreneurs and gave a special deal to street vendors. They also implemented parking reforms to stimulate business activity. Along with these benefits for locals, Cheonggyecheon's scenery itself has become an attractive feature of the city, attracting locals and tourists. The old causeway has become a green belt that unites history, city, culture, and nature. It cemented Cheonggyecheon as a high-quality place to live. One of the reasons for the revitalization of Cheonggyecheon is to become an environmentally friendly city; the

Figure 4.8: Cheonggyecheon, before and after of GBI implementation (Research center director of Seoul development institute, 2002).

local government has ensured that the project outcome and the underlying process are friendly to people and the planet. diamond wire saws and circular saws during demolition to minimize noise and dust. They generated 872,400 tonnes of waste (concrete and asphalt), and 96% of this was reused, while all scrap metal was recycled. They supplied and treated water from the Han River and underground water from subway stations for a constant water supply. They also protected the waterfront for the future by building embankments that could withstand the worst types of flooding (which occur every 200 years) (Seuol metropolitan facilities management corporation, 2010).

4.2.3 Freiburg, The world's most sustainable urban development model, Sustainability plan, Green city

New modern Freiburg was created as the first point where the citizens of this place started a protest against the government to establish a new nuclear power plant in 1975. Therefore, the various parts of the city started the built-up process by cooperative decision-making as a model of thorough environmental planning and eco-friendly living The world's most successful model for sustainable urban development (Abellard, 2017).

Besides consumption, transportation is one of the most complicated challenges of the ecological impact of development in order to reduce.

Although the majority of the citizens own their own vehicle, cars hardly ever pass through streets, and car parking is not catered for. They park in a community lot on the edge of the district, which is unsubsidized by car-free households.

The most significant importance of this city is based on non-motorized vehicle transportation.

Pedestrian and bicycle paths form a continuous connection, efficient, based on the green infrastructure with every home within walking distance of a tram stop, and all schools, businesses, and shopping centers are located within walking distance. Based on the statistics, 57% of households that owned a vehicle would rather let their car go. Altogether, 70% of the residents of this place live without a car The world's most successful model for sustainable urban development (Abellard, 2017).

Figure 4.9: Freiburg city, Green city Freiburg (Green City Cluster Freiburg, n.d.)

The main parts of the sustainability plan in Freiburg divide into three categories: Social, Economics, and environmental sustainability Urban issues& challenges: Freiburg, (PMT Education, n.d.).

- **Social sustainability:**

The definition of social sustainability is that the residents, as well as politicians, have an equal voice in changes in the local area. Participation of all citizens in the decision-making process provides an equal input rather than being made only by local governments. To encourage everyone's decision into account:

- The authorities welcomed groups of children to give their feedback and comments for all new development and construction on each scale.

- Financial investors also have some benefits as their efforts for providing the financial budget for projects like free football seasonal tickets.

- **Economic sustainability:**

There are various aspects which involve in economic sustainability:

-Providing jobs for affordable living.

-Making businesses responsible for the impacts on the environment.

-Implementing Green solutions, technology, and environmental industry.

Statistically, 10,000 people work in green industry occupations, for example, like a large cluster of solar panel manufacturers where they use residential buildings or individual houses in all various criteria.

- **Environmental sustainability:**

Processes in which all developments and daily living activities do not damage the environment are called environmental sustainability.

Figure 4.10: Freiburg city Green city Freiburg (Green City Cluster Freiburg, n.d.)

Processes in which all developments and daily living activities do not damage the environment are called environmental sustainability.

There are almost twice as many bikes as there are vehicles in Freiburg. The reason is because of the narrow streets in order to control heavy traffics, also the expensive cost of parking in Freiburg.

Figure 4.11: Freiburg city Urban issues& challenges: Freiburg, (PMT Education, n.d.)

One way to minimize the food miles and carbon emission of food transportation is to buy the daily products from the daily markets. Eventually, Freiburg hosts a daily farmers market where the majority of crops are growing from organic farming in the city.

Figure 4.12: Freiburg city (Urban issues& challenges: Freiburg, (PMT Education, n.d.)

All new development in this city must be balanced equally with environmental impacts. For instance, in case of any expansion on the railway network, it should be a river in order to introduce new flora and fauna like birds and wildlife back to the city.

Figure 4.13: Freiburg city (Urban issues& challenges: Freiburg, (PMT Education, n.d.))

The majority of public buildings, as they serve the citizens in the city, have powered by solar panels. The local football stadium and Town Hall are two of many of these types of buildings, and any surplus energy is transported to local offices and houses for minimizing the energy waste.

As the data and statistics for counting Freiburg as a green city show us, various parameters have been implemented since 1975 through this place.

The first and foremost reason to change this place as a green answer based on ecological, environmental, and other green solutions is society's demand in this city. It shows that the primary solution of each place is to change it into an Eco-friendly place for both human beings and other living organisms based on the demands of the citizens, and it shows a profound knowledge of how a community may keep maintaining their needs and future based on environmental needs. On the other hand, all the various parameters that can be counted a city as green, which mentioned in the literature review part of this thesis, are planned and implemented in the city even with more details and scrutinizing, where it can be found a bit more thorough in here. Pointing out all other minor details like buildings and even other urban elements in Freiburg are well designed for all the environmental solution matters.

4.2.4 High Line, New York, USA

Throughout the world's post-industrial cities, abandoned railroads, non-functional motorways and canals, and other derelict industrial ruins are subsequently changed into ecologically and aesthetically designed leisure, consumption, and tourist spaces based on landscape urbanism and ideas about sustainable park design.

High Line project in New York City is one example of this growing phenomenon described above.

Sustainable parks like the High Line are also supported by primary sustainability parameters as economic, ecological, and equity benefits.

Based on the research implemented by Lang and Rothenberg, New York City's High Line project has a significant economic piece of sustainability regarding its promise of generation growth. Its success in terms of the ecological dimension of sustainability is still a bit unclear. One part of sustainability that is more or less neglected upon implementing the High Line project is the social equity component (Lang and Rothenberg, 2016).

Figure 4.14: High Line, New York City (Ascher and Uffer, 2015)

One of the main reasons to build the High Line project at a higher level from the street was to provide safety compared to the rail freight line. The trains mostly carried out the daily products to Manhattan's west side warehouses, and they passed through buildings at the third-story level buildings. The majority of decayed and unused portions of the High Line were demolished in the early 1990s.

Stakeholders and owners of land and properties adjacent to the railroad had a verdict to demolish its remaining, and mayor Giuliani supported their decision. Although there was an excellent lobby process in order to destroy the High Line, another simultaneous movement happened by a unique combination of citizen engagement, city planning, and celebrity support. Alongside the civic movements and political support, federal rail-banking was the primary authority to verify the legislation to turn the old railroad to park (Ascher and Uffer, 2015).

Figure 4.15: High Line, New York City (Ascher and Uffer, 2015)

On the very opening day of the project in 2009, one thing that no one could predict before was the vast crowds that lined up to visit.

The answer for this phenomenon was a simple brief one: It will reduce the time of passing up on the High Line compared to street level. Contrary to the conventional parks, which provide just recreational spaces for users, this one is a dynamic place that allows them to walk by all over places of it and enjoy the city in entirely new ways (Balmori, 2010). Moreover, the other parameter that changed this project as a very significant success is the economic impact of adjacent properties which rapidly increase their value of them.

One of the primary parameters of choosing the ones who participated in the competition of this project was to choose a group which unable to have built experience in this scale. As a consequence of the final design, the quality of the High Line has been renowned as a magnet for unusual architectural form and design for the building at its adjacency. Also, some of the characteristic buildings at the premises, like the meatpacking district and Chelsea, which were in the densest place of the city where the High Line exists, make it more successful.

On the other hand, in 2005, the city proposed and implemented a new rezoning plan that enables the developer to start with new constructions of residential and commercial buildings along the High Line.

As a result of all mentioned explanations, it can be said that the High Line can be implemented in other similar places before the construction of civic monuments; However, not all the ideas are equally transferrable (Ascher and Uffer, 2015).

Figure 4.16: High Line, New York City (Ascher and Uffer, 2015)

4.3 Introduction to implementation site

The case of interest to implement the methodology and research of this diploma thesis locates in Prague, the capital of the Czech Republic.

Prague is the historical capital of Bohemia and the 13th largest city in the European Union.

The main characteristic element of this city, alongside its historical bridges and ornamented buildings, are the Vltava river which passes through the northern side of the city to the south part. Prague, with a population of almost 1,300,000 (IPR Praha, 2021), located at 50°05'N 14°27'E, in the center of the Bohemian basin, is the same latitude as Frankfurt, Germany; Paris, France; and Vancouver, Canada.

As far as the methods to implement the purposes of this thesis are very decisively manipulated for a small parcel of Prague, and by the guidance of the supervisor, the specific location to describe the analysis are a part in Prague 6; as it can be seen in Figure 4.17 which demonstrates the site clearly.

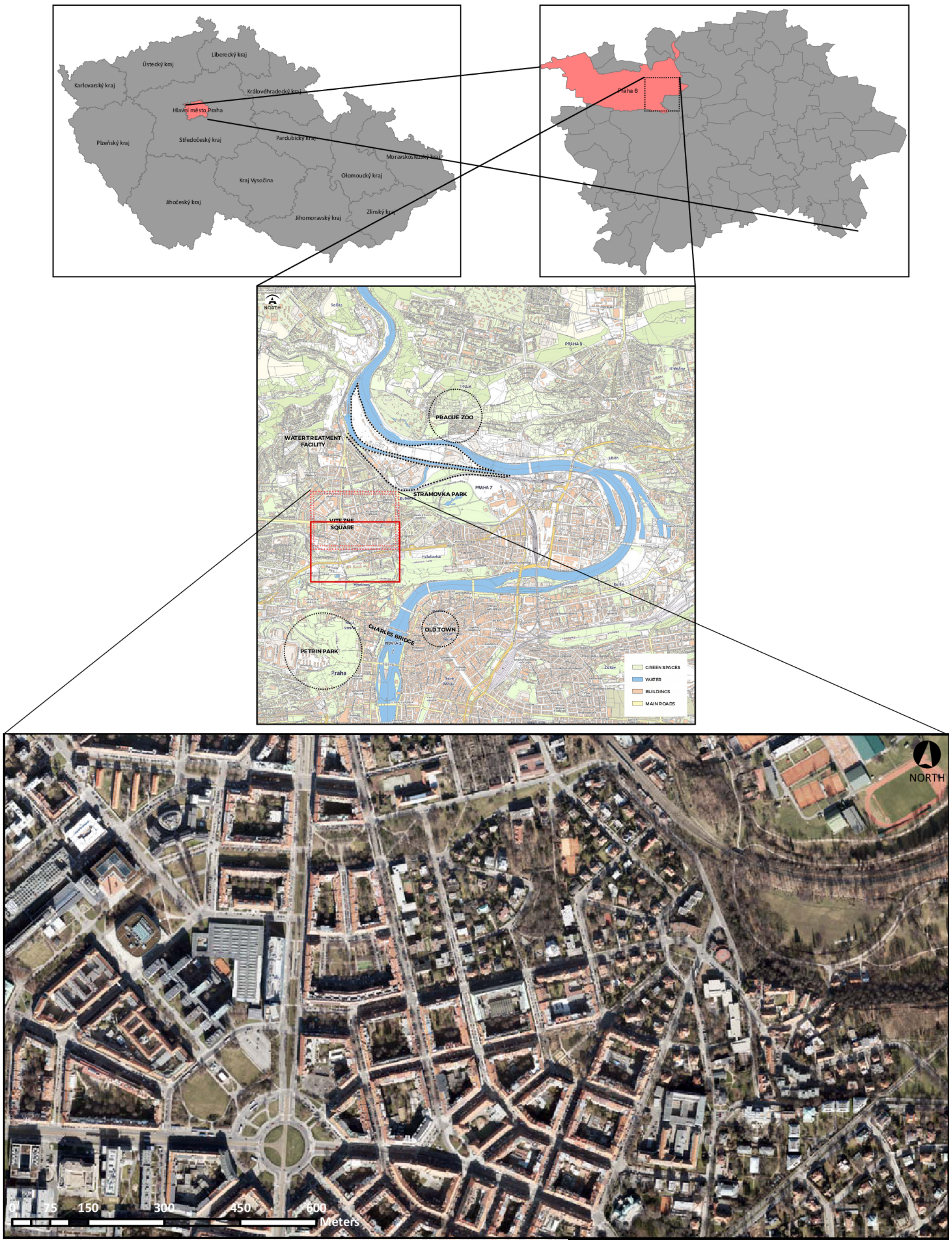

Figure 4.17: Location of Prague in the Czech Republic and the implemented site (IPR Praha, 2021)

4.3.1 Analysis methods for site

The present study compares the mentioned case of studies with the site of implementation in Prague, where the undeveloped open spaces and further connection of green-blue infrastructures will base the evaluation of this thesis. The methodology and sequence of the analysis in this thesis, such as questionnaire implemented by the author of this thesis, processing the questionnaire and weighing them via the ANP method, finding the best location to establish GBIs, and scrutinizing various layers which may affect the territory of study are demonstrated in the chapters that will follow up after this section; Moreover, the methodology part's backbone is scrutinizing all data sources and technical details of the cases of interest.

A significant part of the research is made via using the geographic information system (GIS). The software in use for data processing is Super Decision and ArcGIS Version 10.8.1.

The Geoportal's geographic data is managed by the Prague city hall and Prague Institute of Planning and Development (IPR Praha) (Table 4.3.1) (Geoportal, 2022).

The coordinate reference system (CRS) used in the datasets is EPSG:5514 - S-JTSK / Krovak East North.

The author has used the same CRS in the course of the whole research section.

Type of data	Last update	Indicate	Description
Polygon shapefile	28.05.2021	Various Landuse of Prague	Current state of land use
Polygon shapefile	02/07/2019	Flood Plain and protection line	Categorization of flood-plains - Vltava, Berounka (category - active zone, flow, non-flow, protected by the city, protected individually), Object (equipment) for flood protection of the Vtava and Berounka floodplains
Polygon shapefile	07/01/2021	Price map	Price map Hl. m. Prague - areas
Polyline shapefile	06/24/2019	Cycling map	plan for the development of bicycle traffic in Prague - main and backbone routes
Polygon shapefile	02/12/2019	Noise map	Computational noise map of surface transport. Overall acoustic situation. Time of day (06: 00-22: 00) Noise bands of 5dB at a height of 4 m. Status in 2016. Prepared by EKOLA group, spol, sro 2017 for IPR Prague.
Polyline shapefile	02/06/2019	Contour line	The contour lines are generated from the Digital Terrain Model 2018. The contour plan corresponds to the content and accuracy of the 1: 5000 map level. Accuracy approx. 1 m.
GeoTIFF raster	07.12.2021	Orthophoto map of Prague- Case study	Color non-vegetation orthophotomap of Prague. Resolution is 5 cm / px Shooting date: 6.3.2021, 7.3.2021 and 25.3.2021

Table 4.3.1: GIS datasets used in the research

Apart from the GIS datasets developed by IPR Praha, anaother main part shape the methodology section for a great conclusion comprising SWOT table of analysis. More details on the data as mentioned above and how the data have been used for further methodology analysis are presented in the following chapters.

4.3.2 Evaluation of GBI and case studies of various land uses

Prague's green infrastructures have been assessed thoroughly by the city and local authorities on each scale. The authority in charge of classifying various green infrastructures is the landscape institute (2009) which assessed all the mentioned sections as demonstrated below (Table 4.3.2). Furthermore, it should be mentioned that a thorough definition known by green-blue infrastructure is demonstrated by Bartesaghi Koc et al., (2017) (Fig. 4.17), where they mention that the bigger the scale, the more challenging to maximize the level of detail for each and every element participate in the design approach.

The classification of various land use elements used in the GIS dataset has laid a foundation to determine categories of GBI, whereby the further analysis goes under four primary categories, sub-branched by 25 types of land use. Based on the GIS datasets and what is used in this research thesis, there is a thorough classification of GBI elements translated from the attribute table of the GIS land use and demonstrated in (Table 4.3.3).

City region, Regional and national scale	Town, City, District scale	Local, Neighbourhood, Village scale
● Regional parks ● Rivers and flood-plains ● Shorelines ● Strategic and long distance trails ● Forests, woodlands and community forests ● Reservoirs ● Road and railway networks ● Designated green-belt and strategic gaps ● Agricultural land ● National parks ● National, regional or local landscape designations ● Canals ● Common lands ● Open countryside	● Business settings ● City/district parks ● Urban canals ● Urban commons ● Forest parks ● Country parks ● Continuous wa-terfronts ● Municipal plazas ● Lakes ● Major recreation-al spaces ● Rivers and flood-plains ● Brownfield land ● Community woodlands ● (Former) mineral extraction sites ● Agricultural land ● Landfills	● Street trees, verges and hedges ● Green roofs and walls ● Pocket parks ● Private gardens ● Urban plazas ● Town and village greens and commons ● Local rights of way ● Pedestrian and cycle routes ● Cemeteries, burial grounds and churchyards ● Institutional open spaces ● Ponds and streams ● Small woodlands ● Play areas ● Local nature reserves ● School grounds ● Sports pitches ● Swales, ditches ● Allotments ● Vacant and derelict land

Table 4.3.2: Typical green infrastructure assets and their associated scales (Landscape Institute, 2009)

Green-Blue infrastructure category	Land use codes	English translation	
Forest parks	LRO - lesy LRR - lesoparky	Forests Forest parks	Urban Greenery
Urban fringes	ND - doprovodná vegetace NM - mokřadní porosty bez dřevin NNK - nelesní porosty dřevin nezapojené s keři NNO - nelesní porosty dřevin nezapojené se stromy a keři NNS - nelesní porosty dřevin nezapojené se stromy NZK - nelesní porosty dřevin zapojené s keři NZO - nelesní porosty dřevin zapojené se stromy a keři NZS - nelesní porosty dřevin zapojené se stromy	Road verges and various boscages and thickets encompassing different types of greenery such as small trees, shrubs, and wetland vegetation.	
Recreational spaces	RAG - golfová hřiště RAP - rekreační areály přírodní RAZ - rekreační a zahrádkové osady RPH - hřbitovy RPP - parky RPU - parkově upravené plochy RV - rekreační areály vzdělávací (ZOO, botanické zahrady)	Golf courts Natural recreation areas Recreational and allotment gardens Graveyards Parks Parklike spaces Educational recreation areas (ZOO, botanical gardens)	
Gardens and grasslands	ZA - zahradnictví ZHB - zahrady rodinných domů ZHV - zahrady a hřiště občanské vybavenosti ZL - louky, pastviny, travnatá lada ZSO - sady opuštěné ZSP - sady produkční ZSV - vinice ZSZ - zahrady	Gardening areas Family houses' backyards Playgrounds and gardens as public facilities Meadows, grasslands, grazing lands Disused gardens Yielding gardens Vineyards Garden yards	
Pedestrian zones	VC - cesty VPP - pěší prostranství VPN - pěšiny	Paths Walkways Plazas	Other GBI elements
Brownfields and transformation areas	XD - devastovaná území, deponie bez staveb, deponie XP - plochy bez využití - proluky XZ - nevyužívané plochy s nálety dřev	Disused or devastated territories without constructions including landfills and different forms of vacant lots.	
Agricultural lands	PLP - pole produkční PLU - pole - úhor	Arable lands Fallow lands	
Water bodies	HY - vodní toky a plochy	Water streams and objects	

Table 4.3.3: Typical green infrastructure assets and their associated scales (Landscape Institute, 2009), and (Pachapski, 2021)

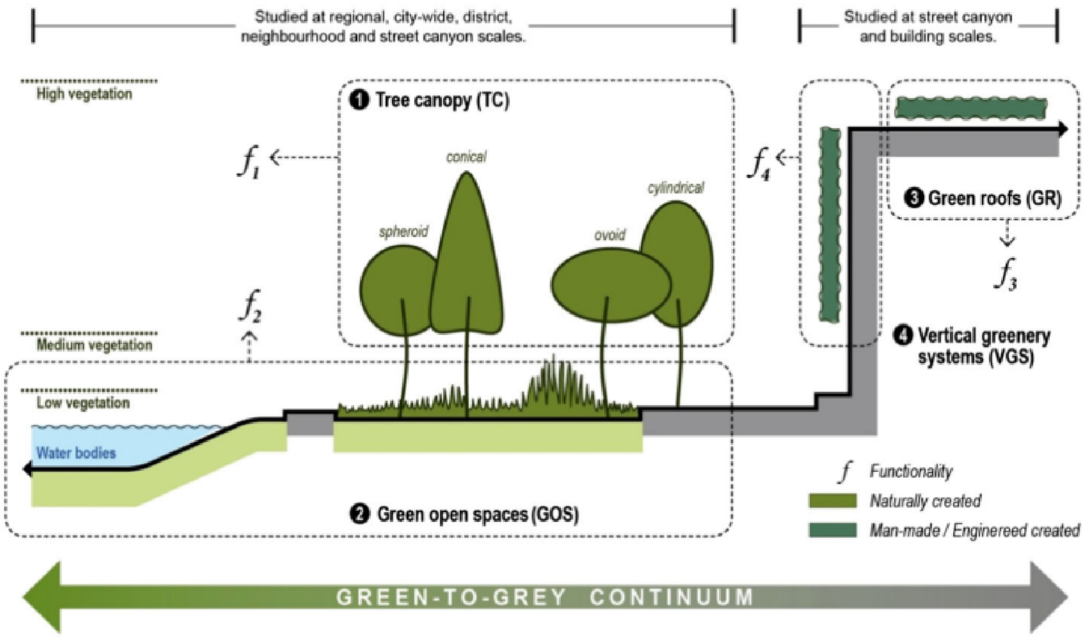

Figure 4.18: Concept of green infrastructure spectrum (Bartesaghi Koc et al., 2017; Pachapski, 2021)

Concerning Prague green spaces, the author identifies all the undeveloped open spaces in the case study as public lands allocated to the municipality of Prague. Besides the public spaces that exist in the case of interest for further scrutinization, other ecosystem services in this specific part are fascinating to address. One parameter that also increases the fragmentation of interconnectivity from CTU university to Stromovka park, a vast city park and a type of GBI, is non-useful green coverage in this axis, which is shown in (Fig. 4. 19), and (Fig. 4. 20).

Figure 4.19: Map of case of interest, Prague, Vitezne Namesti (Geoportal, 2022)

Figure 4.20: Photos from the case of interest's axis, marked by number on Fig 4.19

Figure 4.20: Photos from the case of interest's axis, marked by alphabetic order on Fig 4.19, and Fig 4.21

Based on the observation of this territory, sparse vegetation, low coverage of canopy, and lack of blue infrastructure coverage (Fig. 4. 21), are various parameters that reduce the ability of this place in order to respond to ecosystem service where it should be responsive to provisioning, regulating, and supporting.

Furthermore, one issue of IPR data classification is the connection of the majority of pedestrians and sidewalks with parks and urban forests.

Another parameter that needs to take into account in this place is the topography which demonstrates no hardshipti access the green infrastructures of this territory. In contrast to easy reach to this place, most of the cycling line coverage in this area passes through streets, where they are not exceeding more than a 5% slope ratio.

Although the landscape of Prague mainly consists of steep slopes, this particular region is almost flat in most parts, and the users either by foot or bicycle do not see any trouble to pass.

Following the analysis of the case location, there are also some photos (Fig. 4. 20) taken by the author to demonstrate the quality of spaces in the study territory, also a holistic perspective of the exact ecosystem services that can be provided in order to respond to GBIs in one specific location (Table 4.3.4).

The other sections that will scrutinize through other chapters of the methodology comprise non-motorized vehicle transportation, price map of the study location, noise map, flood plain threats, and how to mitigate it.

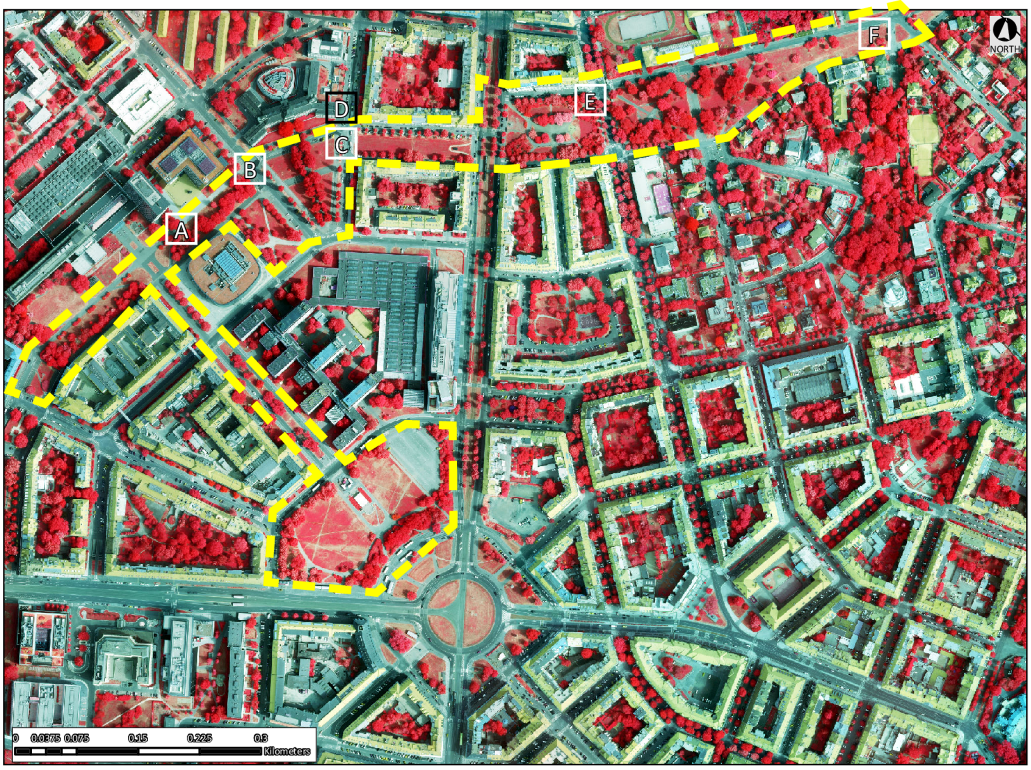

Figure 4.21: Tree canopy and coverage in the site of study (Geoportal, 2021)

Group	Ecosystem service
Provisioning services	Food supply
	Water supply
Regulating services	Urban temperature regulation
	Noise reduction
	Air purification
	Moderation of climate extremes
	Runoff mitigation
	Waste treatment
	Pollination
	Global climate regulation
Cultural services	Recreation
	Aesthetic benefits
	Cognitive development
	Social cohesion
Habitat services	Habitat for biodiversity

Table 4.3.4: Ecosystem services classification(Gómez-Baggethun et al., 2013)

4.3.3 Non-motorized vehicle transportation implementation in GBIs

The bikeway system of Prague is a fractured form of lane designated all over the city, meaning that Some of the bike infrastructures are designated lanes separate from the roadway, and in other locations, it is a marked or striped area of about 1 meter in width, and in other locations, there is no designation at all. Moreover, the majority of these bike lanes suffer the lack of proper infrastructure in order to provide safety or even companionship with GBIs.

Based on the sparse nature of cycling routes from motorways, the classification of bikeways goes under two groups:

(a) in-roadway cycle lane and (b) non-motorized vehicle transportation.

This diversification within each mentioned group also comprises three various levels as the first group is as below:

- Joined cycle routes which are alongside the roadway with the motorized vehicle with no physical infrastructure. The matter of safety in this specific case for cycling is very detrimental.
- The physical presence of bike lanes is marked via paint on the asphalt to demonstrate the cycling lanes on the study site. The matter of safety is still very detrimental.
- Lanes without traffic in places where the traffic is calm and quiet in non-urban areas or vehicle restricted zones.

The non-motorized vehicle transportation lane is also comprised of three various categories with the levels of separation:

- Mixed-use lanes dedicated to non-motorized transport mean no evidence of separation.
- Bike lanes often follow alongside the other mixed-used roads.
- No cycling zone in places where due to the narrowness of sidewalks, the cyclists should have dismounted the bicycle for some designated distance.

The case of interest in our specific allocated site is under the heavy influence of the non-existence of non-motorized vehicle transportation. Another solution will present by the author in the following part of this master's thesis, here the companionship of the non-motorized vehicle transportations demonstrate at its most exemplary level with green-blue infrastructure.

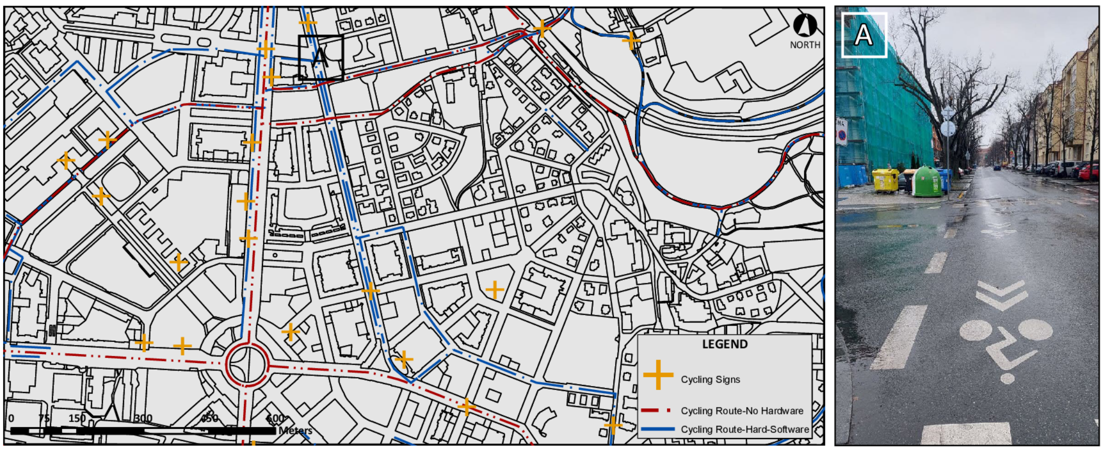

Figure 4.22: Cycling map of case study (Geoportal, 2022)

As it can be seen in Figure 4. 22, the majority of this territory is suffering from the lack of proper missing hardware or software properties for the cycling lanes.

Furthermore, the presence of a vast majority of undeveloped open spaces in the case study area provides a great opportunity in order to define new bikeway corridors in companionship with green-blue infrastructure while it has proper design and safety for all users.

The elements mentioned above of the infrastructure can be classified into the following levels of traffic safety and the overall stress that affects the rider: minimal traffic stress, acceptable traffic stress, alleviated traffic stress due to measures (e.g., cycle lane). Disadvantages such as poor surface, stairs, the need to use the sidewalk can be included in the group, causing stress-reducing driving comfort.

The city of Prague is gradually developing infrastructure for bicycle transport. It is a not very easy process, in which the fact that in larger cities, which are historically congested, the demand for transport and its implementation must be managed.

There are several other reasons for the difficulty in developing a fully integrated bike network like topography, narrow streets, trams, travel lanes, street parking.

Most journeys in smaller parts of city can be done on foot or bicycle, and there is no need for transport systems such as trams. The connection of Smíchov, Vinohrady, Karlín, and other parts to the capital was greatly supported to a broader extent. At some points, it is ubiquitous to travel further within the city to urban fringes, and with the availability of individual car transport, this important will take place; however, it has many consequences like traffic and what comes afterward. That is why it is necessary to regulate car traffic in the city, to promote alternatives, and to look for quite demanding solutions to problems in moments when the network is flooded with car traffic itself. Successes in improving cycling, pedestrian, or public transport infrastructure are always very challenging, as it is an unpopular search for ways to solve the problems that every major city finds itself in.

There is still very considerable potential for the future, which is difficult to fulfill and complex, and infrastructure for safer travel is slowly emerging. The Prague Monument Reserve still suffers from a high amount of unnecessary car traffic due to major roadway access points inside and outside of Prague, the diversion or regulation of which will mean a jump in area benefits for other modes of transport.

Like the development of bicycle transport and pedestrian and public transport, the key is to grow the efficient use of public space, especially the proper management of transport in peace within it. This vital task can only be established via GBIs implementation, where it connects enormous greenery in the study area location and enhances landscape connectivity via this continuous connection.

4.3.4 Affordability and noise map connection to the built environment

The introduction examines the historical transformation of the urban landscape from gradual growth, fortification, construction of new neighborhoods to modernist cities and their further (un) controlled expansion.

The experience from other countries inspires and offers to well organize suburbanization through the so-called green belt system or green ribbon.

The topic explains the perception of the whole city as a landscape and refers to the issue of the interface, i.e., the interface between the urban and open landscape by an imaginary separative line. Precisely because the city is perceived as a part of the landscape, it is impossible to solve it within its administrative boundaries and in the context of the surrounding region.

New housing construction and population migration are changing the socio-spatial structure of Prague. In some parts of the city, the population has been declining or stagnating for a long time (e.g., the city center, some housing estates), while other parts are highly incremental (peripheral districts, where there is significant residential construction). The result is an imbalance between the city's population development and civic amenities. Gentrification is a process of gradual physical revitalization and social change in selected areas of the inner city. It is a long-term process that has ambivalent effects on companies (IPR Praha, 2021). On the one hand, it is about increasing the quality of the housing stock and public spaces and increasing the social status of the locality by increasing the quality of public spaces with a change-over to GBIs, and recreational acitivities.

On the other hand, the rising rents forced existing residents' departures from city to urban fringes in order to buy a house and not live in a flat; the phenomenon is called suburbanization. Suburbanization is the process of transferring population development and activities to the urban background at the city's expense. Residential suburbanization in Prague has been going on for a long time and is reflected primarily in the growth of the number of family houses built outside the city limits. Suburbanization has several negative consequences, such as increased mobility and poorer civic infrastructure.

According to IPR Prague demographic forecast from 2019, the population should grow in virtually all parts of Prague. Obviously, the number of inhabitants will be determined on the one hand by the age structure of the locality and on the other hand by the expected new residential construction and (associated with it) immigration (especially of foreigners).

In the following years, cities can expect the highest relative population growth, especially in the peripheral parts of Prague, which are relatively small in population, and further residential construction can be expected (e.g., Prague-Kolovraty district, Prague-Dolní Měcholupy). In recent years, apartment buildings have been built and sites with great potential for new construction. These are mainly the districts of Prague 22, Prague 9, Prague 7, Prague-Zličín, Prague-Štěrboholy. On the other hand, the population decline could occur mainly in the city center because it is dominated by tourists and not considered as an alive place for families to live (Prague 1 district).

This is why GBIs establishment in various parts of the city will help the other future problems. As so, it does not only cause the ecosystem services to work in the best way but also by considering non-motorized vehicle transportation as means of transportation for those ones who have already migrated to urban fringes or may move there in the future due to lower residential prices, the assurance of a future easy, economical, ecosystem friendly, and safe way to the daily commute is already provided by the establishment of GBIs with the potential of non-motorized vehicle transportation system within in.

There is a social change, which turns a locality of relatively lower social status into a place where high-income residents live. Gentrification usually begins inconspicuously by moving young, more educated, but at the same time low-income people (mostly artists) to a neglected neighborhood, where rents are relatively low and attractive (authentic) character.

As a general overview, new residents are gradually improving the location, as they become more attractive. As a result, rents are starting to rise, and some people leave the area involuntarily. Ultimately, even those who started the site's restoration cannot pay rent. Gentrification is, therefore, an ambivalent process. Under the communist regime, investments in Prague went primarily to the construction of new houses in prefabricated housing estates, and far fewer investments went to the renewal of the housing stock in the more expansive city center. As a result, even prestigious districts such as Vinohrady and the city center were physically neglected, and the social status of the then inhabitants was relatively low. However, after 1989, the city center has become dominated by tourism and related activities and many people from Prague choose to not live there, in often avoid it entirely.

Localities such as Žižkov, Smíchov, Vršovice, Holešovice and Karlín were even worse. Gradual revitalization of the housing stock, which began in the 1990s (and continues more and more intensively), leads to a partial population change. These localities have become very popular and sought after, especially for residents of young, relatively wealthy people and foreigners (IPR Praha, 2021). These are mainly foreigners from Western Europe, North America, and Russia. In these neighborhoods, a higher number of flats purchased by the elderly or foreigners is evident, for whom that can assumed that they are buying real estate as an investment. Suburbanization is a process where the background of a city (both in terms of population and trade) is growing faster than the city itself; the primary source of growth is usually the immigration of residents and commercial activities from the city to the hinterland. However, people who move to family houses do not leave the city entirely but continue to come here for work, entertainment, and services. The leading causes of suburbanization are mainly the desire of the inhabitants for their own family house outside the busy city, the development of car traffic to commute, high prices of land and real estate in the city, or the efforts of some municipalities in the city to increase the population.

Suburbanization has many negative consequences for society and the city. Above all, the traffic load is growing, with people being dependent on using their cars (it is not adequate to introduce public transport in sparsely populated areas). Suburbanization also brings the occupation of valuable arable land and higher costs of building public facilities. The process of suburbanization has been taking place in Prague for a long time since the fall of the communist regime, especially in municipalities outside the administrative borders of the city.

Suburbanization also takes place to a lesser extent within the administrative borders of Prague. Peripheral urban areas clearly have the highest population growth. The construction of apartment buildings in the city hinterland is usually not considered suburbanization, it is a continuation of the city's development.

As it can be seen in the below figure, the development of offer prices of new and older flats in Prague is surged up year by year, and consequently, it will turn the capital of the Czech Republic into a non-affordable city, also hard to cause any changes upon turnover to GBIs (Figure 4.23)

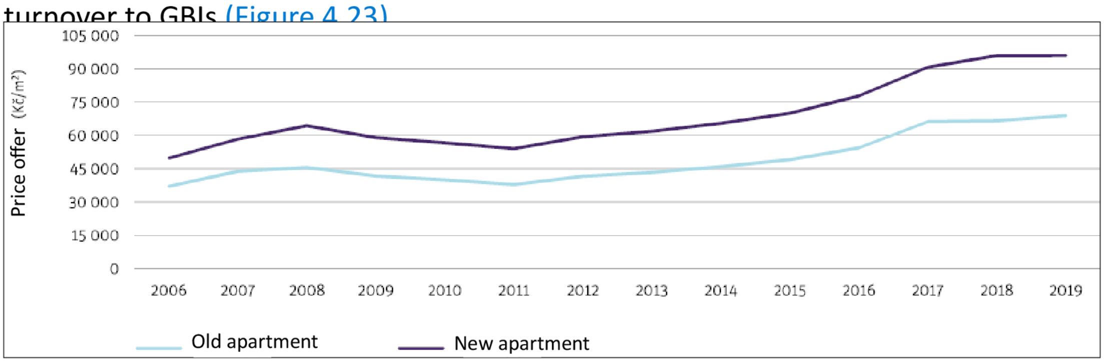

Figure 4.23: Development of offer prices of new and older flats in Prague (IPR Praha, 2020)

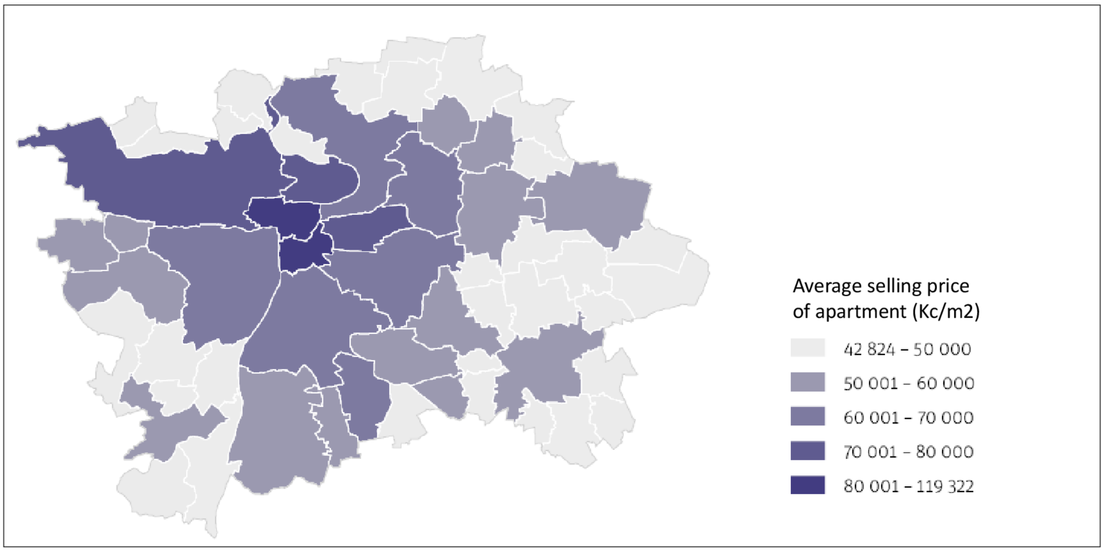

Figure 4.24: Average sales prices of older flats in the period from the 2nd half of 2016 to the 1st half of 2018 (IPR Praha, 2020)

As it can be seen in Figure 4.24, the development of offer prices of new and older flats in Prague is surged up year by year, and consequently, it will turn the capital of the Czech Republic into a non-affordable city, also hard to cause any changes upon turnover to GBIs.

Another parameter for establishing a thorough green-blue infrastructure is to comprehend how this territory will reduce the adjacent noise pollution. Tree canopies and the presence of greenery have the capability to diminish the built noise of various means inside a city territory. Therefore, as it can be seen in the following Figure 4.25, the presence of the green spaces within the borders of streets concludes to a huge diminish of noise, to a broader extent, all these Ecos just stopped on the first layer of green spaces. In other words, the only colossal noise which is still tolerable for the human being presents itself inside the streets, and it starts to fade away on the second or third level streets and alleys.

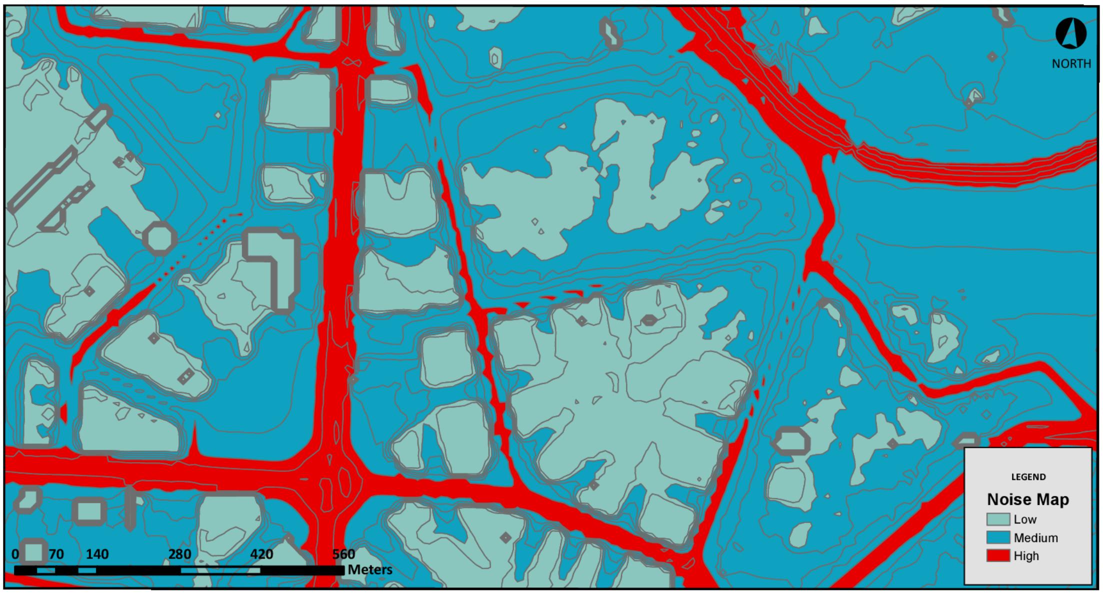

Figure 4.25: Noise map of case of interest (Geoportal, 2019)

There are also some other analyses that should be implemented in this territory to strengthen the foundation of the thesis by illuminating the case of interest related to a broader extent of Prague. These analyses are comprised of porosity, proximity, diversity, permeability, interface, accessibility, and effectiveness. These methods are executed via the integrated modification method (IMM) to investigate the potential of the urban system within the UN's sustainable goal developments (SDG) through a series of analyses for a resilient environment for better systemic performance. All the data mentioned above is demonstrated in Appendix 1 of the present work.

To distill all the mentioned sections into a specific conclusion, two other items can be helped the author to maintain the focus of the thesis to it. SWOT table, which identifies various parameters in the study territory and a questionnaire asked within a group of people.

4.3.5 Questionnaire, Standard deviation

After analyzing the first part of the methodology based on research through the case studies, identifying the documents and previous scholars' work, and scrutinizing the proposed site, it is time to extract data concerning each standard deviation of the implemented case study by using the Analytic network process (t) and Super decision software to identify various people perspective. Also, a questionnaire was provided and handed over to a group of

57 different people (Table 4.3.5), and (Appendix 4) in different groups and ages to modify the answers based on a numerical system to implement this method. The date of execution of this questionnaire was from November to the end of December 2021, based on Google survey forms. The questions that asked are as below:

- Do urban development and built-in environment considered a threat to urban spatial planning?
- Will the following mass construction in undeveloped open spaces endanger the city's formation to a non-eco-friendly atmosphere?
- Do you think that this area has the capability to change thoroughly to a non-motorized open landscape?
- Are there any chances of intervention for the study site to change the spatial formation?
- Are there any chances to alter these vast non-usable green spaces to one eco-user friendly?
- Do you prefer to see non-motorized vehicles in this newly implemented area?
- What are the chances you occasionally travel within this newly implemented green area?
- Do you think this green-blue corridor can simultaneously help the environment and people?

The answers to the following questions were respectively divided from numbers between 0 to 0.1, which will give a chance to give standard deviation to them by using ***Super Decision*** software. In order to get the best quality of standard deviations out of it based on interviewees' ideas, quantitative parameters were defined, as explained before (Table 4.3.6).

Category		No. of Respondents	Percentage
Total		57	100
Sex	Male	35	61.4
	Female	22	38.6
Age	20s	13	22.8
	30s	17	29.8
	40s	19	33.3
	50s	8	14.0
Organization	Government	11	19.3
	Academia	13	22.8
	Private Sector	33	57.9
Subject	Environment	11	19.3
	Architecture	1	1.8
	Landscape	38	66.7
	Forestry	3	5.3
	Policy	2	3.5
	Other	2	3.5
Experience	Under 5 years	18	31.6
	6–10 years	10	17.5
	11–15 years	10	17.5
	16–20 years	6	10.5
	More than 21 years	13	22.8

Table 4.3.5: Population of interest who participated in Questionnaire completion

Criteria	Weight
Continuity	0.169
Readability	0.204
Visual index	0.121
Cityscape Elements	0.135
Aesthetical Qualitative Elements	0.104
Natural Landscape	0.123
Continuity of Facades	0.130

Table 4.3.6: Standard deviation based on interviewees perspective on the defined corridor (The inco-sistancy index is 0.0943. It is desirable to have a value of less than 0.1)

After having the standard deviation based on interviewees' perspectives, the other quantitative-based on observation of study site bt author gives a specific deviation. To complete this ranking table, all the criteria for each sequence got standard and normalized. Thus, based on what has been achieved during the physical site assessment, each criterion quantity is calculated and divided by the number of criteria in relation to the sequence length. Therefore, the standard deviation for each criterion has been resulted based on the specific sequence. The table below demonstrates the description mentioned above (Table 4.3.7).

Visual index	Corridor A	Corridor C	Corridor E	Corridor G
	0.054	0.08	0.084	0.037
Continuity	Corridor A	Corridor C	Corridor E	Corridor G
	0.111	0.129	0.117	0.122
Continuity of Facades	Corridor A	Corridor C	Corridor E	Corridor G
	0.076	0.1	0.056	0.11
Natural Landscape	Corridor A	Corridor C	Corridor E	Corridor G
	0.419	0.216	0.28	0.495
Aesthetical Qualitative Elements	Corridor A	Corridor C	Corridor E	Corridor G
	0.011	0.009	0.01	0.005
Cityscape Elements	Corridor A	Corridor C	Corridor E	Corridor G
	0.661	0.38	0.183	0.151
Readability	Corridor A	Corridor C	Corridor E	Corridor G
	0.835	0.912	0.933	0.672
Final Value	1.33	0.914	0.73	0.92

Table 4.3.7: Final value of quality creteria in the casea study sequence. It is desirable to have a value of less than 0.1 for each parameter

According to previous studies, the connectivity of cities in case of fragmentation events has two main qualities: First intrinsic quality, which includes operational activities such as daily basis routines of commutation under normal circumstances.

Furthermore, by getting a thorough conclusion out of the previous research components as questionnaire, finding the weight and standard deviation, and marking them by ANP method, SWOT analyses, and physical site assessment, consequently, it reveals that the main corridor of interest for interviewees or random users is the one that continuously goes through the pre-exist green spaces where it starts from the near side of the faculty of architecture of CVUT University and follows by a straight route to Stromovka park which gives a huge benefit to increase the connectivity either by foot or for non-motorized vehicle transportation (Figure 4.26).

Significantly, the results which concluded from the previous methods either completed by the author or gathered from interviewees demonstrate that almost all willingness would rather have a connection with greenery and what needs to integrate into this territory, better be accompanied by what already exists in order for preserving or updating it to a better fixture to enhance functions concerning Green-Blue infrastructure. The result of each part and previous methods are implemented in the next section. To a broader extent, the numbers gained via the ANP method and using Super Decision software filtered by ArcGIS software and with kriging technique in Spatial analysis method in the same software exports a spatial-location output which demonstrates it.

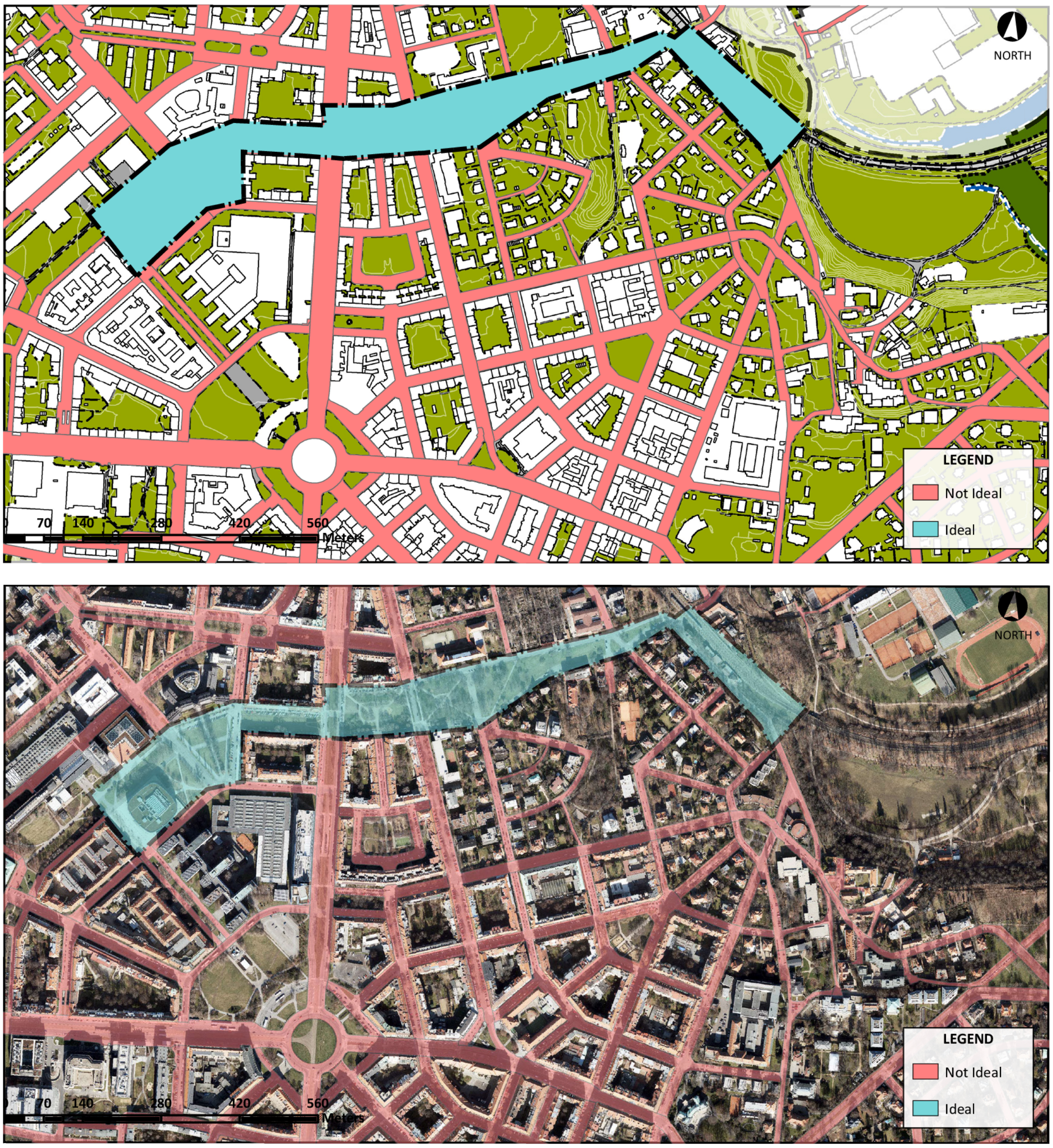

Figure 4.26: Ideal location to implement Green-Blue infrastructure based on distilled analysis and weights of standard deviation

5. Results

Prague city covers approximately 496 square kilometers, contains nearly one million people, and has grown substantially in land area and population over the last 30 years (Lecouteur, 2002). Woodland, meadow, pasture, and cropland have been and continue to be replaced by urban development. Despite significant losses of natural habitat due to development, the Prague area is still rich in natural areas and parkland. The extent of natural areas varies significantly across the urban gradient from exurbs to center city. In a territory like Prague 6, vestiges of natural vegetation remain primarily along the stream corridors, and larger habitat patches are primarily found in public parks such as Stromovka park. The following sections summarize findings from the five-part Prague 6, the case of interest study.

5.1 Corridor mapping and analysis

The modeling suggests that habitats are fragmented in Prague, but green-blue corridors could be developed primarily using vacant land, the city's extensive alley system, and existing public green space to connect existing city parks and facilitate connectivity.

The Least-cost path analysis resulted in 20 potential corridors (see Appendix 1 or Fig. 4.26) running primarily through vacant parcels, alleyways, and existing small green spaces. Given the city's limited resources, only a subset of these would really be developed. The method that had been used to select the corridors that would enhance landscape connectivity most efficiently is Kriging, Spatial analysis method. Of the 20 corridors, only 4 met the minimum threshold for the kriging model.

The highest scoring corridor would connect patch 1 - Studentska to Antonina Cermaka with patch 2 - Stromovka Park (Fig. 5.1). Besides the commonly used indices above, it has been examined how adding the corridors would impact structural and functional connectivity.

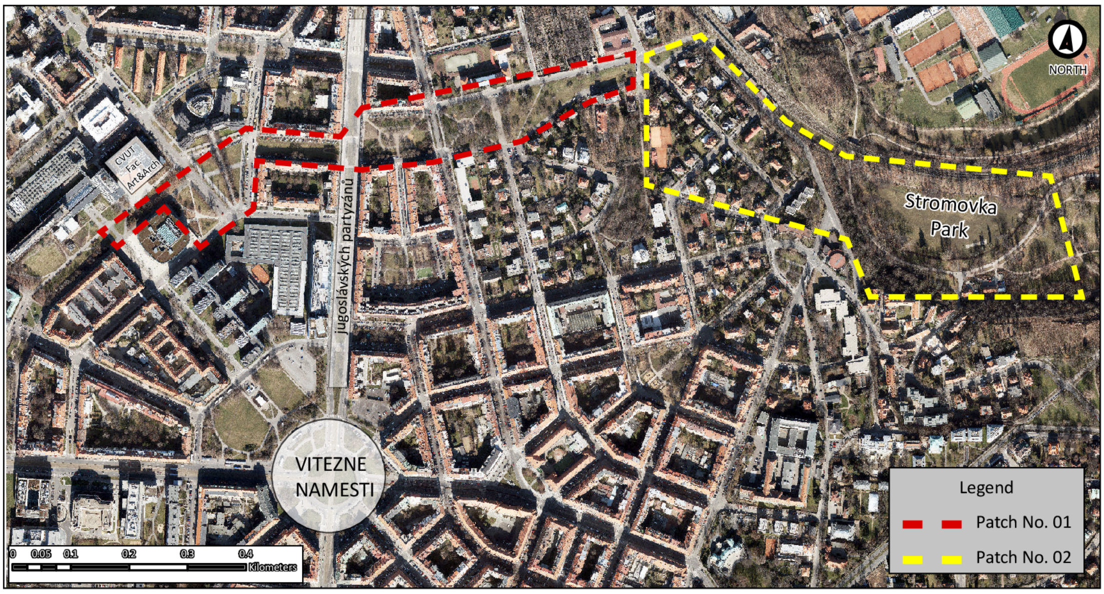

Figure 5.1: Patch No.01, and Patch No.02

Therefore, by finding the main axis which identified as the best one in order to implement the green-blue infrastructure in the case of interest by the numbers achieved via metric calculations in the mentioned softwares, it is the moment to identify them based on a SWOT table.

The distilled description of previous data and information (site assessment) is concise in a SWOT table (Table 5.1.1) which illuminates the scope of this methodology more clearly by using the standard deviation and krigin method in ArcGIS to identify which corridors are the best to implement GBIs in the study site.

SWOT Table

Opportunity	Threat
- Presence of the Vltava river - Possibility to introduce Blue infrastructure to control water surface run-off - Underdeveloped sites and lands - Renovation - Presence of a major city park (Stromovka) - Presence of pre-exist parks (Green infra-structure)	- Passing by traffic - Air pollution - The high percentage of elderly people - High allocation of vacant land to residential func-tions - Changeover of various functions to residential buildings
Strength	**Weakness**
- Picturesque scenes - Parallel skyline of buildings - Greenery existence - Presence of educational function buildings - Music festivals - Weekend farmer market - Short story buildings - Continuous pavements - Lack of city's highway	- Lack of economical accommodation - The intervention of motorized vehicle mobility VS Human - Streets full of parked vehicles - Lack of continuous Bazar or commercial - Lack of anchor or node spaces - Lack of readability - No central core for tourism excursion

Table 5.1.1: Demographic characteristic of the interviewees&
SWOT table implemented by physical site assessment

There was no difference in the ranking of Tier 1 criteria between male and female respondents (Table 4.3.5). However, more female respondents stressed the importance of ecological aspects compared to male respondents. All age groups indicated that ecological aspects were the most crucial consideration for GBI; however, respondents in their 20s and 30s also recognized the importance of landscape and usability aspects. In comparison, older respondents favored ecological aspects more heavily. Respondents from academia and the private sector found that ecological aspects were the most critical Patch 1 criteria, while government respondents also stressed the significance of economic factors. This reflects the importance of cost and ongoing maintenance to government respondents, who are generally responsible for the ongoing management and maintenance of GBI. Differences were also apparent based on the professional backgrounds of the respondents. For example, experts in the field of landscaping stressed the importance of both landscape and ecological aspects, while experts in environmental and other fields favored usability aspects. Notably, respondents with more experience stressed the importance of ecological aspects.

Respondents with fewer than five years of experience considered all factors equally, while those with 6–10 years of experience felt that usability was the most crucial consideration.

5.2 Landscape characterization

In the landscape characterization portion of this study, Prague's physical, biological, and social characteristics and features were mapped. This inventory provided all of the study participants, including the users, information on critical conditions affecting biodiversity and helped identify and quantify the remaining natural habitat in the watershed.

Terrestrial habitats are found primarily in parklands, open space lands, golf courses, cemeteries, vacant parcels, and low-density residential areas. In terms of wildlife, conditions in this territory are generally favorable for generalists or adaptable species. Specialists or less adaptable species are uncommon, while those that can successfully inhabit human-dominated environments tend to fare better. Forest trend information indicates a 32% decrease in forest resources in Prague from 1957 to 1992 (IPR Praha, 2011). Remnant natural woodlands are dominated by oak and hickory species. Few detailed surveys of vegetation have been conducted in this area. A 2001 survey (Simmons et al., 2001) of Prague identified 78 native species of plants and 19 exotic species, most of which were highly invasive.

Based on field reconnaissance and review of applicable site surveys, it is clear that invasive species dominate the herbaceous flora of mostly water catchment. There are no official ecological green-blue ways in the case of interest, but recreational trails are numerous. These trails are strictly motorized paths. An opportunity exists to expand this conception of green-blue way to include natural areas protection.

Biodiversity enhancement programs could be established through community involvement in the planning and design of the green-blue way(s). The basic structure of ecological greenways already exists in the watershed in the form of undeveloped riparian corridors, much of which is already in public ownership.

5.3 Land cover analyses

This analysis revealed that the case of interest, which is Prague 6, is still primarily residential (67%). Impervious surface coverage ranges from 23 to 41% across the watershed of Vltava river. Parks and open space comprise 11% of the land area, forested land cover is 30%, and vacant land is 5%. According to this analysis, eighty-five percent of the land in Prague 6 is developed.

The remaining 15% is either parkland (10%) or vacant (5%). The forest land cover co-occurs with various land uses, primarily residential. Together with the existing parks and the resource protection areas in the stream valleys, forested patches represent the potential for biodiversity conservation and enhancement.

An analysis of potential interior forest habitat, using Landscape Analyst with ArcView 3.2, reveals patches outside the riparian zone that hold promise for conservation. According to land trust representatives working in the area, small parcels, even as little as 800 sqm2 in size, make valuable contributions to landscape protection efforts, especially if they can be connected to the land that is already protected.

Undeveloped upland habitat is particularly in short supply. Even a tiny portion of these interior habitat patches could be a valuable addition to an ecological greenway. This analysis indicates an over 30% increase in the amount of developed land uses in Prague 6 over the 18 years, with a corresponding population growth of nearly 40%. An interesting phenomenon is that forest cover in residential areas appears to be increasing as the trees have matured in the now-aging inner-ring suburbs.

5.4 Environmental quality corridors

Prague defines "open space" as parks, conservation areas, private open space, and vacant land. In the city, open space has declined by more than 30% from 1975 to 1995. In recognition of the fragmentation of remaining ecologically significant land, the continued loss of open space, and the corresponding loss of environmental resources, Prague has made a commitment to identify, protect and enhance an integrated network of ecologically valuable land and surface waters.

This involves adding land to the Environmental Quality Corridor (EQC) system, the core of which is the city's stream valleys. Lands achieving the following purposes that may be included within the system are those that: (1) have a desirable or scarce habitat type or host species of interest; (2) provide connectivity for the movement of wildlife; (3) different land uses, providing passive recreational opportunities; (4) induce significant reductions to nonpoint source water pollution; and/or (5) affect microclimate control, and/or reductions in noise. Corridors shall be selected to augment the habitats and buffers provided by the stream valleys and add figurative elements of the landscapes not represented within the corridors (IPR Praha, 2000).

5.5 Greenway initiatives

If urban ecological greenways are to conserve and restore urban biodiversity, they cannot be designed in a piecemeal fashion. At least to some extent, understanding the entire metropolitan area is essential for building a comprehensive conservation program.

These policies and programs have enormous potential to contribute to forming an ecological greenway network for the entire Prague area. The National Capital of the Czech Republic, Prague, has no shortage of public spaces, including the green variety. While a significant amount of land contributes to biodiversity and the ecological health of the city area, there is no comprehensive inventory or plan that examines the amount, location, function, or connections between these land areas. The first fledgling effort to create such a vision was undertaken in the fall of 2002 with a mapping forum organized as part of the Green Infrastructure Demonstration Project, conducted by the National Park Service (Lecouteur, 2002). A comprehensive overview of ecologically sensitive areas, protected lands, and green-blue ways in the city is needed if biodiversity is protected.

A coordinated conservation effort is significant in the Prague area, where two provinces, central Bohemia with Prague, each pursue. As a result of historic open space planning efforts, Prague had a framework of protected green space before the tremendous urban expansion after independence from Soviet unions. The modern programs described below carry on the tradition of recreation and conservation that began two centuries ago. Each of these programs can contribute to the development of ecological green-blue ways and urban biodiversity protection.

6. Discussion

Concerning the results and a thorough approach of this thesis, the author believes that the majority of the previous research implemented by other researchers is a bit away from what we know as a multi-disciplinary or inter-disciplinary approach.

In other words, some of the literature reviews like (Chan et al., 2018), and (Benedict and McMahon, 2006) only depicted the Green-Blue infrastructure as a decisive environmental issue. Also, the only matter they interpreted for the ecosystem services is only the provision and regulating services (Ahern, 2007).

Furthermore, some other research refers to the undeveloped open spaces or other vacant lands caused by fragmentation in urban areas to find a linkage between them Zhange et al., 2019).

Finding a sequence of mathematical relations between these spaces is hard work by defining various mathematical formulas, although we can substitute this one by ranking ecological value in the patches. However, the matter of fact is in this part also one thing that the authors somehow neglect is the phenomenon which is the presence of human and human intervention as a fluid motion through these spaces. Thus, bringing humans back to nature in a more proper way is one of the many results of ecosystem service, which is known as cultural service. Also, it needs to be taken into account that a viable consequence of vast vacant lands' presence in the urban areas is the possibility of construction by stakeholders and politicians in power to have more short time profit to the organization they rule.

Another controversial part of the analyzed literature review is to put all the responsibility of decisions on interviewees. To clarify this part a bit more, it means that having participated the users or other random citizens and people as non-detached components of the city is very precious. However, the best approach to get a complementary result is to present an extensive analysis method covering questionnaires, site assessments, and data gathering. All these data together means a valuable asset to the users and designers.

The primary ethical purpose of this research is to increase the quality of livability of human beings in this small territory, where it respects nature and brings recreational and joyful activity by bringing social cohesion and providing ecosystem services to citizens and other elements of the environment.

One significant component of the GBIs, which taken into account by the author of this thesis, is to combine it with non-motorized vehicle transportation where this continuous path not only solves the problem of fragmentation by some vast scale, not well-designed landscape greeneries but also brings a sense of cohesion to the users.

At the same time, it connects some other parts of the city by increasing their interconnectivity of them.

The results of this research can be a guide for future similar case studies with similar specifications. Accordingly, it is possible to suggest suggestions for related complementary research. These suggestions attempt to synergize research, relying on this research thesis. The findings of the present study can address the following thematic areas to additional research:

1. It is suggested that due to the need for green-blue infrastructure at various macro to micro levels, a study in line with green-blue infrastructure architectural requirements is to be met at the scale of residential, commercial, and office buildings.

2. In such similar cases, it is suggested that practical solutions in the design scale for public spaces be considered.

3. It is proposed that in order to coordinate easily between various organizations active in the field of green infrastructure, research has been done in order to identify their duties accurately and by identifying the hollow areas, the duties of these organizations in connection with the planning, design, and conservation of green-blue infrastructure, elements should be reviewed.

4. To pay attention to green-blue infrastructure as a fundamental principle in urban projects, research concretes the definition of green infrastructure in urban development plans and a checklist to be provided green-blue infrastructure in the urban development plan.

5. It is suggested that in the form of research, the desired functions following the environmental performance of the green infrastructure elements should be identified using more successful global experiences, and appropriate classification should be provided.

6. It is suggested that green-blue infrastructure assessment methods be identified in the form of research, and a checklist of analysis and design for paying attention to green-blue infrastructure in urban areas be provided.

Moreover, due to the presence of linear nature of the territory and not highly steep topography in the case of interest, there is a potential to establish landscape and site seeing scenes to increase social cohesion. Therefore, to provide ecosystem services in use such as non-motorized vehicle transportation, recreational spaces, entertainment spaces, social cohesion, and other facilities, it is recommended to set some principles to design them as:

- Continuous and homogeneous design of non-motorized bicycle and pedestrian movement cooridors
- Correction of existing intersections along the route by giving priority to pedestrians, especially at intersections
- Creating visual index elements and providing the possibility of visual pleasure along the axis by defining visual arts or well-designed greenery
- Creating communal spaces, children’s play space near residential areas
- Use of crime prevention through environmental design by design programs
- Creating picnic areas, shortstops for elderlies to rest, and related facilities
- Creating bicycle lanes with proper infrastructure as a means of public transportation
- Location to establish economic activities on the site to ensure a sustainable environmental economy like urban agriculture or horticulture.

This research is for the extensive use of site facilities and overcoming its developed limitations, design strategies, and preferences match users with the site’s physical, cultural, and biological capacities.cultural, and biological capacities.

6.1 Visionary roadmap to sustainable design

As a visionary roadmap to guide a historic capital city towards sustainability, equity, and resilient development, one important criterion to take into account is the companionship of pre-existing greenery spaces with a developed version of these spaces.

In other words, it helps the quality of green spaces be enhanced by upgrading to another dimension, which brings new thriving detailed designed spaces to increase ecosystem services. The overall effort for the design of the weighted chosen territory consists of one main component: To integrate a Green-Blue infrastructure which helps the issue of fragmentation in these undeveloped open greenery spaces by providing ecosystem services and, as the consequence of all above-mentioned descriptions, to help continuous non-motorized vehicle transportation via the implemented site to a bigger GBI which is the Stromovka park in Prague, the Czech Republic.

This sort of *Urban Design Framework* also helps cover a range of issues shaping Prague's form: infrastructure, housing, mobility, safety, greenery, sustainability, and resiliency. Fragmentation across sectors and a lack of capacity at the local level is a challenge many countries face. This blend of site-specific design and citywide guidance is also applied to other topics, including the opportunity to integrate informal settlements into the city.

Therefore, the author of this diploma thesis comes up with some ideas to illuminate the definition of Green-Blue infrastructure in the allocated corridor, and the following parts of this Results section are about to show a sequence of how the design of this area is going to be. A green and public corridor attached with different kinds of facilities and functions connects the city center with the constructed wetlands and recreation area (1st phase) as well as the protected landscapes around Prague (Figure 6.1).

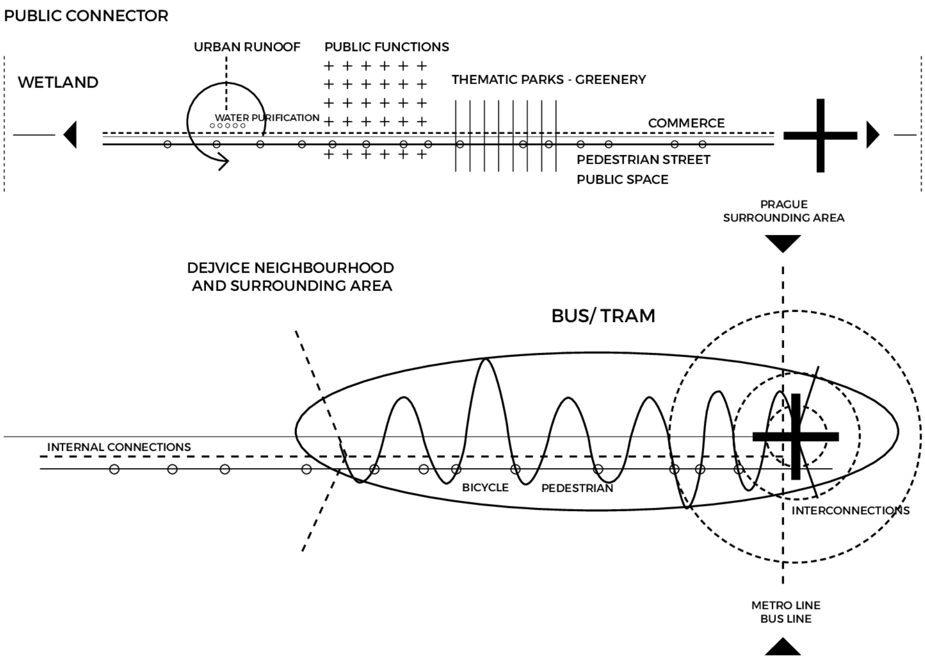

Figure 6.1: Functions of the territory based on local scale design

Based on the literature review and research that the author has done, another parameter that enhances the resiliency and sustainability of cities in case of sudden incidents like natural disasters or war is implementing GBIs, which is based on two primary qualities:

a) Intrinsic quality, which comprises activities in daily routine conditions and no chaos moments.

b) Compatibility in case of chaos situations and flexibility in response to the sudden incident like natural disasters or war, which can be used in infrastructure, social or economic systems.

Therefore, GBIs as a based model of a sustainable module can be considered a conceptual framework to scrutinize the criteria of the *Urban Planning* design as Sustainable Space which intertwined of four dimensions as; framework, activities, imagination/ definition, and ecosystem. Thus, the author of this thesis comes up with a conceptual diagram that illuminates the variety of parameters in which sustainability and resiliency are the outcomes of this idea as a shining future (Figure 6.2).

In many sites in urban spaces, there is no chance to increase the safety of open spaces.

Hence, due to the reason that a public facility like green corridors intertwines with a fluid motion known as human intervention either by doing recreational activities or presence in the green place, it is very much vital to keep safety as a primary matter.

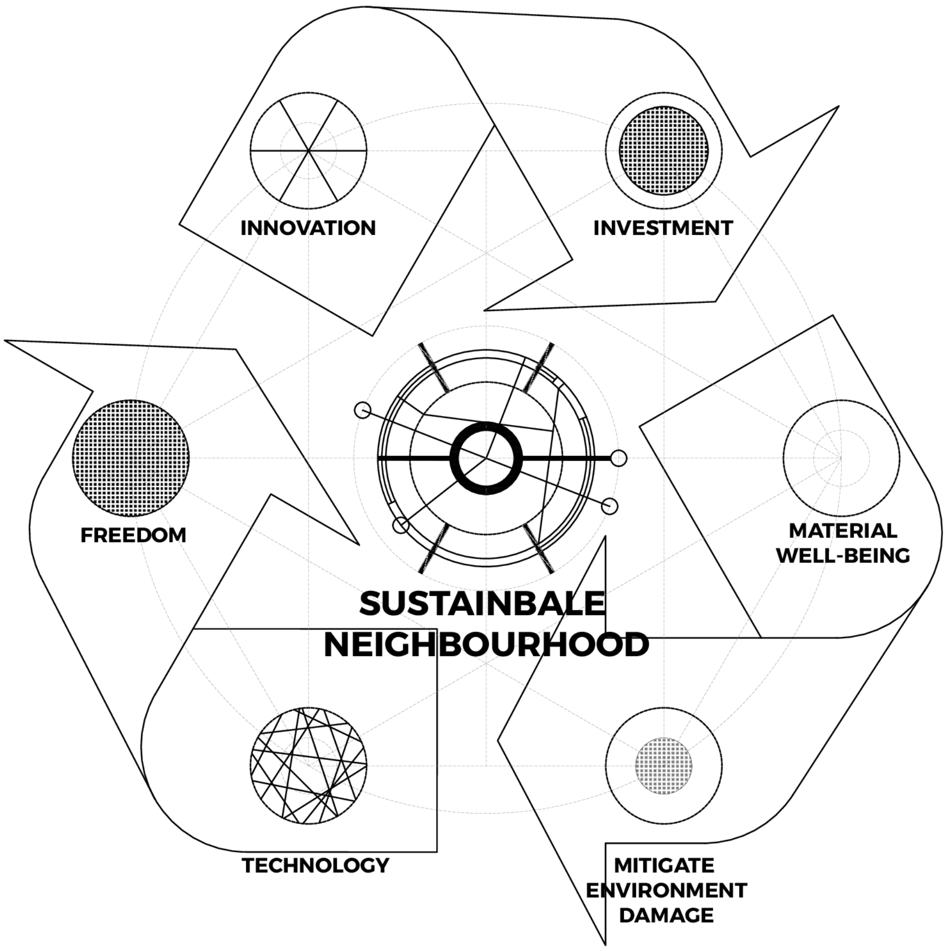

Figure 6.2: Transformation of various components to have a sustainable approach

6.2 Corridor design typologies

This thesis presents three design typologies for potential GBI development strategies that correspond to different site conditions, which represent common vacant land types in Prague; 1) commercial vacant land; 2) alleyways separating commercial and residential land; 3) vacant residential land; 4) undevelopable open green spaces

The first typology is designed for vacant land parcels, exemplified by vacant land in junction of Nikoly Tesly, and jugoslávských partyzánů (Fig. 6.3, left image). Here vacant land is adjacent to the main road, with limited tree canopy and no buffer between commercial and residential zones. These conditions are in the study site and other legacy cities, and in these cases implementing a small green space (such as a pocket park) is recommended (Fig. 6.3). This park would provide cultural services such as recreation, physical activity, and social contact (Lovell and Taylor, 2013). Adding street trees in rows with mown grass emphasizes the neatness of the landscape, upholding cohesion, legibility, and cues to care while also mitigating the urban heat island effect.

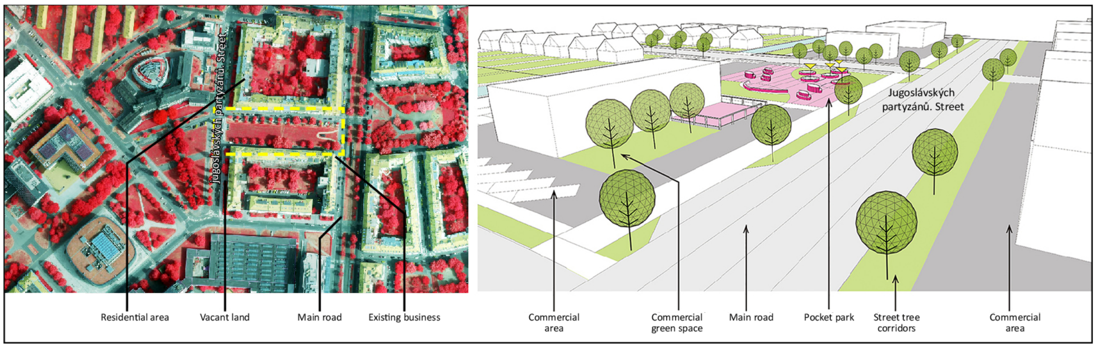

Figure 6.3: Corridor design typology 1: Commercial vacant land (yellow)

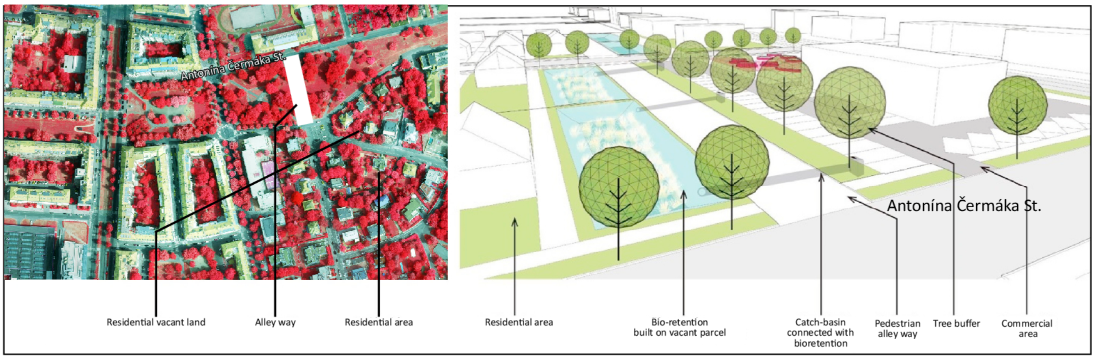

Figure 6.4: Corridor design typology 2: Alleys between vacant lands

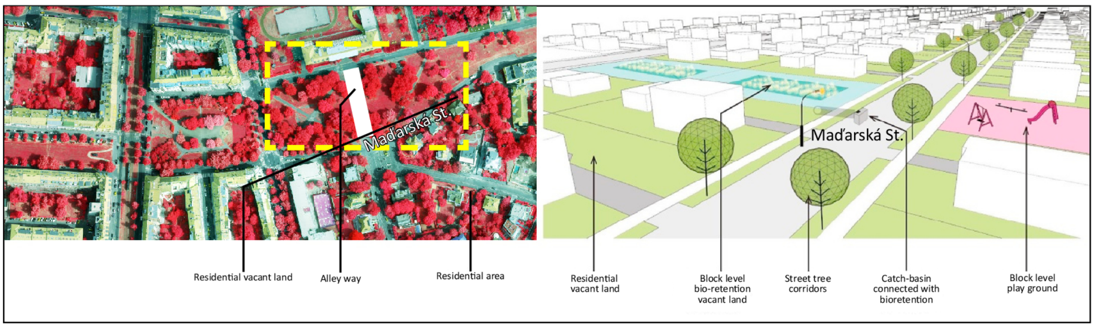

Figure 6.5: Design typology 3: Residential vacant land with block level bio-retention, playgrounds, and street trees

The second typology focuses on areas where vacant land is located in close proximity to residential or commercial areas, separated by an alleyway (Fig. 6.4, left). For these areas, the proposed design (Fig. 6.4, right) takes advantage of the vacant parcel to implement a bio-retention basin, capturing stormwater and reducing harmful combined sewer system (CSS) overflows. With proper planting design, bio-retention basins can provide aesthetic value and pollinator habitat (Hunter, 2011). A pedestrian path and tree buffer are also suggested to separate commercial from residential parcels. The proposed pedestrian pathway can improve public transportation and is further separated from the street to provide a safer environment for walking and biking.

The third typology is designed for building a corridor through a generic vacant residential property (e.g., Fig. 6.5). In many Prague neighborhoods, storm and sewer water from parcels flow into CSS pipes under adjacent alleyways. When the system backs up, it can flood basements. To address this, small bio-retention basins are developed on vacant properties and catch basins along the streets. Bio-retention basins are connected to catch basins intended to retain the stormwater from the road before it enters the underground sewer system. Additionally, vacant land could be fitted with playgrounds, supporting outdoor activities (Fig. 6.5), strengthening community cohesion, and improving opportunities for recreation in the surrounding neighborhood. Figure 6.5 shows how vacant residential land like that shown in Figure 6.5 could be converted from a combined sewer system (top) to a bio-retention system (bottom) as part of corridor development.

6.3 Design principles

Some basic principles to design a safe passage from the perspective of architecture and landscape architecture are comprised of the below parameters:

a) Surrounding the spaces:

Covering the premises with low height walls, variation in levels, and trees. The ratio of the design space is one vital matter to be taken into account not to have a cold, senseless, and prison-like for the users.

b) Establishment of safe corners:

It can be implemented by various primary method components, which are:

- Variation of elevation by the natural land slope: The lower level spaces can be covered by various types of walls trees, which can protect the users on the lower level from the threats of the higher elevation possibilities.
- Surrounding buildings: By designing types of buildings that pilot storey be on the ground floor to have a safe space, in case of a possible threat, provide safety of facade collision and protection against precipitation.

c) Form of the buildings and attached ornaments:

To design the buildings in a way where the balconies and traces be on the inner yard to prevent the collision in case of an incident. Also, extra ornaments such as flower boxes or big arches which is outmoded better not be on the facade.

d) Usage of the best and non-invasive vegetation and tree cover:

Trees are the other components that can provide vital safety for the design spaces, and a long list of mentioned benefits as such in the literature review part.

e) Parapet walls:

In open spaces, due to the presence of flat and immense surfaces, there should be some elements to provide various activities such as sitting to provide better safety and keep the spaces away from being designed simply.

f) Pavement material:

Soft materials should be used in places that are the gathering point in open spaces, and rigid and non-flatten surfaces like stone pebbles are not much recommended. However, some materials that provide a bit of hardship for movement (clay, silt, Dry or soft sand) on some small scale are highly recommended. In order to provide more safety, instead of establishing unnecessary steps, it is much better to integrate the spaces with ramps of a maximum 5% slope rate and a proper width not lower than 1.8 m. Also, the material of the ramps should be rigid, rugged, and bumpy to provide safety.

g) Other arrangements:

- Possibility of site access for emergency vehicles
- Possibility of transportation of injured people with ambulance either in the green corridors or adjacent premises
- possibility of a helicopter landing in case of emergency

As the consequence of all gathered information, data, analysis, and distilled description of the results section of this diploma thesis, and for fulfilling the enthusiasms of the author, there are some minor depictions in some outputs render images which show how he imagines this Green-Blue corridor should be either in a city-scale and in design one. The below pictures are some demonstrations of what the author managed to design for the final part of the results section (Figure 6.6). The software used to produce these imagery pictures is ***Autodesk 3dsmax, V-ray rendering engine, and Sketch-up software***.

Figure 6.6: Render images of case of study based on human perspective angle

7. Conclusion

Undoubtedly, every research seeks to answer the questions on which it has begun. This research has also sought to achieve three main goals. The first goal is to get acquainted with the concept of green-blue infrastructure as the title of the life support system in new cities. It can be said that new cities will perform well at some point that had to respect their field and have proper design and planning in the field of the city's green-blue infrastructure. In this regard, it is necessary to first identify green-blue infrastructure in the field of new cities and other planning with prioritizing these elements.

This research introduces urban green infrastructure elements (such as trees, soil, and built infrastructure) that are located in specific networks and perform functions (such as runoff management and urban heat island effect).

In addition, green-blue infrastructure is part of a hierarchy: it also includes several subsystems (For example, hydrological subsystem, vegetation, and movement) and, on the other hand, within a subsystem of a more extensive system (for example, a district, city, or neighborhood) where it interacts with other systems (such as transportation, economy, and government).

In order to properly design and plan the GBI network, it is necessary to identify factors and principles affecting it as a non-detached existing part of the studied territory.

In this research, the elements of GBI and their function as internal factors of green-blue infrastructure identified and scrutinized as an influential external factor.

These internal factors and externals are reciprocally related to each other and interact with each other. Therefore, it is necessary to identify existing elements in an existing site or parts of it that have the potential to become GBI elements. Also, their current functions and the desired functions that can play have been identified through the principles governing urban green infrastructure that are placed next to each other, and the GBI network form in new cities.

It should be noted that it is possible to distinguish the elements of GBI in new locations from the typology presented in this study in literature review and methodology sections.

Principles of GBI in this study, according to the existing theoretical literature as well the use of global experiences have been developed.

This research's final and primary purpose is to formulate strategies and policies related to design and planning. Therefore, strategies and policies to achieve a healthy environment for the residents of new cities have been identified.

According to the perspective of cities in the Czech Republic, this goal seeks to achieve the highest level of sustainability and resilience. The sustainability of cities will only be achieved if they are observed at different scales. Therefore, strategies and policies have tried to consider micro and macro scales in the compilation. Another important point in designing and planning the city's green-blue infrastructure is the compliance of development plans with these principles. It is necessary to measure the compliance of this plan with green-blue infrastructure and their ability to meet the criteria presented in this research. Based on the principles of green-blue infrastructure, these valuable elements should be considered acceptable defaults when other measures are taken only if they do not conflict with them.

This study shows that green corridors can create and protect a particular personality within an urban area. They can affect the ecological quality of the city as well as the quality of the urban environment to carry out selective and social activities of citizens and, as a result, the sense of belonging to the environment and the quality of the place resulting from the performance of all social cohesion increases. Green roads can also improve citizens' economic, educational, and cultural quality, promoting recreation, environment, and security. On the other hand, as a result of the expansion of the use of green corridors, especially in the form of continuous green-blue networks in cities, this can be implemented as a place to attract people to perform social activities and achieve citizens' choice in urban public spaces. A phenomenon in which, to a broader extent, will affect the citizens to a sense of belonging to the atmosphere and sense of responsibility in case of savings and protection of natural components and positivity of city's ecological. The final outcome of this thesis implements a comprehensive framework in case of expansion of greenery in cities of the country and sustainable development by concreting the idea of GBI as a beneficial tool.

Therefore, to identify these parcels and integrate them to the highest level of detail, it is mandatory to make a multi-disciplinary approach to get the best result out of it to alleviate the environmental tensions and respond to the users by going through a hierarchy of decision-makers.

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