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MASTER THESIS

Green and Blue Infrastructure Strategies for Liveable Cities

A comparative analysis of experiences to identify best approaches

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INDEX

List of Figures

List of Tables

Abbreviations

ABC	Active, Beautiful, Clean Waters
AMRUT	Atal Mission for Rejuvenation and Urban Transformation
AI	Artificial Intelligence
ALGG	All London Green Grid
BGF	Blue-Green Factor
CE	Community Engagement
CWs	Constructed wetlands
DDA	Delhi Development Authority

EnRoute	Enhancing Resilience of Urban Ecosystems through Green Infrastructure
EIA	Environmental Impact Assessment
EOL	Ease of Living Index
ERDF	European Regional Development Fund
EU	European Union
GBI	Green and Blue Infrastructure
GI	Green Infrastructure
HEV	Helsinki, Espoo, Vantaa
IPCC	Intergovernmental Panel on Climate Change
IoT	Internet of Things
JnNURM	Jawaharlal Nehru National Urban Renewal Mission
LAP	Local Action Plan
MAES	Mapping and Assessment of Ecosystems and their Services
MGO	Manchester's Great Outdoors
MPD	Master Plan for Delhi
NAPCC	National Action Plan on Climate Change
NbS	Nature-based Solutions
PPS	Permeable pavement systems
QOL	Quality of life
SRFDCL	Sabarmati Riverfront Development Corporation Limited
SuDS	Sustainable drainage systems
SDG	Sustainable Development Goals
SEA	Strategic Environment Assessment
URDPFI	Urban and Regional Development Plans Formulation and Implementation
UGSAI	Urban Green Space Availability Index
UGI	Urban green infrastructure
WHO	World Health Organisation

ABSTRACT

As urban areas continue to expand rapidly, outward and upward, there is an urgent need for sustainable and resilient practices to manage this growth before it turns septic to the environment around us. All major cities of the world unanimously face growing challenges posed by climate change and rapid urbanization that require nature-based solutions. The concept of green and blue infrastructure (GBI) has come forth as an answer for addressing these challenges we face as a civilization.

This thesis explores the potential of integrating green and blue infrastructure strategies and initiatives as a pivotal approach for enhancing liveability.

This thesis uses literature to establish the theoretical basis for the concept of green and blue infrastructure and liveability. The study highlights findings from various scholarly articles to elucidate the multifaceted benefits of GBI, exploring the *social, ecological, and economic benefits in the realm of enhancing liveability*.

Furthermore, the thesis delves into the existing GBI planning initiatives adopted around the world and opts for a comparative analysis to identify optimal strategies. Through an *interdisciplinary approach* that integrates principles from urban planning, judicious community involvement, and environmental management, the study endeavours to provide insights into best functioning strategies, keeping in mind the complexity of the integration of GBI systems that require a context-based understanding to devise a solution. Despite widespread support from both planning practitioners and academics, there is a dearth of scholarly literature that critically analyses what GBI entails or the potential ramifications of its institutionalisation within planning. This thesis aims to fill this gap by investigating the integration of GBI with adopted planning initiatives.

The research aspires to offer valuable contributions towards identifying optimal strategies of GBI by highlighting the liveability benefits aimed at fostering a 'Physiological-Ecological' enhancement at the local level.

KEYWORDS: Green and blue infrastructure, Urban liveability, Stakeholder engagement, Physiological-Ecological enhancement, green equity

I. INTRODUCTION

I. Introduction

I.1. Background

The rapid climate change at the turn of the century has shattered the preconceptions of urban spaces. As climate change ravages the quality of life and eats away at the ecosystems at an unprecedented rate, the existing path of development has been proven to be destructive. Green and blue infrastructure provides a multifaceted solution to these problems by having numerous ecological, social, and economic benefits.

The ongoing debate of solutions to help mitigation and adaptation to climate change and the repercussions of it has swayed from technology-based solutions to nature-based solutions (NbS), one of the essential lauded ones being Green and Blue Infrastructure (GBI) integration. Although there is growing recognition among urban planners and policymakers for the need to develop urban GBI as a means of promoting both sustainable development and resilience in cities, there remain significant barriers to the adoption and effective implementation of these strategies.

There are various reasons why GBI is important for cities, some of which include climate change mitigation, decreasing the urban heat island effect, and increasing standards of living. However, GBI initiatives are often undermined during city planning, leading to missed opportunities for achieving these benefits. This thesis aims to review the integration of GBI in the existing urban tissue, while also identifying potential challenges that could occur during the implementation of a strategy.

I.2. Problem Statement & Research Questions

With the aim of correlating elements of Green and Blue Infrastructure (GBI) with urban liveability within the realm of Planning Policies, the thesis revolves around the central question of:

<u>How can Green and Blue Infrastructure be strategically integrated to improve urban liveability and enhance quality of life in cities?</u>

Subsequently, the following questions that support the thesis will be answered:

1) What are the proven benefits of GBI to the liveability of residents- Social-Ecological-Economical?
2) What strategies are in place or have been proposed for developing GBI on various scales (Internationally, European level, National level, and regional level)?

3) What are the existing strategies adopted for incorporating GBI around the world? Which GBI initiatives and policies are proven to have the most optimal outputs for liveability?

4) What are the strategies that work in engaging stakeholders effectively for equitable GBI planning?

5) What are the practical challenges of implementing and developing GBI in existing urban areas?

I.3. Hypothesis & Proposition

PROPOSITION

This research thesis aims to investigate the role of GBI as a pivotal strategy for enhancing liveability. This study aims to explore the benefits of GBI, along the ecological, social, and economic dimensions, while examining policy implications to address contemporary urban challenges effectively.

HYPOTHESIS

This research validates the idea that implementation of GBI will be an essential Nature-based solution (NbS) to improving environmental sustainability, mitigating climate change impacts, and overall improving liveability. Specifically, it is anticipated to have:

1. Stronger ecological resilience and improved stormwater management.
2. Improved public health outcomes and community well-being metrics through increased access to green spaces and ecosystem services.
3. Mitigation of the urban heat island effect & enhanced liveability.
4. Social engagement in the community and participatory planning, promoting social resilience by fostering inclusive decision-making processes.

Therefore, this research seeks to validate these hypotheses as a basis for providing empirical evidence on the transforming potential of green infrastructure in fostering sustainable environments.

I.4. Objectives

The thesis aims to explore the elements of green and blue infrastructure that optimise and contribute to enhanced liveability. The study involves key factors of interlinkages in other aspects of liveability- social, economic, and ecological, and how these interact with the GBI interventions.

This thesis aspires to review the policy framework in regard to integration of GBI to create climate-responsive strategies aimed at improving liveability. The research objectives have been streamlined:

1. Assessing key metrics of climate impacted by GBI, such as heat mitigation, flood control, air quality, and biodiversity, and identifying how the variables change with these factors involved.
2. Identifying and examining practical challenges in implementing GBI, including technological, economic, regulatory, and social barriers.
3. Reviewing strategies for inclusive stakeholder engagement to ensure effective decision-making and green equity.
4. To compare the existing policy integration of GBI and assess the effectiveness in implementation and monitoring interventions.
5. To identify optimal policy recommendations that support the implementation of GBI. Developing a comprehensive framework for GBI implementation in urban communities at the neighbourhood level.

I.5. Research framework & Methodology

Research Design: The thesis adopts a combination of theoretical and empirical literature to formulate a literature review for the topic.
It will follow a path of qualitative, descriptive, and interpretive research.
The methodology will be divided into four phases:

I. **Data Collection:** Conducting a systematic review of academic papers, reports, and articles related to GBI and urban liveability.

II. **Data Analysis:** Using thematic analysis in order to identify themes and insights from data collected, along with breaking down the existing empirical data of GBI, urban liveability, and urban resilience.
Comparing case study findings to identify best practices, common challenges, and effective solutions.
Analysis of the elements of the research paradigm and identifying gaps in the research landscape.

III. **Framework Development:** Synthesizing findings from data analysis and case study comparative analysis of the initiative for GBI implementation, including planning policy.

IV. **Implementation:** Identifying optimal policies for the implementation context-wise for Delhi, India
   - Documenting the research process, findings, and framework in a comprehensive thesis.
   - Providing actionable recommendations for GBI initiatives for the selected sites.

II. THEORETICAL FRAMEWORK

II. Theoretical Framework

II.1. Concept and Scope

Green and blue Infrastructure (GBI) (interchangeable with blue-green infrastructure) falls under the umbrella of Nature-based solutions (NbS) and has multiple definitions. The term has a multitude of definitions -according to *Ghofrani et al., (2017)*, has been defined as an interconnected network of natural and designed landscape components that provide multiple functions for sustainable urban water management.

The United States Environmental Protection Agency (EPA) defines GI as "*An adaptable term used to describe an array of products, technologies, and practices that use natural systems - or engineered systems that mimic natural processes - to enhance overall environmental quality and provide utility services.''* (USEPA, 2020).

European Commission defines GBI as: "*A strategically planned and managed, spatially interconnected network of multi-functional natural, semi-natural and man-made green and blue features including agricultural land, green corridors, urban parks, forest reserves, wetlands, rivers, coastal and other aquatic ecosystems"* (*European Commission, 2013)*.

Overall, GBI is a strategic integration of natural and engineered systems that utilizes both blue elements (water bodies) and green elements (vegetation) to enhance urban resilience and sustainability. To emphasise the importance of it further, a sustainability pyramid proposed by researcher (Williamson, 2003) illustrates how a 'viable ecosystem', i.e., green infrastructure, is the foundation of society [Figure 1]. The concept of infrastructure itself has evolved over time, and ecosystems were only considered as a type of infrastructure since the 1980s. At first, 'ecological infrastructure' was common, but 'green infrastructure' gained traction after 2004. (Silva & Wheeler, 2017).

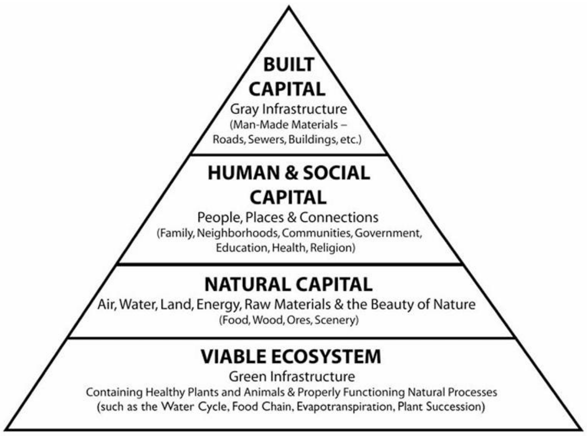


Figure 1: Viable ecosystems- green infrastructure that creates society's foundation (Williamson, 2003)

Importance in Urban Planning

The importance of GBI is in its quality of being a nature-based solution, solving a wide range of modern urban problems. GBI has been an essential method for enhancing flood resilience in developing cities like Semarang, Indonesia *(Drosou et al., 2019)*. Similarly, in Chinese cities, the sponge cities initiative has played an important role in integrating urban greening and stormwater management practices *(Siehr et al., 2022)*. GBI tackles both short-term and long-term urban challenges by maintaining natural water cycles and improving environmental quality, which makes cities more liveable.

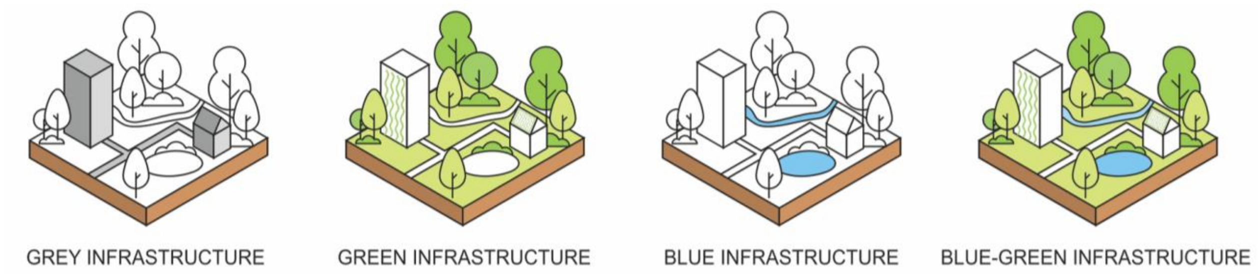


Figure 2: Green Blue Infrastructure (Pochodyła et al., 2021)

GBI is also linked with the broader objectives within the field of urban planning, one of which is the quest for sustainability and resilience. Leaning towards sustainable practices, the integration of natural elements that offer ecological, social, and economic benefits is essential. GBI supports this green approach by enhancing ecosystem services such as stormwater management, air and water purification, and biodiversity conservation (Kimic & Ostrysz, 2021). Furthermore, GBI is projected to improve urban resilience by offering adaptable solutions to the climate crisis. The integration of GBI in urban planning is anticipated to yield numerous benefits. GBI improves environmental quality by expanding green spaces, which contribute to better air and water quality, and support biodiversity *(O'Donnell et al., 2021)*.

II.2. Historical development of discourse

The concept of green infrastructure (GI) has existed for many years under slightly different terminology and is often referred to as "old wine being marketed in new bottles." *(Giudice et al., 2023; Mertens et al., 2022)*

GBI originates from the roots of landscape planning and can be traced as far back as the late 19th century- a period famously characterized by rapid urbanization. Early advocates realized the need for making green spaces inclusive in the urban setting to improve public health. William Pitt the Elder envisioned parks and squares as 'the lungs of London' in the 18th century. So, these rather early concepts set the basis for further ideas of urban planners to include green infrastructure into the very city *(Mertens et al., 2022)*.

Discourse continued to shift in the early 20th century with comprehensive urban planning frameworks, when Patrick Abercrombie's 1943 'County of London Plan', for instance, was a plan that targeted developing a green belt around London. Similarly, the Finger Plan in Copenhagen [Figure 3], developed in 1947, involved the use of green spaces in urban planning, where green corridors were identified in between the urban 'fingers' and protected from development *(Körmöndi et al., 2019)*. These initiatives reflect a growing recognition of green infrastructure to address the problems created by overcrowding.

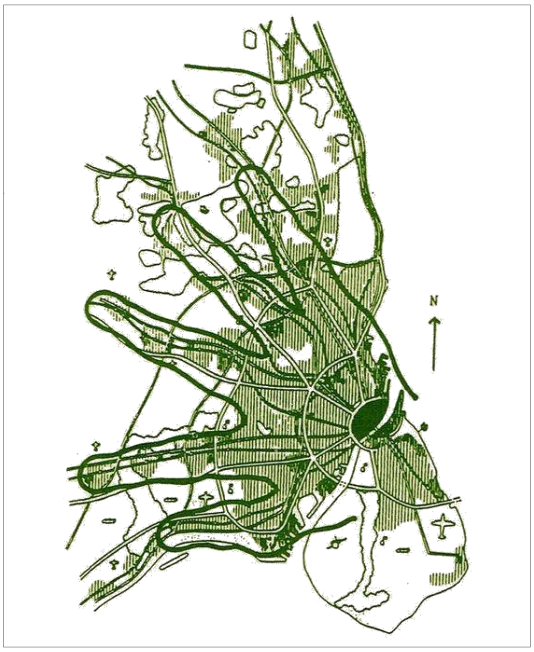


Figure 3: Finger Plan, Copenhagen (Tricker, 2023)

The discourse during the second half of the twentieth century evolved to embrace a holistic notion of green infrastructure in response to environmental concerns. Furthermore, the European Union's 2013 Communication about enhancing natural capital through green infrastructure, which recognised the need for strategic planning of natural and semi-natural capital and its integration into the EU policy *(European Commission, 2013)*. This can be attributed to a change in perspective from viewing green spaces as an aesthetic value to recognising their crucial role within ecosystem services and as a solution to climate change adaptation.

Towards the end of the 2010s, the GBI gained international recognition for water management in cities. Many cities like Portland, Rotterdam, Newcastle, etc proposed to implement extensive plans for GBI in a drive to manage water challenges. These cities have emphasized that policy changes, along with infrastructure multifunctionality, are necessary for optimizing GBI benefits *(O'Donnell et al., 2021)*. In the next decade, the focus has shifted to climate resilience development and how GBI demand interacts with the socio-economic dynamics. Studies done in Nanjing, China, indicated that GBI demand varied spatially and was dominated by economic development and management *(Zhao et al., 2023)*. During this period, optimal GBI initiatives were very targeted at accounting for spatial characteristics and integrating into more holistic urban planning approaches.

At present, GBI is regarded as the most crucial factor in achieving green innovation and pollution reduction in developing countries like Pakistan. In addition, combining green technologies with GBI has been observed to have a positive influence on economic activity and environmental sustainability. *(Nassani et al., 2023)*. This evidence indicates that GBI plays a vital role in solving global environmental problems and furthering sustainable development. The historical development within the GBI discourse shows a line of development from early recognition of the importance of green to more mainstreamed support for the benefits of integrating both green and blue components into planning.

II.3. Components and Perceptions

Green and blue infrastructure consists of two components- specifically, the 'green' and the 'blue' aspect. The combination of these two components of interconnected spaces makes the infrastructure. The components identified under this are elaborated further:

<u>Green Infrastructure- Classification of components according to scale:</u>

It is crucial to comprehend not only Green Infrastructure (GI) multifunctionality but also how these perks vary according to spatial scale and suitability for the intended use. GI measures can be categorised into three levels based on the spatial scale: micro (individual/average size), meso (spanning multiple micro locations), and macroscales (spanning multiple meso locations) (Kumareswaran & Jayasinghe, 2023)

Table 1: Classifications of green infrastructure components (Kumareswaran & Jayasinghe, 2023)

Scale of implementation	GI components
Microscale *(individual site)*	Green walls, green roofs, green facades, street trees and hedgerows, rain garden, domestic garden, green space, permeable pavements, sustainable urban drainage systems (SuDS), storm water harvesting systems
Mesoscale *(neighbourhood)*	Urban parks, woodlands, ponds, canals, and lakes, play areas, recreational grounds, green corridors, blue corridors, orchards, community gardens, street trees and hedge rows, local nature reserves, green spaces, permeable and semipermeable pavements, rain gardens, bioretention, bioswales
Macroscale *(city/ region)*	Lakes and reservoirs, urban forest, regional parks, blue corridors, green corridors, green belts, intensive and un-intensive agricultural land, pastures, woodlands, flood plains, greenbelts, brownfield redevelopment

Blue Infrastructure- Classification for flood mitigation:

Various components of GBI have been identified over the years. The classification of adaptive measures of GBI in accordance with their contribution to flood mitigation has been done according to their *function, scale,* and *position*. *(Cruijsen, 2015; Ghofrani et al., 2017)*

Table 2: Classification of GBI components for adaptive measures (Cruijsen, 2015)

	Surface	Subsurface	Above Ground
Infiltration retention	Parks and urban forests; urban agriculture; Storm water flow-through planters; Bio retention garden; Bio retention swales; Permeable pavement; Storm water trees;	Subsurface storage with retention capacity;	Green facades; Trees; Green Roofs;
Storage retention	Urban wetland; Seasonal Storage and rainwater harvesting; Retention storage basins	-	Rainwater tanks;
Detention	Water square; Surface detention ponds;	Subsurface storage tanks;	Blue roofs;

I. Function- *Retention or detention*

Under this classification, the contribution of the GBI to managing stormwater runoff is considered. This classification has two sub-categories, namely:

- *Detention Components* that store water during and after extreme precipitation events and gradually discharge it to the sewer system.
- *Retention Components* store water and allow it to infiltrate into the ground without any connection to the sewer system *(Cruijsen, 2015)*.

II. Position- *Surface, subsurface, or aboveground*

- *Aboveground*: Green roofs, blue roofs, and green facades.
- *Surface*: Comprises vegetation on the ground
- *Sub-surface*: Involves construction below the surface, such as storage beneath public spaces or existing constructions *(Cruijsen, 2015)*

III. Scale- Private, street, neighbourhood, or city

- *Regional/Urban Scale*: Includes parks, protected areas, wetlands, and retention/detention ponds.
- *Private Scale*: Comprises blue and green roofs, private gardens, and rainwater containers.

- *Block Scale*: Involves components like planters, permeable pavements, and subsurface storage that serve collections of public or private segments *(Cruijsen, 2015)*

Perceptions of GBI

Different stakeholders have differing opinions about BGI, which reflects both the benefits and challenges of putting it into practice. Citizens' expectations and experiences with urban green and blue areas influence how they view GBI initiatives. Citizens express a desire for increased green spaces and better management of existing GBI to address issues such as safety, usability, and conflicts among different user groups. In Leipzig, Germany, citizens highlighted the importance of GBI for health, well-being, and environmental justice. They express the need for secure, easily accessible, and well-kept areas and stated a wish for more GBI in terms of both quantity and quality *(Palliwoda et al., 2022)*.

The perceptions of who leads BGI implementation vary city by city since the governance structure influences how BGI projects are developed. There is a consensus that a transformative change in policy is needed to optimize the delivery of BGI benefits *(O'Donnell et al., 2021)*. While there is generally a positive perception of GBI among professionals, stakeholders, and citizens, many challenges related to implementation, governance, and equitable access are still many. Addressing these challenges is essential for maximizing the benefits of GBI.

II.4. Urban Liveability

Urban liveability is generally considered to be the capacity of cities to meet the expectations of their residents for their well-being and standard of living, even though there is no universally accepted definition of this concept.

The concept highlights the relationship between social aspects, economic values, and the urban form, arguing that a liveable urban environment enhances quality of life by meeting the fundamental requirements of its citizens (Khorrami et al., 2020). Understanding the elements of liveability is aided by the careful selection of indicators, dimensions, and sub-indicators. Indicators are often chosen based on the goal of liveability measurement.

Liveability and Quality of Life Theory

The World Health Organisation (WHO) first defined quality of life (QOL) in 1948 as "a state of complete physical, mental, and social well-being, and not merely the absence of disease and infirmity." QOL in urban areas is influenced by numerous factors that encompass physical, psychological, social, and environmental dimensions. Urban areas frequently provide specific problems that can severely impact residents' quality of life. The concept of 'liveability' gained traction with the Gore/Clinton Liveability agenda in 1999, which was a framework for "new tools and resources to preserve green space, ease traffic congestion, and pursue regional 'smart growth' strategies" (Herman & Lewis, 2017). Since then, the idea evolved and took into consideration other features for a balanced life. Mercer's Quality of Living survey rates cities according to 39 criteria that include economic, environmental, health, transportation, and other public service issues (Marcer Survey, 2011).

The WHOQOL User Manual describes a number of areas that affect a person's overall quality of life, such as comfort, safety, cleanliness, and utility accessibility. A person's ability to carry out everyday tasks and preserve their independence is essential to their QOL (WHOQOL- 100, 2012).

According to Wesz et al., (2023) survey of the literature on urban quality of life, the interaction between people and the built environment influences QOL and necessitates taking into account both quantitative (objective) and qualitative (subjective) components for evaluation. The authors present a holistic concept of urban QoL, entailing different dimensions of urban services, economy, culture and recreation, urban mobility, conviviality, security, and environmental comfort.

The Global Liveability Index

One of the pioneers of calculating liveability has been the EIU- the research and analysis division of The Economist Group. According to EIU, there are several applications for evaluating liveability, “ranging from benchmarking perceptions of development levels to assigning a hardship allowance as part of expatriate relocation packages” *(EIU, 2024)*.

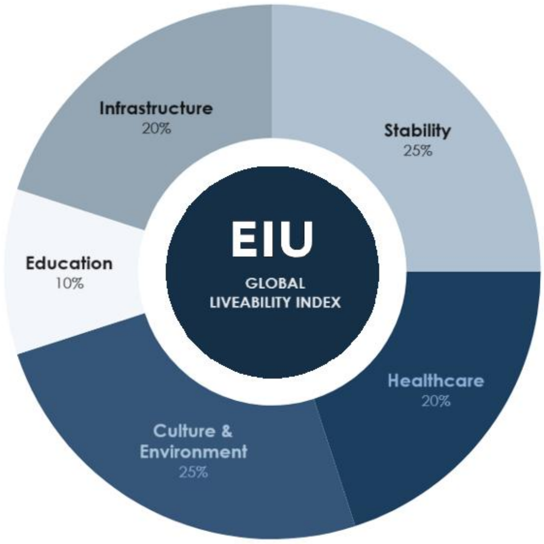


Figure 4: Global Liveability percentage (EIU; Modified by author)

The calculation of liveability done by EIU is based on an assessment of over 30 qualitative and quantitative factors, categorized into five categories: Stability, Healthcare, Culture & Environment, Education, and Infrastructure. The factors that are analysed under these categories include prevalence of crime, civil unrest, availability and quality of healthcare services, cultural events, access to quality education, essential services like energy, water, quality transport, and housing *(EIU, 2024)*.

II.5. Liveability through GBI

For mapping out how GBI is interlinked to citizens' liveability, this study will consider WHO's definition and classify the liveability within the three spheres identified as: *physical, psychological, and social well-being*. This chapter will inspect how each of these aspects is affected by the presence of GBI in the urban setting.

Physical well-being

In its 6th assessment synthesis, the Intergovernmental Panel on Climate Change (IPCC) emphasised that extreme temperatures are made worse by climate change. According to IPPC forecasts, temperatures could rise by 1.6 °C by 2100, highlighting the need to address heat-related issues immediately. Urban emissions show concerning tendencies rising from 62% to 67–72% between 2015 and 2020. The IPCC's 6th assessment report reaffirms 'Green-Blue Systems' as one of the urban planning techniques to improve carbon sequestration *(Calvin et al., 2023)*. GBI gives cities the ability to resist the onslaught of climate change. It helps mitigate urban heat islands by providing shade and cooling through evapotranspiration.

Despite this, the numerous influencing elements make it difficult to integrate GI for cooling into the architectural environment. Plant species, irrigation, climate, spatial distribution, and the existence of additional infrastructure types (such as blue infrastructure and cool materials) all affect GBI's cooling capacity *(Azmeer et al., 2024)*.

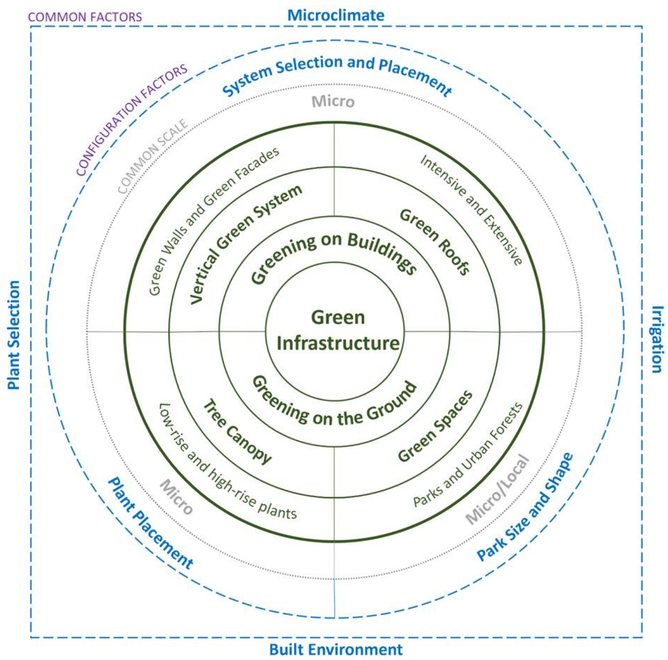


Figure 5: Main approach to the cooling potential of GI (Azmeer et al., 2024)

According to research by *(Bartesaghi Koc et al., 2017),* design interventions fall into one of four categories: *configurational, morphological, functional, or climatological [Figure 10]* provides a graphic representation of key determinants of greening on buildings and the ground. The dotted circle displays the configuration factors (spatial distribution), which vary based on the GI typology, whereas the solid circles indicate the various GI kinds. Other frequent influencing factors, such as the microclimate, plant selection, irrigation, and built environment aspects, are displayed in the outer dotted box *(Azmeer et al., 2024).*

Humans are largely dependent on nature and the ecosystem for our daily activities. Concepts of ecosystem services serve as the foundation for the idea that nature is an essential support system for human health and wellbeing *[Figure 4]*. This leads the world down a solemn path since the degradation of biodiversity and ecosystems affects a majority of the SDGs. Research shows human activity has 'significantly altered' roughly 75% of the terrestrial environment and 66% of the marine environment worldwide, and urban areas have more than doubled since 1992 (Díaz et al., 2019).

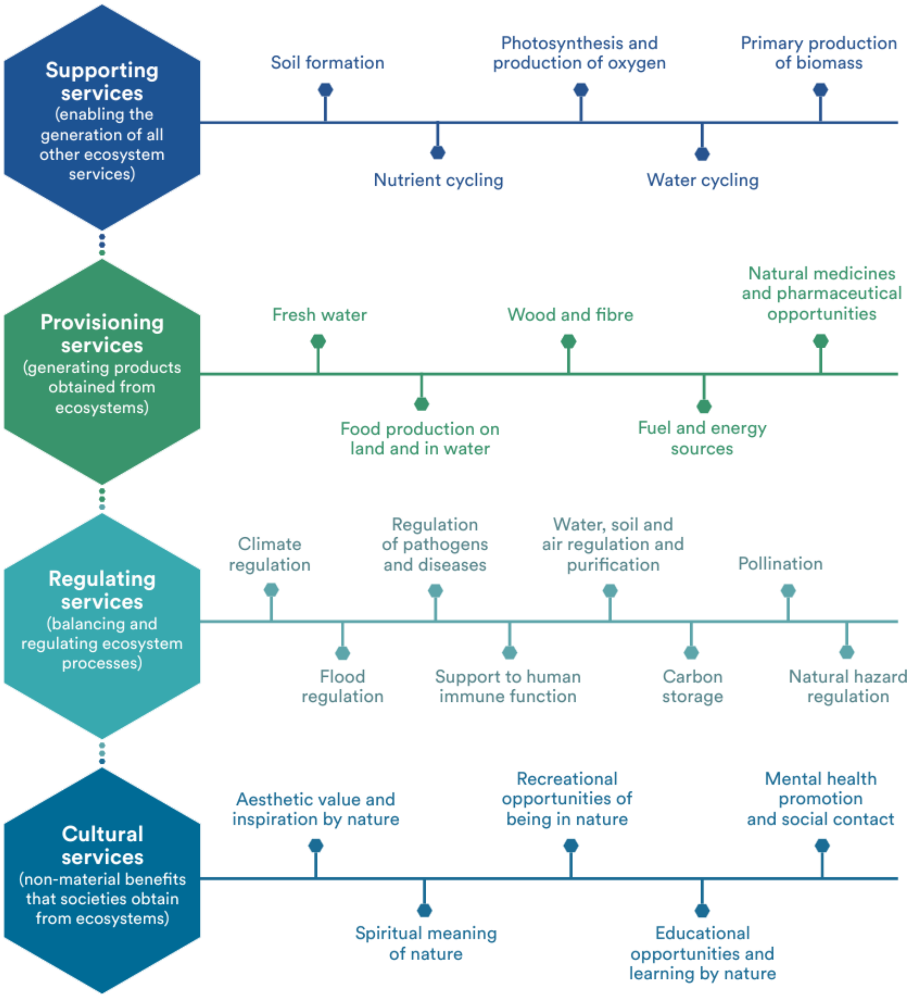


Figure 6: The benefits of nature for health (WHO, 2021)

The European Ministerial Conferences on the Environment and Health Process and the EU Strategy on Environment and Health *(EC, 2003)* states that socioeconomic issues and poverty are the primary determinants of human health, while environmental threats also factor in. Research suggests a strong link between green space, well-being, and health. There is consensus in the opinion that the built environment facilitates or constrains physical activity, supported by several reviews (Lee & Maheswaran, 2011). Epidemiological studies that account for factors including age, sex, marital status, and socioeconomic position have shown a positive correlation between green space and senior citizens' life longevity (*Takano, 2002)*.

GBI, which includes parks, green roofs, and water bodies, provides spaces for recreation and encourages walking and cycling, which contribute to overall physical fitness *(Andersson et al., 2021)*. Access to these areas has been linked to improved mental health outcomes, such as reduced stress and anxiety, which is essential for overall health (Bratman et al., 2012; Lee & Maheswaran, 2011).

According to studies, people who live close to green spaces typically have better health outcomes, including lower rates of diabetes, heart disease, and cerebrovascular illness (Foster et al., 2005; Lee & Maheswaran, 2011; Shaw et al., 2006; Thomas et al., 2006).

The opportunities for social connection in these areas, along with the relaxing benefits of nature, enhance mental health. According to studies, people who spend more time in natural environments report feeling happier and experiencing less psychological distress *(Andersson et al., 2021)*.

Figure 7: Interconnections between nature and health (WHO, 2021)

Psychological well-being

Richard Louv coined the now-famous phrase "nature-deficit disorder" to characterise the negative impacts of children's separation from nature *(Louv, 2006)*, influenced by Edward O. Wilson's "biophilia hypothesis" that highlights the natural bond that people have with nature (Wilson & Kellert, 1995). GI fosters a connection between people and the natural world. The importance of the urban environment in fostering a feeling of place and, consequently, enhancing social cohesion is widely acknowledged *(Pitman et al., 2015)*.

The research conducted by (de Vries, 2010) identified two design concepts for stress reduction: providing high-quality, immersive restorative experiences in green space and optimising visual contact with green features. Planting trees and shrubs along commonly travelled routes to work, school, or shopping could establish visual contact with greenery and reduce stress. To enhance street-level visual contact with green, building facades covered with climbers and creepers would be a highly effective strategy *(de Vries, 2010)*. Research also suggests that green spaces around housing can help residents maintain privacy and prevent feelings of crowding, and green spaces between homes and busy roads can lessen occupant noise annoyance (Nilsson & Berglund, 2006).

According to research conducted on preferences for greenscape designs by *(Honold et al., 2016)*, participants' regular commutes benefit greatly from vegetated pathways and routes. They advise giving greenways more thought during urban planning. Street trees may be a beneficial urban asset to lower the risk of adverse mental health outcomes, according to *(Taylor et al., 2015)*. The characteristics that make an environment restorative are partially determined by the reasons why people visit green infrastructure.

The report by *(Gehrels et al., 2016)* provides many design principles linked to the green space that contribute to human health benefits. The report focuses on developing strategies and design guidelines for green and blue infrastructure that promote climate resilience and create a liveable and healthy space. To foster the design of green spaces for the chosen ecosystem services, pertinent ecosystem services were converted into guidelines or principles by the authors. These design concepts were then divided into five basic categories that affect the efficacy of green spaces: *volume, shape, location, dispersion,* and *maintenance (Gehrels et al., 2016)*.

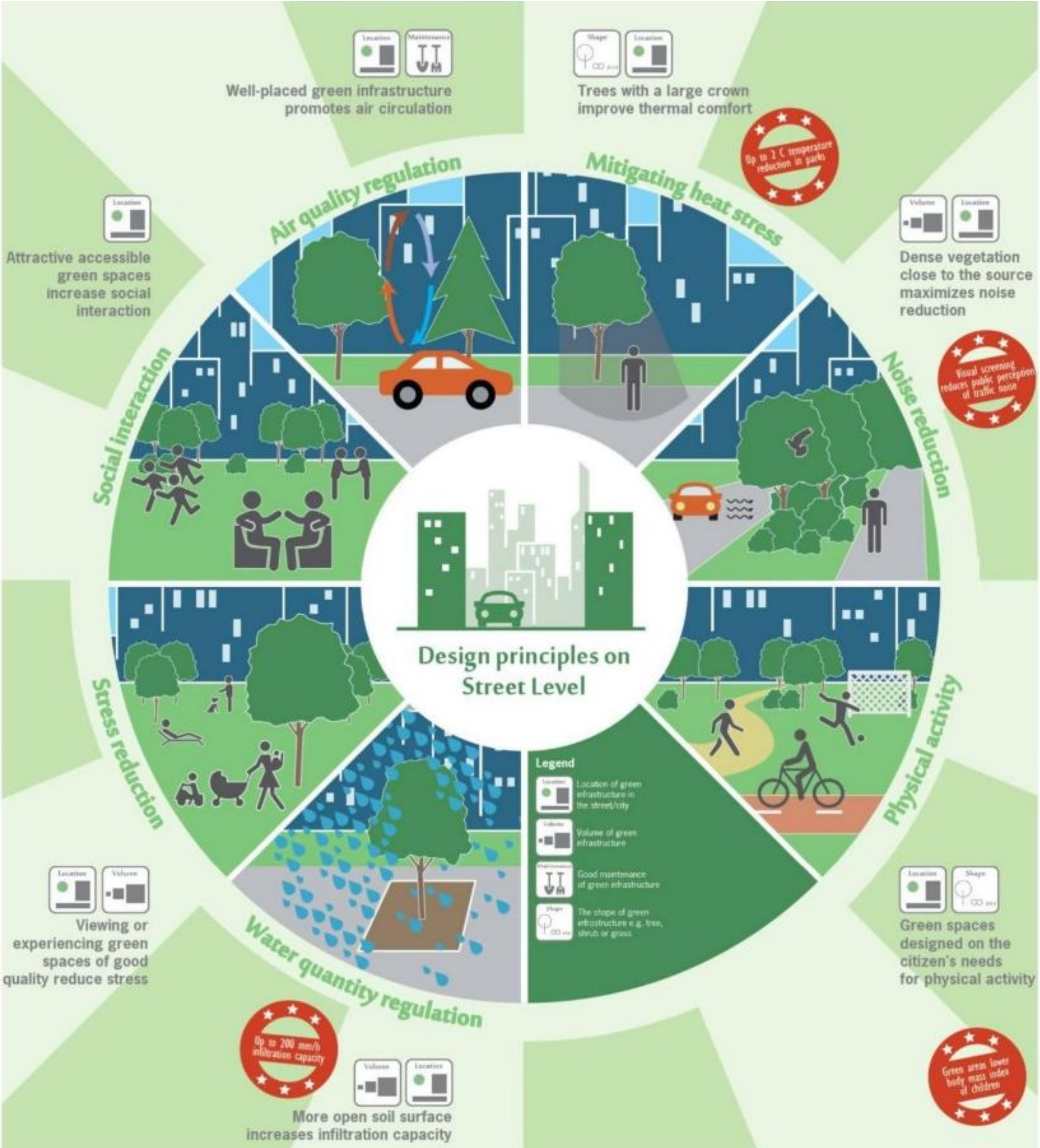


Figure 8: Design Principles for GI at street level to support healthy urban life (Gehrels et al., 2016)

To differentiate when constructing green infrastructure for healthy urban living, two spatial scales were established by *(Gehrels et al., 2016)*: the city as a whole and street level. The design ideas that were developed were combined into the infographics that are displayed in [Figures 9 & Figure 10]. Thus, these two infographics highlight the most crucial elements influencing how well green areas act to provide ecosystem services.

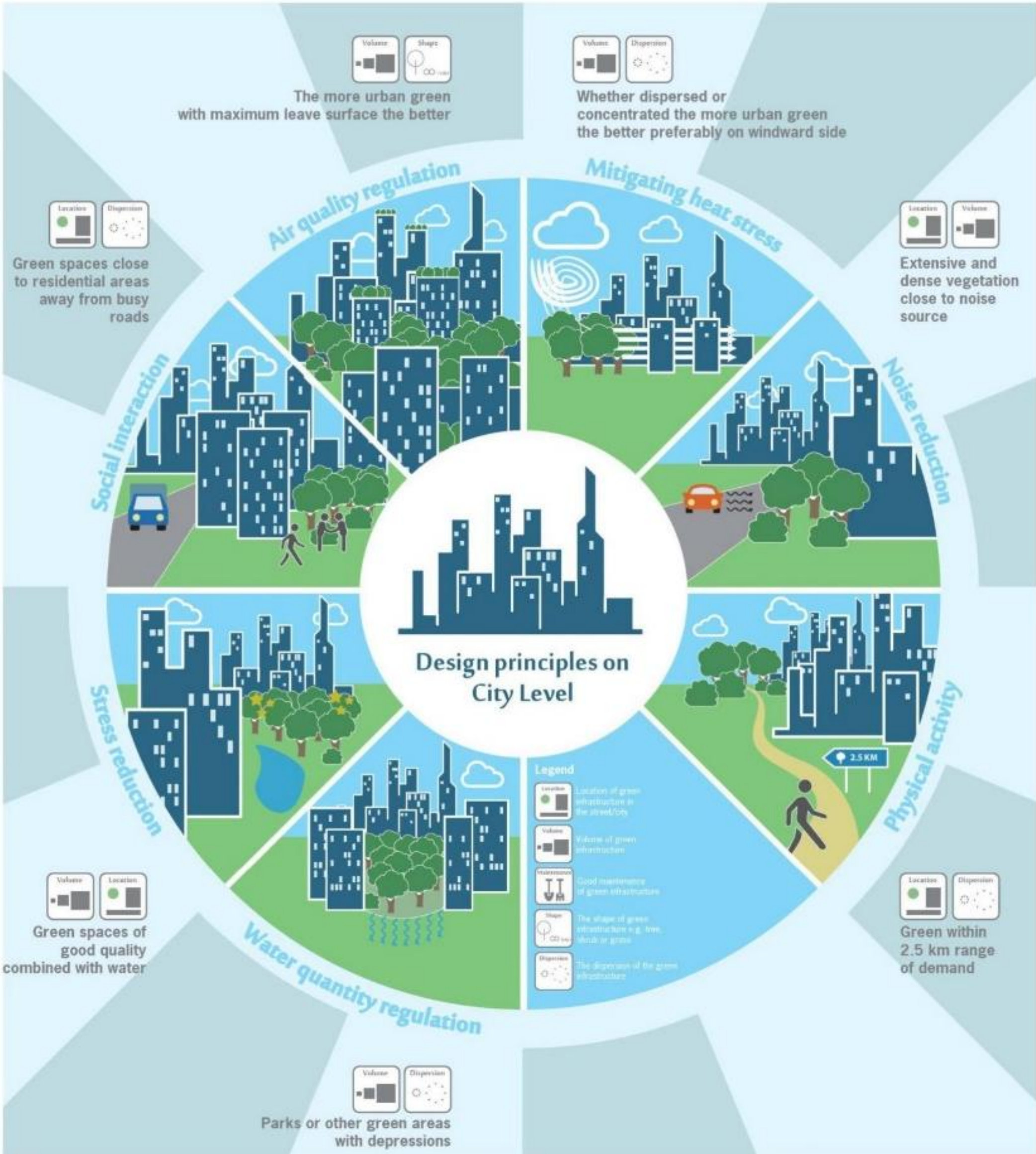


Figure 9: Design Principles for GI at street level to support healthy urban life (Gehrels et al., 2016)

Social well-being

As noted in the previous section, having access to green spaces promotes physical activity, encouraging social interaction (Lee & Maheswaran, 2011). Additionally, GBI highlights indigenous biodiversity and adds to the cultural character of urban areas. The social fabric of neighbourhoods is strengthened by parks and green areas, which provide locations for community events *(Tzoulas et al., 2007)*. Additionally, green areas help citizens in the community feel safe and included, and residents are more likely to interact with each other and take part in community activities when a sense of safety.

On the contrary, neglected green spaces can have a number of downsides. Children and the elderly may be at accidental injury due to factors like overgrown vegetation or uneven ground in neglected areas. Other risks include stagnant water that often acts as a mosquito breeding ground, and overgrown vegetation contains pests that spread disease (Lõhmus & Balbus, 2015). Neglected green areas may discourage people from using them. People are less inclined to exercise in parks that are viewed to be unsafe (Lee & Maheswaran, 2011).

Green space neglect typically disproportionately impacts low-income neighbourhoods, where residents already face numerous challenges to receiving decent healthcare. This inequity has the potential to worsen health disparities among social groups (Ghaleh & Ghaleh, 2020).

II.6. Economic and Ecological Benefits

Economic Impacts of GBI

The economic benefits that come with the betterment of spaces manifest in multiple ways- some of these include an increase in property valuation, creation of green jobs, reduced energy and infrastructure cost, increase in life span of infrastructure, reduction of stormwater fees, increase in tourism and business activity, etc (Shakya & Ahiablame, 2021).

Properties in the vicinity of green areas or blue infrastructure (such as parks, rivers, and lakes) typically have greater value. Social well-being can be further enhanced by the economic upliftment linked to well-maintained GBI, which can result in better funding for infrastructure *(Tzoulas et al., 2007)*. Research indicates that the value of properties near green spaces increased by an average of 5% in Seattle, USA *(USEPA, 2013)*, and that residential properties next to swales, green streets, and other GI practices would have a 3%–5% boost in value *(Bureau of Environmental Services, 2010)*. Another example would be a neighbourhood garden in New York City that increased the value of nearby properties by 9% within five years of its launch *(DEP, 2010)*.

Synthesis research conducted by (Shakya & Ahiablame, 2021) gives a comparative view of the effect on the economic benefits of GI in 16 different cities, out of which 11 cities were situated in the USA, and out of the 16, 15 cities showed an increase in property values and a reduction in energy bills *[Table 3]*.

In Philadelphia, the implementation of GI is projected to save approximately USD 34 million or approximately 370 million kWh (kilowatt hours) in energy costs over 40 years (Raucher & Clements, 2010; Shakya & Ahiablame, 2021). In New York City, street tree shade results in annual energy savings of about USD 27.8 million *(DEP, 2010)*.

Table 3: Economic Benefits of GBI (*Shakya & Ahiablame, 2021*)

Metropolis	Creation of Green Job *	Reduction of Energy Bills	Increase in Property Values	Reduction of Infrastructure Cost and Treatment Cost	Reduction of Flood and Associated Cost
Chicago metropolitan area		√	√		
Cleveland metropolitan Area	√	√	√		√
Greater Austin		√	√		
Kansas City metropolitan Area	√		√	√	√
Los Angeles metropolitan area	√	√	√	√	
Milwaukee metropolitan area	√	√	√	√	
Nashville metropolitan area	√	√	√		√
New York metropolitan area		√	√	√	
Philadelphia metropolitan area	√	√	√	√	
Portland metropolitan area		√	√	√	
Seattle metropolitan area		√	√	√	
Birmingham metropolitan area	√	√	√		√
Copenhagen metropolitan area		√	√		
Greater Tokyo Area (City of Yokohama)		√			
Greater Toronto	√	√	√	√	√
South Australia (Adelaide)		√	√		

Alternatively, the implementation of GI generally necessitates ongoing maintenance and upkeep, which can be costly. Ineffective management of these expenses may result in the degradation of green areas, which could potentially lower property prices. Construction and upkeep of GBI call for a diverse workforce that consists of both skilled and unskilled labour. According to Shakya & Ahiablame (2021), cities like Philadelphia could generate over 250 green jobs a year, eventually resulting in significant savings on social welfare expenses. Over a 40-year period, the savings in Philadelphia are anticipated to be worth USD 125 million *(PWD, 2009)*.

The maintenance of green spaces creates long-term employment opportunities in landscaping, horticulture, and environmental management. The demand for skilled workers in these areas is projected to rise as more cities use GBI as a strategy for climate adaptation *(Lafortezza et al., 2018)*.

Ecological Benefits of GBI

Numerous studies in recent years have indicated that GBI helps contribute to carbon sequestration, increase biodiversity, mitigate of urban heat island effect, and regulate the microbial processes, which all contribute to the ecology of urban areas. Both green and blue infrastructures create corridors that connect fragmented habitats, allowing species to move freely between them, improving ecological functions *(Jim et al., 2015)*.

It has been established that adding urban green spaces will considerably lower daytime temperatures, especially in parks, expecting a reduction of 0.94 °C owing to the cooling effect. Furthermore, depending on emission scenarios, a 10% increase in green area would result in a 2.2–2.5 °C decrease in the surface temperature *(Sussams et al., 2015)*. In addition, the shade of four trees can reduce the amount of energy required to cool a structure by 25%. By doing this, they offset around three to five times as much carbon as a forest tree would.

Research establishes that green roofs support bird species and pollinators, while urban parks serve as a refuge for indigenous flora and fauna. *(Madre et al., 2014)*. Blue Infrastructure, which includes rivers, lakes, wetlands, and ponds are aquatic habitat, crucial for many amphibians and aquatic plants. Wetlands, particularly, are known for their high biodiversity and as critical breeding and feeding grounds for various aquatic species (Zhang & Chui, 2019). In the work done by *Neary et al.,(2009)*, the benefits of water quality are particularly emphasised because they link hydrological and bioecological benefits, since a healthy bioecological regime depends on both the amount and quality of water.

GI can increase the permeability of physical structures, reducing surface runoff and flood risk at a cost of 15-64% less than grey infrastructure *(Naumann et al., 2011)*. According to research, tree cover reduces runoff by 5.7% and green cover by 4.9% in urban areas *(Sussams et al., 2015)*. The highest greening scenario, which comprised a 33% increase in GI and included irrigated green roofs, resulted in a 3∘C temperature drop in Paris *(de Munck et al., 2018)*.

In research carried out by Zhang & Chui (2019), hundred publications related to the hydrological or bioecological benefits of GI practices were selected, and conceptual links were extracted from the literature among the hydrological, water quality, and bioecological benefits of GI practices across various spatial scales (practice, catchment, and continental) [Figure 11]. This gives a clear graphical representation of the bioecological benefits of GBI.

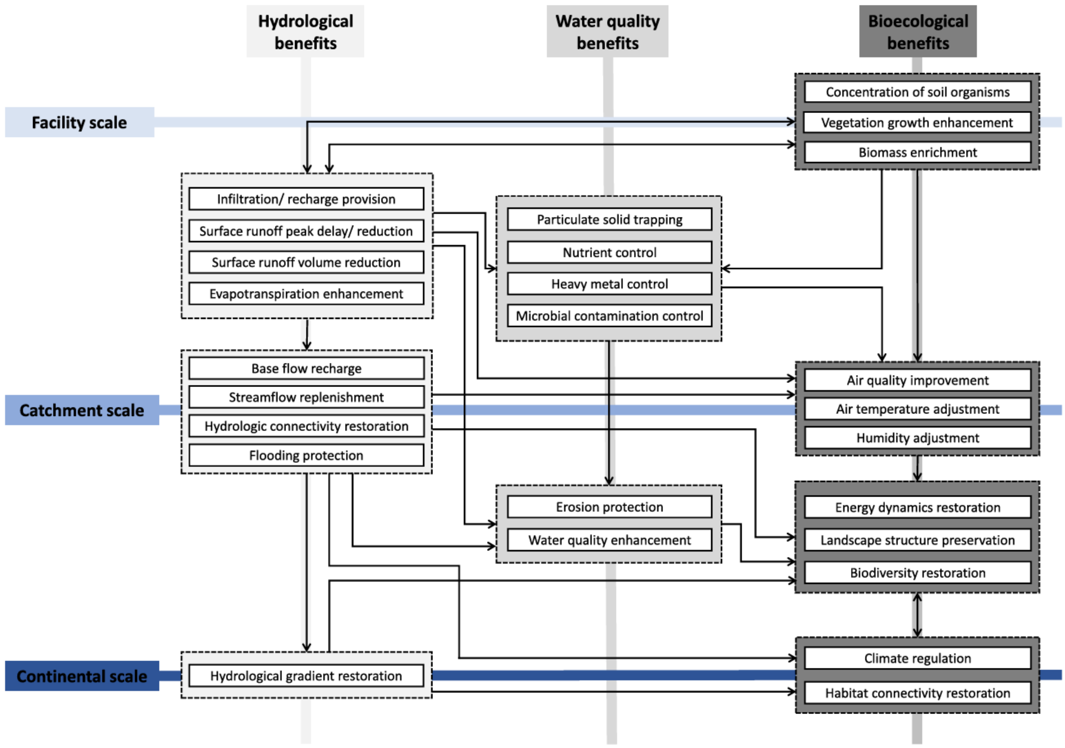


Figure 10: Schematic of the conceptual links between the hydrological and bioecological benefits of GBI practices at various scales (Zhang & Chui, 2019)

In the publication by *(Dhyani et al., 2022)*, the authors list various parts that make up GBI that contribute to urban resilience and sustainability [Figure 10].

Urban wastewater can be sustainably treated with the use of constructed wetlands (CWs). CWs are promising ecosystem-based wastewater treatment technologies with remarkable treatment capability and an environmentally friendly appeal (Dhyani et al., 2022; Stefanakis, 2016). Rain gardens, also known as "bio-retention systems," are frequently utilised to reduce pollution of urban water bodies from nonpoint sources. Rain gardens' physicochemical and biological features help to store runoff water by lowering peak flow and reducing pollutants (Dhyani et al., 2022; Malaviya et al., 2019).

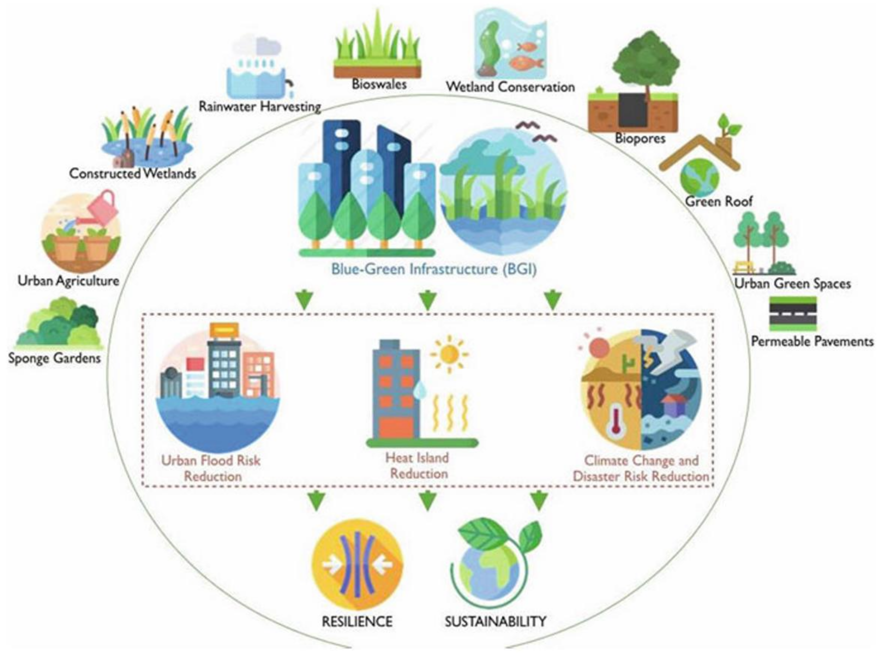


Figure 11: GBI for developing urban resilience and sustainability (Dhyani et al., 2022)

One of the earliest green solutions, bioswales treat road runoff to help prevent flash floods. Trees are an innovative way to release water from flash floods to the atmosphere after the eco-physiological process of transpiration loss, making bioswales an essential component of water-sensitive or low-impact urban architecture. Trees in bioswales contribute 46–72% of water production through transpiration, which lowers runoff (Scharenbroch et al., 2016) According to (Everett et al., 2018), bioswales are seen as highly visible interventions that require the cooperation of urban planners along with citizen participation in order to be implemented and maintained appropriately.

Another efficient way to reduce the effects of flood disasters is to install bio-pore infiltration holes. In crowded cities with marginal water catchment zones, bio-pores are utilised as infiltration holes. By improving groundwater absorption, they decrease the severity and impact of flooding in urban areas (Khusna et al., 2020). These various ecological and economic benefits further improve the liveability of the citizens, cementing the need for GBI in urban planning policies and initiatives.

II.7. Community Participation and Green Equity

In order to properly develop GBI, Community Engagement (CE) is essential to both the planning and maintenance phases. CE is often thought of in a passive way, with citizens being viewed as recipients of information rather than as active participants. In response, researchers Everett et al., (2023) call for "BGI-CE needs to be a broad, inclusive and continuous process with two-way, open and clear communication, transparency and accountability, responsiveness to local context and a focus upon both process and outcomes".

To address current environmental, social, and economic issues, the wide range of benefits of GBI should be enhanced through cross-sectoral collaboration and holistic approaches. All parties—policymakers, citizens, scholars, and others—must establish a shared vocabulary and working methodology (Pamukcu-Albers et al., 2021).

Collaboration involves working with academic research, management practitioners, and creative design groups to support citizen-driven and citizen-conceived processes that leverage existing social capital networks (Hostetler et al., 2011). A notable change in the planning paradigm, citizen-led planning aims to collaborate with planning stakeholders on an egalitarian level while assisting communities in developing a concept for their future requirements and desires (Pichler-Milanovič & Foški, 2015).

The authors Dhyani et al., (2022) call for a "Collaborative, Multiscalar, and Adaptive Management Approaches to guide GBI mainstreaming in urban planning and policy in the global south" [Figure 12]. Various institutional, financial, and legislative incentives can be used to increase public involvement in the implementation of GBI. Maintaining local participation through regular community monitoring is a successful strategy that unites new networks of practitioners, institutions, and communities (Hamel & Tan, 2022).

The authors (Deely & Hynes, 2020) point out that it may be difficult to get support and can hamper the efficacy of projects if the public doesn't comprehend BGI concepts.

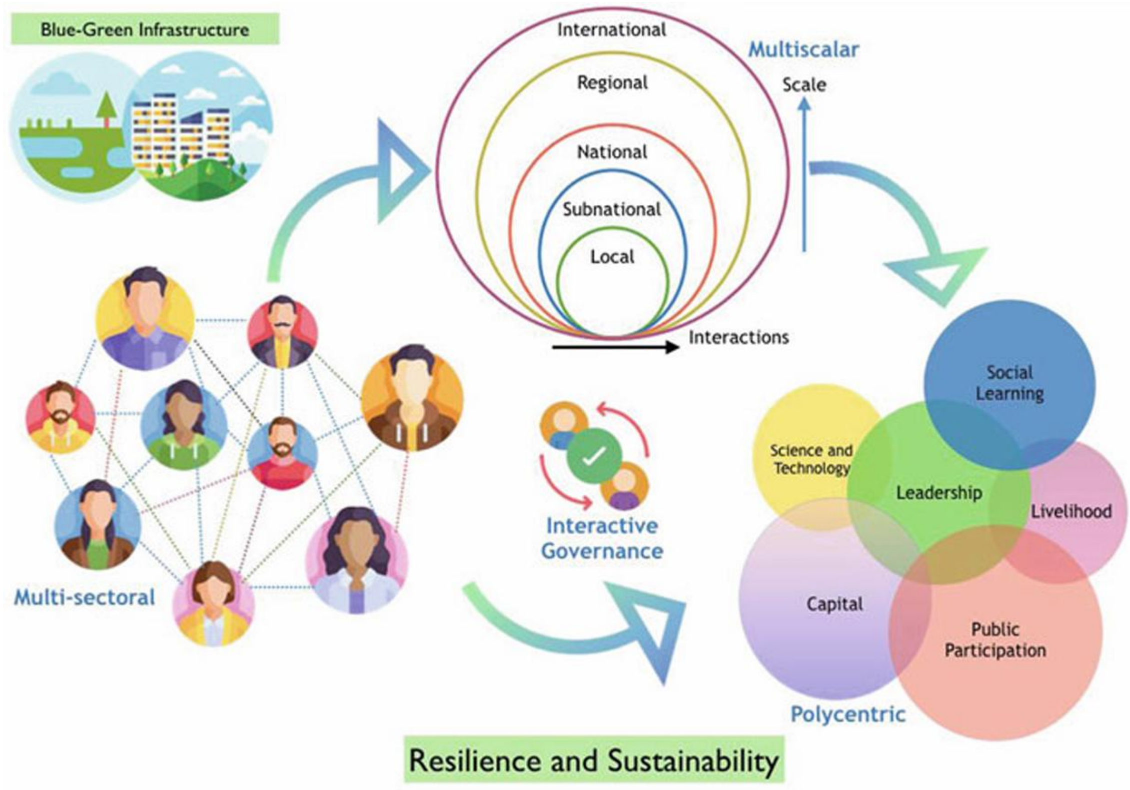


Figure 12: Collaborative, Multiscalar, and Adaptive Management Approaches to guide GBI mainstreaming in urban planning *(Dhyani et al., 2022)*.

Researchers Ghose & Pettygrove, (2014) suggest holding interactive workshops among environmental specialists, urban planners, and community members so that the objectives and culture of the locals are represented, as this offers a platform for an exchange of ideas. Green education programs have also proven to greatly benefit in raising awareness on the advantages of GBI and offering programs on biodiversity conservation by creating an ecologically aware population.

GBI availability and quality

As urban areas continue to expand, the demand for space often leads to the encroachment on green areas, which ultimately affects the ecological balance. The distributional equity of urban greenery in ten US cities was examined in a study by Nesbitt et al., (2019) analyses vegetation using high-resolution land cover and census data. The research showed an unequal distribution which correlated with the existing socioeconomic divisions, and racialised minorities generally had less access to 'mixed and woody vegetation', and higher income and education levels were linked to greater access.

Another study conducted in Germany indicated that higher income, older age, and higher education levels correlated with greater access to urban green space. In this study, households with children also had more access compared to those without, which could be attributed to the need for safe recreational areas for children (Wüstemann et al., 2017).

Furthermore, in the case of Bengaluru's (India) lakes and wooded groves, common BGI management practices like fencing off green and blue spaces and charging for admission frequently run the risk of excluding underprivileged and marginalised urban groups (D'Souza & Nagendra, 2011; Mundoli et al., 2017). Despite this, BGI elements have long been incorporated into informal settlements, which are prevalent in the Global South, to benefit livelihoods. For instance, it was discovered that Bengaluru's slums are rich in different tree species that meet cultural and nutritional needs, and slum residents have unique customs and relationships with urban nature (Gopal & Nagendra, 2014). Incorporating such a variety of land uses and lives will give the urban planning process a pro-poor viewpoint.

Many minority and low-income communities face significant barriers to accessing well-maintained green spaces, which is increasingly recognized as an environmental justice issue. Historical and systemic factors contribute to this inequity, including the philosophy of park design, land development histories, and socio-economic inequalities. Access to urban green space is said to be stratified based on numerous factors, including income, race, and ethnicity, which necessitates targeted interventions to address these inequities (Wolch et al., 2014).

Nesbitt et al., (2019) highlights the importance of understanding local contexts and socioeconomic factors in addressing urban green inequity and suggests that cities should focus on enhancing street trees and residential vegetation to improve access for disadvantaged communities. To avoid further marginalisation of vulnerable social groups, adaptive and responsive planning techniques must be developed that consider all user preferences and analyse social trade-offs in connection with greening outcomes. Rethinking urban green areas as resource commons that benefit all societal segments is necessary, particularly for low-income individuals and women who are frequently excluded (Basu & Nagendra, 2021).

Paradoxical effects associated with Urban Greening Initiatives

Urban greening has numerous positive impacts on the environment and people's quality of life; however, it can also have unintended drawbacks. "Urban greening orthodoxy" tends to overlook fundamental problems of access and distribution, which leads to a situation where the advantages of green projects mask the underlying inequality. The term "green gentrification" or "ecological gentrification" describes this situation, which results in a "green gap" where the advantages aren't distributed equitably and could result in the eviction of the lower-income population (Anguelovski et al., 2018).

Greening strategies have been appropriated as urban regeneration instruments that largely serve the interests of wealthy communities. They usually focus on how the real estate market shapes urban growth, as investors' and developers' interests outweigh those of existing communities. This process frequently creates significant problems with social inclusivity and equality because the process may put profitability ahead of the welfare of residents (Haase et al., 2017).

To address these ramifications, researchers suggest that the quantity of green spaces has a favourable effect on property values, whereas the area ratio has a negative effect. Therefore, in terms of environmental factors, green spaces' accessibility is more significant than their size (Du & Zhang, 2020). There is a call for re-evaluation of planning strategies to ensure they are equitable and inclusive, that give marginalised communities' needs priority, and deal with the underlying social injustices that urban greening can exacerbate.

II.8. Policy Frameworks

THE EU STRATEGY

For the majority, the potential of GBI is already acknowledged. GBI can contribute significantly to regional development, climate change, disaster risk management, agriculture/forestry, and the environment. What is needed now is to make it a standard component of spatial planning and territorial development, fully integrated into policy implementation. In terms of Europe, the EU encourages the use of GBI and NbS for the benefit of citizens and biodiversity. The European Commission claims that GI solutions are especially crucial in urban settings, where over 60% of EU citizens reside (European Commission, 2013). The EU is pursuing this goal through several strategies, some of which include:

“The **EU Green Infrastructure Strategy** aims to preserve, restore and enhance green infrastructure to help stop the loss of biodiversity and enable ecosystems to deliver their services to people.” (European Commission, 2013)

The scale of GI projects can be local, regional, national, or transboundary. However, work on the various GI scales should be interdependent and interconnected in order to maximise GI's benefits and functionality. This indicates that when a minimum level of coherence and consistency is attained across the various scales, the rewards are enhanced. The EU suggests taking actions to raise GI awareness among important stakeholder groups and to encourage best practices, such as creating a specific IT platform for information sharing, within the framework of these primary policy areas *(European Commission, 2013)*.

“The **EU Biodiversity Strategy for 2030** promotes investments in GBI, as well as the systematic integration of healthy ecosystems, GI, and NbS into urban planning. It is a core part of the **European Green Deal** and aims to support a green recovery following the Covid-19 pandemic.” *(European Union, 2020)*

The **European Union’s Horizon** program provides substantial funding for research and innovation projects that combat climate change, advance the EU's growth and competitiveness, and aid in the UN's SDGs. This program supports identifying five mission areas [*Figure 13*], some of which contribute directly to green transitions, including adaptation to climate change, societal transformation, climate-neutral and smart cities, soil health, and food *(European Commission, 2020)*.

Figure 13: Horizon Europe Five mission areas(European Commission, 2020)

A trans-European network for GI, or TEN-G, "would have significant benefits for securing the resilience and vitality of some of Europe's most iconic ecosystems, with consequential social and economic benefits," according to the GI strategy (European Commission, 2013). It was stipulated in 2013 that the Commission would conduct research to evaluate the prospects for creating an EU TEN-G initiative, including a cost-benefit analysis of the initiative's economic, social, and environmental advantages.

According to the 2016 cost-benefit analysis, a more strategic approach to GI at the EU level could yield higher returns per euro invested than the current funding allocation and implementation of GI policies (with a benefit-cost ratio more than double the current approach) (European Commission, 2019).

The EU macroregional strategies (Adriatic-Ionian, Alpine, Baltic Sea, and Danube) serve as effective platforms for designing and implementing GI projects, as well as bringing together countries (EU and non-EU), regions, and stakeholders. A partnership was established in 2017 under the EU's Urban Agenda on Sustainable Use of Land and Nature-Based Solutions, and a call for proposals is also planned under Urban Innovative Actions (ERDF, n.d.), which gives cities the capital to test creative solutions on specific sustainable urban development issues (European Commission, 2019).

Table 4: Policy instruments related to green infrastructure (BISE, 2021)

POLICY	RELEVANCE
The 8th Environment Action Programme (EAP)	The action programme reiterates the EU's long-term vision for 2050 of living well and within planetary boundaries. It sets out priority objectives for 2030 and the conditions needed to achieve these. Building on the European Green Deal, the action programme aims to speed up the transition to a climate-neutral, resource-efficient economy, recognising that human

	wellbeing and prosperity depend on healthy ecosystems.
2013 European Commission strategy for Green Infrastructure (COM/2013/0249)	GI can make a significant contribution to the effective implementation of all policies where some or all of the desired objectives can be achieved through nature-based solutions.
Regional development and cohesion Policy 2021-2027	The EU's main investment policy. In the Commission's proposals for the Cohesion Fund and the European Regional Development Fund (ERDF), GI is specifically identified as one of the investment priorities. GI is recognised as contributing to regional policy and sustainable growth in Europe and facilitating smart and sustainable growth through smart specialisation.
Birds and Habitats Directives (COM/92/43/EEC and COM/79/409/EEC)	Both directives include various connectivity conservation measures for protected areas and the wider environment. Connectivity measures are required to maintain or restore the coherence of the Natura 2000 network.
Water Framework Directive (2000/60/EC) Nitrates Directive (91/676/EEC) Floods Directive (COM (2006)15)	All directives offer GI-related opportunities (for instance, by supporting actions to put in place GI improve soil retention, act as buffer strips between agricultural production and water sources, and provide water storage during flood events)
EU Strategy on Adaptation to Climate Change (COM (2021) 82 final)	The new EU Adaptation Strategy paves the way for a higher ambition on climate resilience: in 2050, the EU will be a climate-resilient society, fully adapted to the unavoidable impacts of climate change.
LIFE 2014-2020 Regulation (EC) No 1293/2013	Amongst other aims, the LIFE Programme dedicates significant financial resources to strengthening the ability of ecosystems to provide multiple crucial ecosystem services, and to increase effectiveness and uptake of GI.
Thematic strategy on the urban environment (EC, 2005)	The strategy underlines the importance of the development of GI in the urban environment.
EU Urban Agenda	The Urban Agenda for the EU is an integrated and coordinated approach to deal with the urban

	dimension of EU and national policies and legislation. GI and nature-based solutions are part of this agenda.
EU forest strategy for 2030	The strategy will contribute to achieving the EU's biodiversity objectives as well as the greenhouse gas emission reduction target of at least 55% by 2030 and climate neutrality by 2050. It recognises the central and multifunctional role of forests, and the contribution of foresters and the entire forest-based value chain for achieving a sustainable and climate-neutral economy by 2050 and preserving lively and prosperous rural areas.
Soil strategy for 2030	The EU soil strategy for 2030 sets out a framework and concrete measures to protect and restore soils and ensure that they are used sustainably. It sets a vision and objectives to achieve healthy soils by 2050, with concrete actions by 2030. It also announces a new Soil Health Law by 2023 to ensure a level playing field and a high level of environmental and health protection
Nature Restoration Law 2022	The aim is to cover at least 20% of the EU's land and sea areas by 2030 with nature restoration measures, and eventually extend these to all ecosystems in need of restoration by 2050

With the help of the 'EnRoute' (Maes et al., 2017) project and 'Horizon' (European Commission, 2020) initiatives on NbS applied in urban settings, understanding of urban GBI is also growing. GI has also been included in the criteria for the European Green Capital and Green Leaf awards, which incentivise practices. Numerous projects started by European cities also focus on GI at the local and city level.

GI can be made more effective if it is further integrated with spatial planning assessment tools such as Environmental Impact Assessment (**EIA**) and Strategic Environment Assessment (**SEA**) that help monitor the progress of the benefits. (European Commission, 2013)

The 2030 Agenda for Sustainable Development

Green and blue infrastructure (GBI) is a crucial strategy contributing towards achieving the UN's 2030 Agenda for Sustainable Development Goals (SDGs).

Research by Tate et al., (2024) includes applying systematic review methodologies to create an evidence gap map of the literature, which looks at GBI's contribution to the SDGs. The results show that most of the studies focused on pollution, urban heat island effects (SDG 11 and SDG 13), and good health and well-being (SDG 3). Whereas SDGs such as responsible consumption (SDG12) and gender equality (SDG5) were under-represented, it seems that the evidence-based data on GBI needs to be supported for policy and program development to improve public health. According to the authors, a transdisciplinary perspective has to be undertaken in identifying varied types of GBI benefits and how it could contribute to sustainable urban development (Tate et al., 2024).

II.9. Innovative Approaches

Smart Technologies for GI Monitoring and Maintenance

Many new technologies are estimated to improve GBI monitoring and maintenance, some of which are the Internet of Things (IoT), Artificial Intelligence (AI), and digital twins. According to research, using IoT sensors strategically aids in gathering environmental data, such as soil moisture and quality of water and air (Yang et al., 2024). IoT integration has additionally been shown to reduce high operating costs and increase GBI maintenance efficiency by up to 30% (Loos et al., 2023).

Along with this, AI includes machine learning and deep learning techniques to analyse the large data collected from IoT devices. AI-enabled GBI management solutions are predicted to reduce maintenance expenses by 25%. With the use of digital twins, GBI designs can be represented virtually, along with their effects on their surroundings & climate. This makes it possible to test GBI initiatives by simulating and predicting the effects of different scenarios, such as extreme weather and long-term climate alterations. (Yang et al., 2024).

Role of GIS and Remote Sensing in GI Planning

Geographic information system (GIS) software like QGIS and ArcGIS, and Storm Water Management software like EPA SWMM (Storm Water Management Model) can greatly aid in analysing and designing GBI. ArcGIS and EPA SWMM analyse urban landscapes and design networks of multifunctional spaces that enhance biodiversity, reduce runoff, and provide health benefits (Kuzniecow Bacchin et al., 2014). High-resolution remote sensing data enables detailed mapping of urban green spaces, surpassing the spatial detail of existing datasets like CORINE Land Cover and Urban Atlas (Vatseva et al., 2016)

ArcGIS can be employed to analyse the spatial configuration and help in mapping flood susceptibility, identifying ecological corridors, and assessing the suitability of various land facets for retrofitting GBI. It can work with various data layers, like soil, geomorphology, and hydrological features, to model and design green-blue corridors. This integration is crucial for understanding the relationships between different landscape elements and their hydrological performance (Kuzniecow Bacchin et al., 2014).

EPA SWMM is a software used to model hydrodynamic behaviour in stormwater systems to simulate the performance of the existing drainage infrastructure for different storm events, thus highlighting flooded nodes and links. The Performance Assessment model assesses the carrying capacity of drainage systems through the simulation of design storms with different return periods. This analysis becomes very important for understanding the actual effectiveness of the proposed GBI in managing stormwater. SWMM can also be used for assessing potential green-blue measures at the micro-catchment level. It gives particular emphasis on the urban form parameters and their consequences on stormwater management, also permitting the modelling of LID controls, such as vegetative swales and bioretention cells to enhance stormwater conveyance and retention (Kuzniecow Bacchin et al., 2014).

III. EMPIRICAL EXPERIENCE OF STRATEGIES AND INITIATIVES

III. Empirical Experience of Strategies and Initiatives

III. 1. Overview

Based on the obtained research data, 15 case studies were selected for in-depth analysis, taking into account their relevance to the research questions and objectives. These 15 cases were chosen based on a number of factors, including their applicability because of their location, which has a distinct geographical, social, and environmental context that greatly contributes to the understanding of how GBI is adopted over various countries. The second is the use of various spatial scales to gain understanding of the scope of its impact and to comprehend how initiatives, ranging in size from small to large, are implemented.

Amongst the 15 case studies, 9 have been conceived under three distinctive programs that support and fund GBI initiatives. These give the study a multi-city perspective of how the resources were used for different projects and aims. The case studies will be analysed according to four stages: the background of the problem, the key initiative or strategy, the outcome, and the limitations. These segregations will provide a broader view of how the GBI affects the liveability of people in a more streamlined manner. Additionally, in order to extract effective design strategies that further support the final section of the research thesis about designing and planning the specific case of GBI to enhance liveability, the selected case studies are examined overall based on their impact.

III. 2. Practices and Initiatives

III.2. 1. Enabling Green and Blue Infrastructure Potential in Complex Social-Ecological Regions [ENABLE]

ENABLE was conceived under the BiodivERsA COFUND Call (2015-2016) on *"Understanding and managing biodiversity dynamics to improve ecosystem functioning and delivery of ecosystem services in a global change context: the cases of soils and sediments, and land-river and seascapes (habitat connectivity, green and blue infrastructures, and naturing cities)*."

Figure 14: Case studies location (BiodivERsA, 2015)

The EU-funded BiodivERsA project 'ENABLE' uses a transdisciplinary systems approach to investigate how social-ecological dynamics relate to GBI's capacity to achieve several objectives, including climate change adaptation and biodiversity conservation. The Stockholm Resilience Centre leads the four-year BiodivERsA-funded research project, which is supported by Ecologic Institute and nine additional research partners (BiodivERsA, 2015). The main goal of ENABLE was to advance the knowledge of GBI to fully realise its potential and effectively manage new global issues. An emphasis was on creating and utilising new analytical methods and tools to assess GBI performance in a transdisciplinary setting (*ENABLE*, 2022).

As part of the transdisciplinary research framework, Ecologic Institute took the lead on evaluating citizens' sociocultural perceptions and preferences and valuation of various GBIs. Together with NINA, Ecologic created methodological guidelines and assisted the five cities in conducting various types of research, including online surveys, structured interviews, group-based deliberative valuation, Q methodology, and multi-criteria decision analysis. The evaluations specifically focused on GBI's supporting services as an urban biodiversity habitat. In the case study sites, Ecologic also assisted with the policy and institutional analysis, as well as the creation of potential policy options (BiodivERsA, 2015).

The initiative used New York City as an external benchmarking node and worked on five case study locations—in Halle, Barcelona, Lodz, Stockholm, and Oslo—

using a systems perspective to examine three main issues related to GBI solutions:

1. How and under what conditions are the benefits provided by GBI most appreciated by people?
2. How are GBI benefits distributed among urban residents, and how accessible are they?
3. How can the continuation of GBI benefit flows be secured in the long term?

Collaborative Focus

Utilising a multimethod approach, the study examined various perspectives on the three topics and compared and contrasted the five case studies. A wide range of data, including surveys and census data, modelling, and participatory research, was used to examine each situation. In the five cities, the project sought to facilitate ongoing communication between the research team and local stakeholders (policy makers, local businesses, civil society initiatives, and citizens) to promote mutual learning and use of diverse perspectives. Factsheets, webinars, social media, a conference, and multi-stakeholder meetings will all provide chances for participatory discussion and learning throughout the project. They also aimed to help mainstream scientific findings in policy and practice across Europe (BiodivERsA, 2015).

The program compiled a series of approaches and tools to support the implementation of urban GBI and published its findings. The project has three main policy briefs published along with a post-analysis of the initiative.

a. Nature Reserve Flaten

Location: Stockholm, Sweden

Year: Feb 2017 - May 2020

Scale: Nature reserve

Main Intervention: Ecological connectivity in Flaten

BACKGROUND

Stockholm is experiencing an influx of citizens and is expected to have 1.3 million inhabitants by 2040. The Stockholm city plan of 2018 – drawing on the city's '*Vision 2040 – a Stockholm for everyone'* aims to improve its parks and natural areas to create stronger green links, along with better features and accessibility within the guidelines of Greener Stockholm. A network of parks, natural areas, and green corridors combine with the many lakes, watercourses, and coastal inlets to create the local green-blue structure reaching into the centre of the city [Figure 16]- helping citizens be close to the GBI. Stockholm has a historically significant landscape that includes old oak landscapes and rocky pine forests with trees, along with waterbodies with high natural value.

Figure 15: The municipal green infrastructure- a network of habitats for oak woodland species, coniferous forest species, and wetland species (Stockholm City Plan, 2018).

As the city grows denser, parks that can handle higher footfall with different activities are required, which is why the city plans to design “Stockholm corridors,” which are essentially green links along frequently used walking routes to improve accessibility. The city plan states the importance of proximity to green spaces as well as the importance of accessibility to these spaces (Stockholm City Plan, 2018).

In February 2017, the City Council approved guidelines for planning, project implementation, and management of the city’s parks and green spaces under ‘Grönare Stockholm’ or ‘Greener Stockholm’. Since its inception, 33 projects have been completed, and more are ongoing or planned. On a spatial scale, the distribution of the project can be visualized in [Figure 17] (*Stockholm Stad*, n.d.).

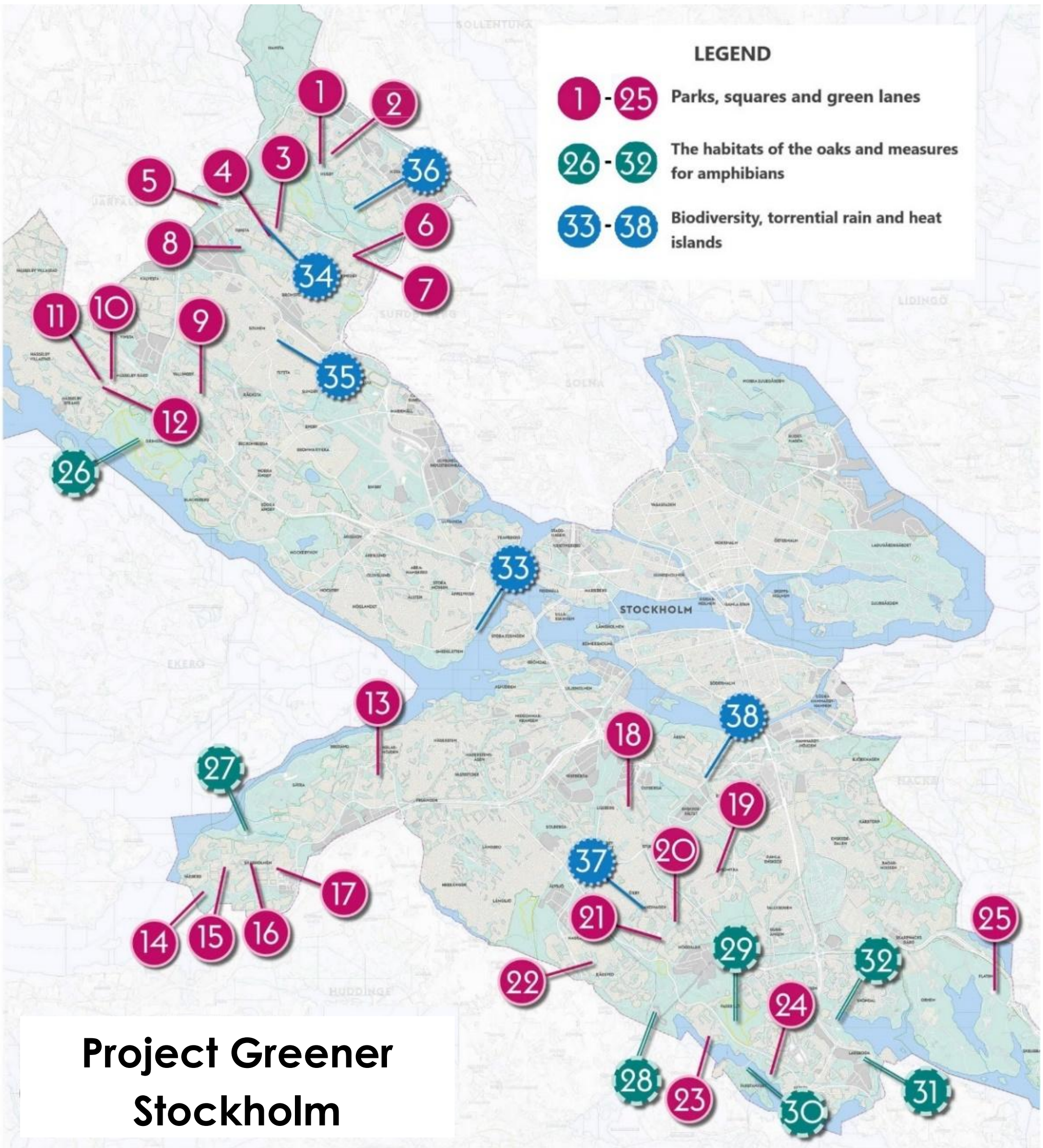


*Figure 16: Grönare Stockholm initiative areas (*Stockholm Stad*, n.d.);*

Nature Reserve Flaten under ENABLE

The GBI intervention under ENABLE focuses on the nature reserve Flaten, located in the southern part of Stockholm, and its surrounding landscape, emphasizing the establishment, maintenance, and development to create functionally connected components of the urban system.

The intervention aimed to benefit the biodiversity of the region and the recreational value by making accessibility better. The design is in response to the intense urbanisation by densification and sprawl. The initiative had numerous obstacles, like ecological connectivity and accessibility in the environment, and a range of socioeconomic standing in the local population. In order to identify the various user groups of the area, as well as common preferences for GBI elements, the Q-method was adopted for urban green spaces in Stockholm as a part of the ENABLE project.

KEY POLICIES

In Sweden, municipal governments have the majority of the real decision-making authority, with a few sector-specific exceptions, while national legislation establishes the institutional framework for local operations. Land use plans and management choices are made and approved by the municipalities, which are also in charge of protecting inhabitants' well-being, conserving biodiversity, and granting access to green space and outdoor recreation.

According to the Stockholm municipality standard, the program "Den gröna promenadstaden" (2006) offers guidelines that seek to provide citizens with accessible parks and green spaces that sustain a vibrant and healthy urban life and meet the requirements of a growing population. Building on this, a successful policy instrument is the Stockholm City Policy- 'Greener Stockholm' (2017) uses a similar formulation and outlines goals that includes which green amenities should be within specific radius of 200, 500 and 1000 meters for the good parks and nature availability to their citizens (Stockholms Stad, 2017). These rules are essential for achieving sustainable growth and safeguarding Stockholm's parks, nature preserves, and waterways. Green spaces and parks in the city are becoming more and more important in addressing the effects of climate change and improving the standard of living for urban residents (ENABLE, 2020c). Another programme in Stockholm that's been going on for 10 years is the 'Aldrig långt till naturen', which is a county-wide initiative for the protection of urban nature. The programme now encompasses 71 new reserves, representing a doubling of the protected area in Stockholm County (*Stockholm Stad*, n.d.). Regulatory Standards - At the national and city-regional levels, Stockholm has qualitative standards; at the municipal level, more quantitative norms are occasionally found; however, these are not legally binding and cannot be enforced (Naumann et al., 2018)

Support for GBI implementation

As part of policy instruments, Stockholm has several guidance documents and tools pertaining to green infrastructure. The Planning division of the Stockholm County Council and the Stockholm County Administrative Board have collaborated for decades on the concepts, policies, and tools pertaining to the **ten green wedges** in relation to the Regional Plan, RUFS 2010. The ten green wedges [Figure 19] of Stockholm are large, continuous green areas that stretch from the surrounding countryside towards the centre of Stockholm, to ensure Stockholm's residents are never far from nature.

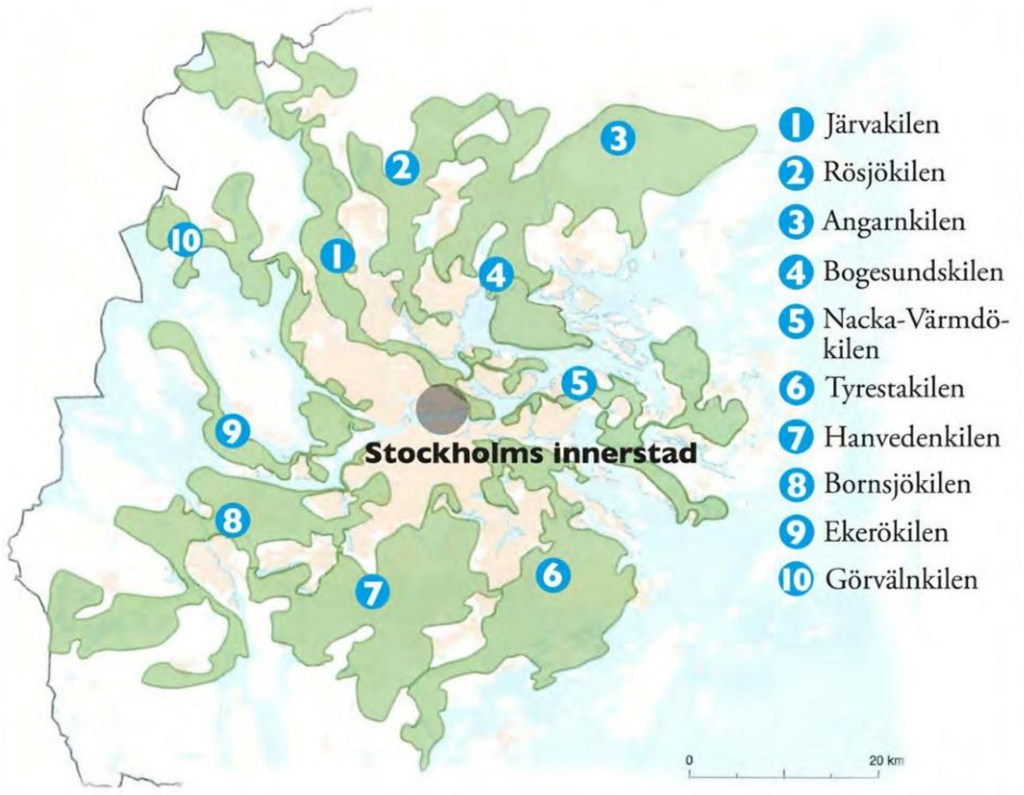


*Figure 17: Stockholm's Ten Wedges (*Gröna Kilar*, 2021)*

The collaboration produced in-depth reports, evaluation of ecologically weak points, the establishment of cooperative platforms for managing individual wedges, and the expression of the wedges' values in landscape analysis and ecosystem services (Naumann et al., 2018).

Stakeholder Collaboration

In Stockholm, stakeholder collaboration is welcome during the development of regional and municipal plans as well as the design of the GBI interventions.

Meetings, remittance procedures, consultations, online commenting platforms, etc., are some ways these are encouraged. Even though participation in these processes can be low, they provide a platform for discussion and debate and for strengthening the role of the citizens in government-led planning processes and alternative planning and design formats. In the aspect of maintenance, municipalities assume the major role along with civil society organisations like the Swedish Society for Nature Conservation and allotment garden associations. During the planning process for the Flaten area of Stockholm, visitor studies were conducted in the nature reserve. These studies included enquiries about activities, transportation, and accessibility (Naumann et al., 2018).

Use of Q-methodology

Within the framework of ENABLE, to adequately address cultural and other ecosystem services associated with GBI and biodiversity, the Q-methodology was chosen for the case of Stockholm. The Q-methodology supports in-depth, qualitative interpretation while also allowing for the statistical interpretation of human subjectivity (Kamal et al., 2014). Using the Q-method in Flaten within the ENABLE project, a study was conducted to identify shared user preferences focusing on potential applications of the result for policymaking in the realm of GBI, where a total of 147 individuals participated. The study identifies 4 main factor profiles that the participants valued [Table 5]. Within the four profiles, the elements valued are the "access to water and the opportunity to spend time on the beach or along", "beauty of untouched nature", and the use of "lakes for water activities" (Röschel et al., 2019).

Table 5: Factors valued in Flaten, Stockholm (Röschel et al., 2019)

Factor profile	Narrative
Wild nature	Value the more "wild" and unmanaged areas to escape the city and noise, and find solitude.
Comfortable nature	Value areas and amenities that are in close proximity to nature, but which are rather grey than green or blue features
Affordable and social nature	Enjoy simple and inexpensive social activities outside.
Well-maintained nature	Wants to execute daily physical activities, such as walking and jogging, in well-maintained surroundings

Research shows that the Q-method tackles concerns like environmental justice and social equity and has a high degree of adaptability. This method is useful because it incorporates the preferences and opinions of people who may be adversely impacted by decisions within planning. The Q-method demonstrated a high degree of inclusivity in capturing the opinions of a wide range of stakeholders with diverse cultural backgrounds (Röschel et al., 2019).

CHALLENGES

Administrative: Since outdoor recreation, education, nature conservation, and urban park management are all housed within separate administrative units in Stockholm, it is unclear who is responsible for implementing GBI measures (Naumann et al., 2018).

Institutional: Due to a lack of capacity to handle cases at both the municipal and regional levels, institutional barriers played a big part. This leads to establishing protected areas even after plans are formulated. Given the fragmented nature of green space management, different stakeholders working on various interventions operate in isolation due to a lack of resources to coordinate relevant actors, which becomes a barrier (Naumann et al., 2018).

Cultural: Although residents appreciate the high proportion of urban green space in the city, the potential of the GBI intervention (i.e., a protected area) was deemed intangible enough.

Financial: The GBI intervention has been unable to maintain a long-term budget due to competition for financial resources with other public services (Naumann et al., 2018).

b. Green Roof Transition

Location: Oslo, Norway

Year: Feb 2017 - May 2020

Scale: City-wide

Main Intervention: Green roofs and walls (building-integrated green structure)

BACKGROUND

In order to establish a shared vision for the city's green roofs strategy, the Agency for Urban Environment in Oslo hosted a number of workshops. The Oslo Municipal Plan chalked out objectives for pollution, greenhouse gas emissions, access to excellent networked green spaces, and stormwater management, creating a strong foundation for the creation of green and blue spaces. These objectives are in line with the European Green Deal and the EU Biodiversity Strategy.

During the pandemic, the physical accessibility of GBI was especially problematic. People could only access green spaces if they were close to their homes during lockdowns, since transportation was limited and travel distances were restricted. Their features also gained significance, for example, to address COVID-19 mobility restrictions, residents of Oslo looked for the greenest public areas with the highest tree coverage (Venter et al., 2020)

Green Roof Transition- ENABLE

The 2019 conference "A Green Transition on Oslo's Roofs" included the participation of the Oslo municipality, suppliers, consultants, researchers, and entrepreneurs, producing some intriguing policy action and tool recommendations for restoring and increasing green roofs (ENABLE, 2020c). This process produced an online mapping tool to assist in prioritising green roofs in Oslo as well as a set of targeted and widely accepted policy recommendations. To ensure that research findings could influence policy, the team also took part in technical committees that developed official guidelines and standards for green and blue infrastructure (ENABLE, 2020b).

The goal of the Oslo GBI intervention was to create methods and tools that incorporate the GBI benefits into both public and private decision-making processes in Oslo. There were several pilot or "beta-version" tools for calculating the advantages of GBI, but they were not well tested and were even less successfully incorporated into Oslo's planning and building permit procedures. The focus was on the evaluation of blue-green structures, such as green walls and roofs, that are primarily intended for flood control and surface run-off management.

KEY POLICY/ STRATEGY

Oslo had two key policies in the realm of GBI: ‘Strategy for City Trees’ and ‘Strategy for Building Integrated Green Structures’.

The goal of the ‘Strategy for City Trees’ (regulatory) is to manage trees to promote public health and well-being. City trees will help solve several environmental issues, preserve biodiversity, and play a key architectural role in urban areas. The ‘Strategy for Building Integrated Green Structures’ (Administrative) aims to outline management objectives, partly by calculating the feasibility to make a case for budget allocation. This administrative policy was noted to be a high-impact strategy for the city of Oslo. It is anticipated that Oslo's Municipal Plan, a regulatory tool that includes targets for transport, pollution, greenhouse gas emissions, and access to excellent networked green spaces, will have a high or medium impact (Naumann et al., 2018).

The goal of the ENABLE program was to establish the standards and prerequisites for the municipality's approval of green roof construction. In order to facilitate decisions regarding green roof investment and maintenance costs in shared ownership estates, another goal was to amend the laws for tenants of collective housing (ENABLE, 2020c).

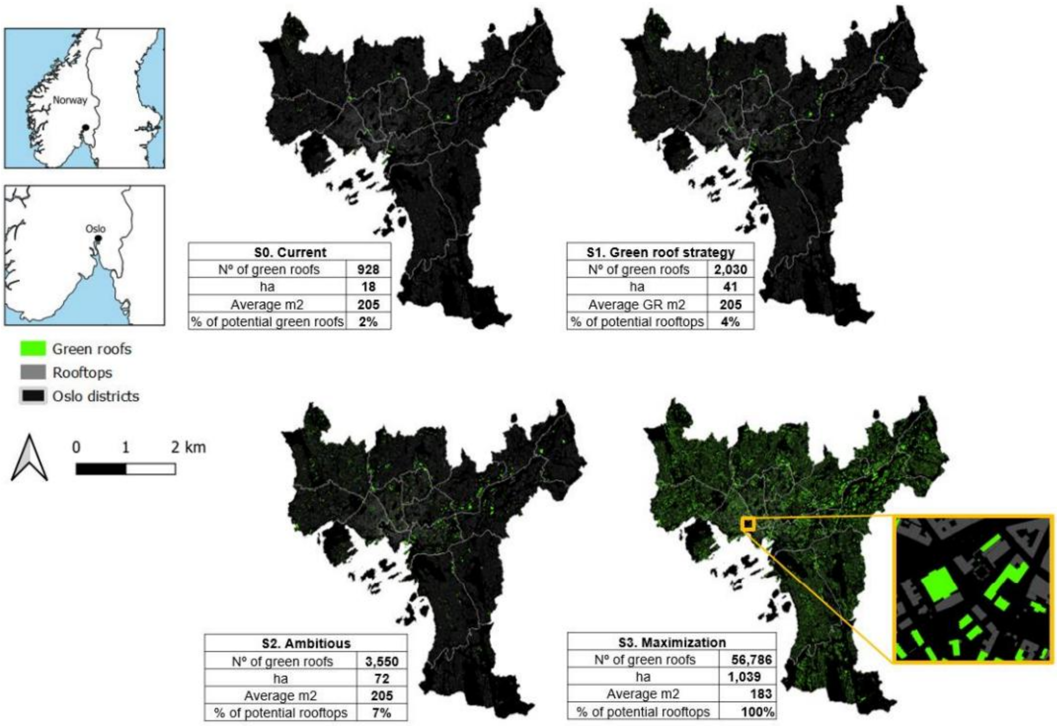


Figure 18: Proposed scenarios for estimating green roofs' impacts on local and broad-scale vulnerabilities (Camacho et al., 2024)

BLUE GREEN FACTOR

Within the framework of ENABLE, to adequately address cultural and other ecosystem services associated with GBI and biodiversity, an assessment method chosen for the case of Oslo was Blue-Green factor scoring. The Blue Green Factor (BGF) is "a factor-based policy tool used to ensure and sustain desired levels of green and blue in new development initiatives". An area-weighted score is calculated for a proposed property development by assigning a score to various 'green' and 'blue' elements according to their significance for one or more ecosystem services (UNaLab, n.d.).

Thus, a green roof module was developed within Oslo's Blue-Green Factor scoring system for existing and newly constructed roofs. To encourage progressive developers to use the BGF as a future "eco-labelling" strategy, the tool suggested minimum standards that serve as voluntary incentives. In a number of the Oslo Region's smaller municipalities, the BGF manual was made mandatory (Naumann et al., 2018).

STAKEHOLDER ENGAGEMENT

The Oslo Green roof transition strategy won an award for green roof ambassadors. In order to involve pertinent stakeholders in the green roof's strategy in Oslo, the Agency for Urban Environment hosted a number of workshops. A wide range of stakeholders participated in policy co-creation processes with the ENABLE team in Oslo. Building owners and managers, social entrepreneurs, the Green Buildings Council, green roof suppliers, and municipal stakeholders participated in a co-creation process centred on green roofs.

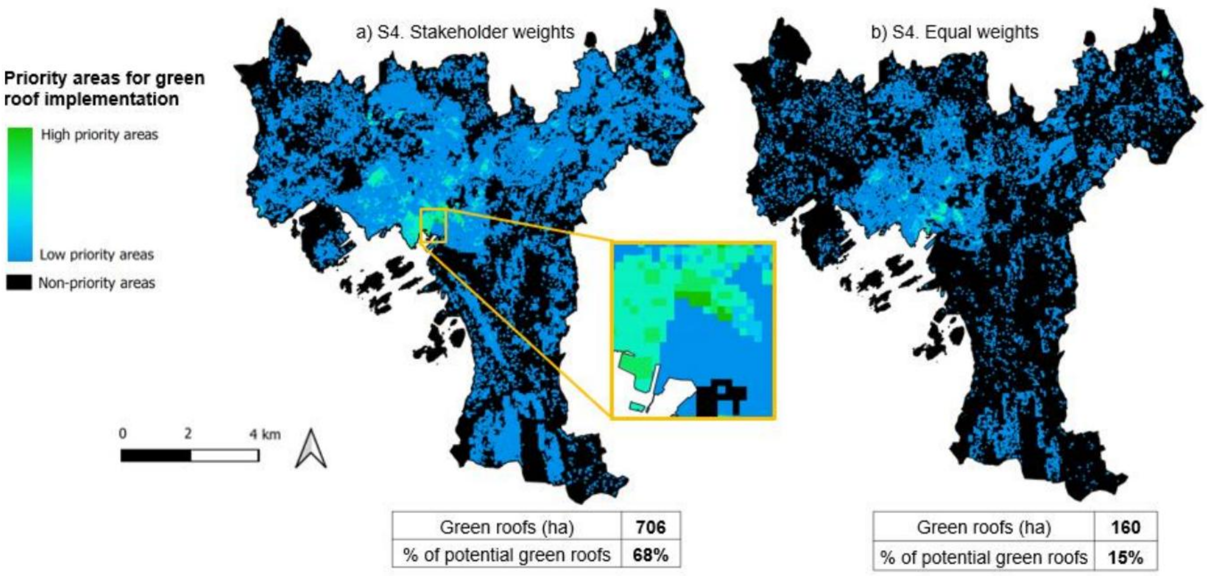


Figure 19: Priority areas for green roof implementation using stakeholder weights (Camacho et al., 2024)

When incorporating GBI preferences, an integrative approach steers clear of designing green spaces that the target group does not actively use. In most case study cities, this strategy has worked well, resulting in the realisation of shared visions between the stakeholders and the administrative city through the integration of preferences and values for GBI. The market potential and the benefits of extensive thin green roofs were promoted as an effort to raise awareness. Along with this, the government made information available on best practices and guidance online. Another citizen's awareness initiative was 'Junior citizen science' – which was a school green roofs lab programme, engaging pupils in simple green roof monitoring (Naumann et al., 2018).

CHALLENGES

Implementation efforts are limited since the government offers no incentives for the use of green roofs. Inexperience with contemporary green roofs has also led to a lack of acceptance, which eventually makes it more difficult to implement them. As for the maintenance, private gardeners look after the rooftops. Although spatial maps of potential for green roofs have been created, there is currently no financial and economic cost-benefit analysis for the GBI intervention's implementation (Naumann et al., 2018). Through programs like the Green Roof Strategy and the Blu-green factor score in urban property development, the Municipality of Oslo is currently pushing for the active planning and development of green roofs to meet the city's 2030 urban targets (*Oslo Kommune*, n.d.).

CURRENT SCENARIO

A similar process of ENABLE was replicated in a participatory workshop organized by URBAG in January 2024, focused on the implementation and impacts of green roofs in Oslo by 2030. Four scenarios for green roof implementation were proposed, ranging from the current state to a maximization of green roofs. During the workshop, a new scenario was suggested and agreed upon by the majority, suggesting 706 hectares of green roofs, which is 68% of the potential area. The workshop also outlined several policy measures (Camacho et al., 2024). Stakeholders underlined that a vulnerability approach might be effective in increasing public awareness of the value of urban green spaces. Additionally, by managing local resources and defining spatial priority areas for green roof implementation, the current assessment would help develop a long-term green roof policy. In order to enhance its scoring system and take into account the effects of NBS on both local and broad-scale vulnerabilities, the Blue-Green Factor approach could integrate findings from vulnerability assessments (Camacho et al., 2024).

c. Natural Park of Collserola

Location: Barcelona, Spain

Year: Feb 2017 - May 2020

Scale: Park

Main Intervention: Natural Park of Collserola

BACKGROUND

With 3.2 million residents spread across 36 municipalities, the Barcelona metropolitan area occupies 636 km^2. Even though the region is densely populated and has complicated metropolitan dynamics, 54.6% of it is made up of open spaces, the great majority of which are protected (more than 90%) (PDU Servei de Redacció Del Pla Director, 2019). Despite this, Barcelona has comparatively little green space per person, as is the case throughout Europe (ENABLE, 2020a). Barcelona, in 2014, published the 'Barcelona Green infrastructure and biodiversity plan for 2020'- which aims to "achieve green infrastructure to act as a resource providing a wealth of services in a city where nature and the urbanity converge and enhance one another"(Ajuntament de Barcelona, 2014). In 2012, the average number of green spaces (parks and forests) per person in ENABLE cities was 155 m^2, while in Barcelona, the average was 13 m^2. In its 2017 stimulus plan for urban green infrastructure, Barcelona set the target of increasing municipal green spaces by 1 m^2 per resident by 2030 (compared to the baseline of 2016).

Natural Park of Collserola

Covering more than 8,000 hectares, the Collserola mountain range is a unique natural area at the centre of a complicated city. As a result, it has a lot of potential to provide ecosystem services at the regional and metropolitan levels, but there isn't much ecological continuity with other adjacent open spaces. The protection plan, PEPNat, was created in 2010 as a result of the establishment of the Serra de Collserola Natural Park. Its goal is to maintain biodiversity and enhance ecosystem services through dynamic and adaptive management (UrbanNext, n.d.).

A special preservation plan has been in place for the Collserola massif since 1987. As part of the Natura 2000 network, it is currently protected as a Natural Park with the goal of preserving these regions' ecological and social functions. In response to the challenge of maintaining biodiversity while offering ecosystem services to the populace in its densely populated surroundings, a new special conservation and public use plan was prepared to appropriately manage Collserola's new protected area classification (Naumann et al., 2018).

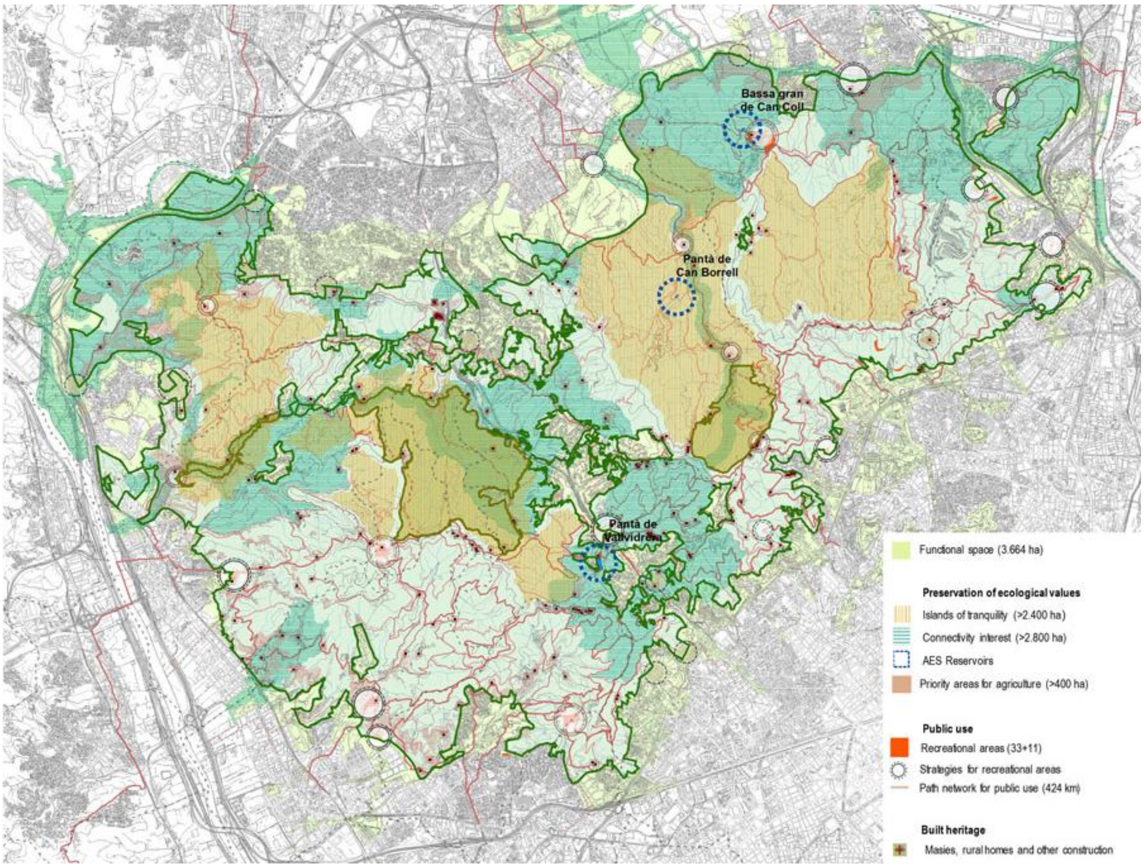


Figure 20: Preservation of ecological values in Barcelona (*UrbanNext, n.d.*)

In order to incorporate the findings of a resilience assessment workshop into the city's open space resilience policy, the ENABLE researchers in Barcelona established a new working relationship with the municipal resilience office. The working relationship entailed determining shared or complementary objectives in order to establish a trusting atmosphere that would facilitate the development of green and blue infrastructure (ENABLE, 2020b).

In Barcelona, the adjacent municipalities fund various initiatives to promote the Natural Park of Collserola, primarily through connecting municipal green spaces to the park, in addition to providing financial support for the park management at a higher scale (Àrea Metropolitana de Barcelona, Diputació de Barcelona, and Generalitat de Catalunya) (Naumann et al., 2018).

KEY POLICY/ STRATEGY

The Metropolitan Master Plan that oversees the implementation of GBI in Barcelona, including 35 more municipalities that are part of the Barcelona metropolitan area. All instruments for Barcelona under ENABLE were plans or programmes, like 'Barcelona Biodiversity and Green Infrastructure Plan 2020', ‘General Metropolitan Plan’, or ‘Trees for Life – Master Plan for Barcelona’s Trees’. Barcelona's ‘Biodiversity and Green Infrastructure Plan 2020’ is a regulatory plan that protects and improves the city's natural heritage so that its residents can enjoy and benefit from it.

‘Trees for Life: Master Plan for Barcelona's Trees’ (2017), which is also a regulatory plan, aims to maximise the benefits that healthy trees offer to the city and the welfare of its citizens by achieving more sustainable management and upkeep that enhances the living conditions for Barcelona's citizens. With the use of this instrument, the city's tree cover has grown by 5%, making up 30% of the total surface area of the city. Additionally, no single tree species makes up more than 15% of the urban area's population, maintaining the diversity of the tree heritage. Making sure that 40% of tree species in urban areas are climate change-adapted (as opposed to the present 30%) has helped to promote resilience to climate change. Within its policy tools, the city already has guiding, non-binding targets and standards for the availability and accessibility of green spaces. The ‘Barcelona Biodiversity and Green Infrastructure Plan 2020 (2013)’ and the ‘Stimulus program for the city's urban green infrastructure’ were two examples of policy tools that were assessed as being highly effective (Naumann et al., 2018).

STAKEHOLDER INVOLVEMENT

The Special Plan for the Protection of the Natural Environment and Landscape of the Collserola Mountain in Barcelona was approved through an integrated public approval process that included public meetings in each participating municipality and interest groups, as well as comments on published documents obtained on the initiative of the general public. The design of the GBI interventions and the creation of regional and local plans invited comments and consideration from experts, stakeholders, and the public.

There were several opportunities for the public to participate in the PepNAT Plan's design and development process in Barcelona. There were open invitations to: attend informational meetings with council members and municipal staff; hold interest group meetings to gather more detailed information and comment on the government-published document online, by mail, or in person.

There is a general advisory board and a scientific board in the Natural Park of Collserola. It consists of 54 officially recognised stakeholder groups and convenes every two years to offer recommendations that the executive board must take into account during decision-making. The board, which is involved in the design, implementation, and management of the park, is made up of various government entities, such as the Catalan government, the Barcelona Provincial Council, the Metropolitan Area of Barcelona, and the nine nearby municipalities.

A separate organisation in Barcelona is responsible for maintaining the park, and a scientific advisory board is present for monitoring it.

CHALLENGES

At the city level, Barcelona occasionally lacks the ability to work across departments. Furthermore, GBI implementation is limited by urban planning master plans, which spatially specify the kinds of land uses permitted at the planning level. Different stakeholders involved in the planning process had different visions, which caused a cultural barrier in Barcelona's Collserola Park. The idea of reducing private transport and turning streets was not supported by the general public.

The implementation was also hampered by a lack of financial incentives to initiate private stewardship action. Another challenge was the insufficient data on the assessment of species richness and habitats in Collserola Park to make informed decisions (Naumann et al., 2018)

In this case, researchers Andersson et al., (2019) propose a framework consisting of three systemic filters that affect the flow of ecosystem service benefits: the interactions among green, blue, and built infrastructures; the regulatory power and governance of institutions; and the perceptions and values of individuals and communities. They argue that addressing these filters is crucial for ensuring equitable access to the benefits provided by GBI. Overall, in order to provide a steady flow of GBI benefits over time in a more resilient Barcelona, knowledge of—and techniques for thoroughly evaluating and aligning—the three systemic filters will be required (Andersson et al., 2019).

III.2. 2. Enhancing Resilience of urban ecosystems through green infrastructure [EnRoute]

The 'Urban Pilot' is a pilot study on urban ecosystems and their services and was conducted in 2015 by the Mapping and Assessment of Ecosystems and their Services (MAES) working group. In order to support their policies, evaluation, and monitoring of GI and the urban ecosystem, cities throughout Europe utilise the framework for GI assessment provided by the 4th MAES report. The European Parliament awarded a grant to EnRoute, a two-year project titled "Enhancing Resilience of Urban Ecosystems through Green Infrastructure," in response to the Urban Pilot (Maes et al., 2017).

The European Commission's EnRoute project is part of the EU's Green Infrastructure and Biodiversity Strategies. EnRoute offers scientific insight on how urban ecosystems can assist with policymaking for sustainable cities at different policy stages and for different spatial scales. In addition to providing guidelines on the development, management, and governance of GBI, its goal is to encourage the implementation of this technology at the local level (Maes et al., 2017) . The project essentially outlined three tasks:

i. Operationalisation of the URBAN MAES framework
ii. Science-policy interface on urban green infrastructure
iii. Networking and improving flows of knowledge and information

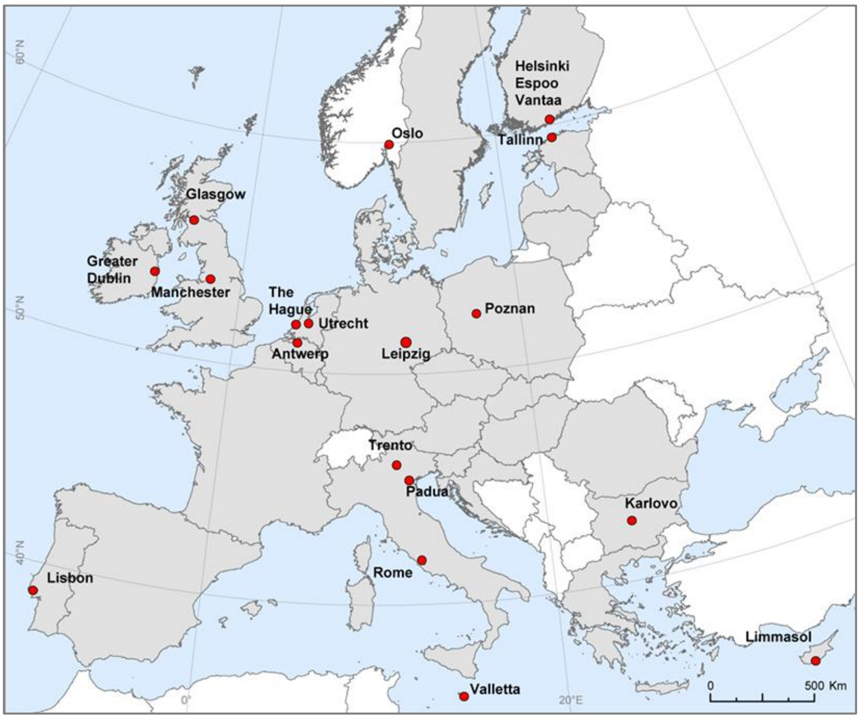


Figure 21: Locations of the 18 EnRoute City Labs (Maes et al., 2019)

EnRoute established 18 case studies, also known as city labs, throughout Europe. In these labs, a group of scientists and policymakers would typically explore how mapping and evaluating urban green space and ecosystem services may help with particular policy issues or challenges.

A unique partnership on sustainable land use and nature-based solutions is part of the EU Urban Agenda (2016), and EnRoute contributed to this partnership. Additionally, Enroute supports SDG 11, which has seven specific goals aimed at improving living conditions in cities and communities. By 2030, universal access to green and public areas that are secure, inclusive, and accessible is another crucial goal. Six key policies/themes emerged from the program that can be addressed using a natural capital approach based on maintaining or enhancing GI *[Figure 20]*

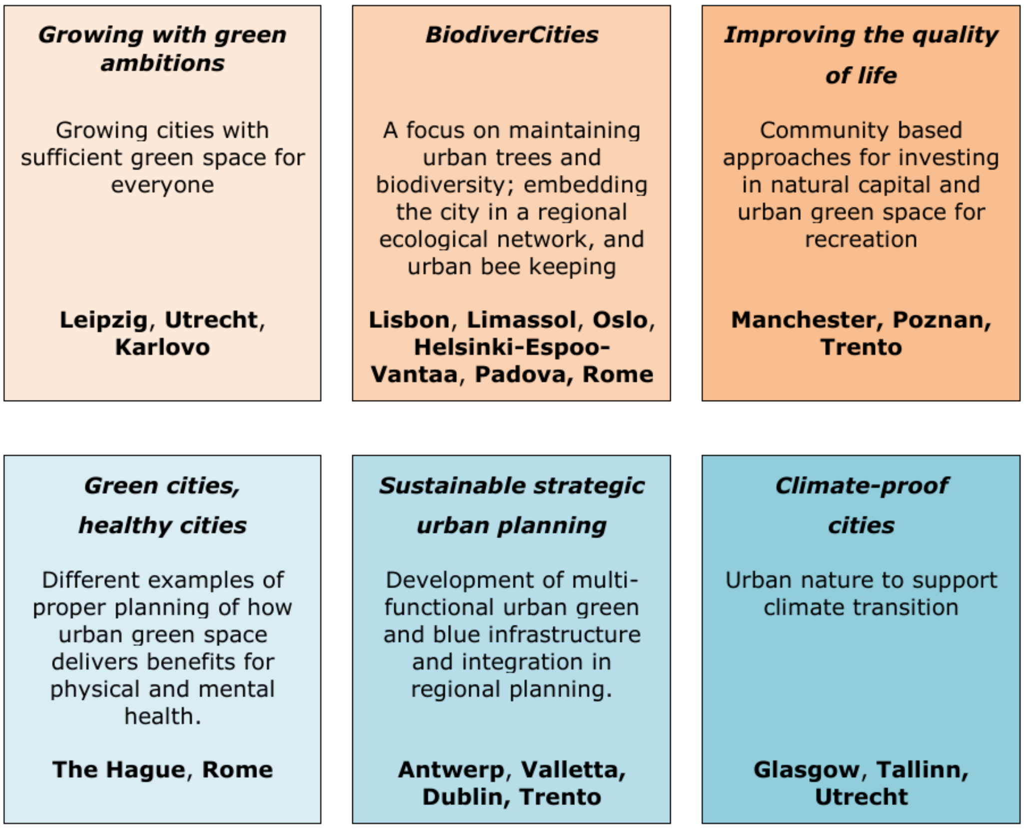


Figure 22: Six Emerging policy challenges in the EnRoute cities (Maes et al., *2019)*

a. Mapping Green Infrastructure

Location: Leipzig, Germany

Year: 2017

Scale: City level

Main Instrument: Accurately mapping green infrastructure

BACKGROUND

Leipzig is an expanding city and is also among the greenest cities in Germany. The city had many brownfields in most areas of the city as a result of deindustrialisation and shrinkage in the 1990s. In 2012, an area of 517 hectares was commercial brownfields (Banzhaf et al., 2018).

The early 2000s saw the development of new green spaces as a result of the urban restructuring, including urban forests, local district parks, urban gardening initiatives, etc. Furthermore, more than 200 green interim uses were created on brownfields (Rink & Behne, 2017). The fundamental principle of planning in the city at the time was "More green, less density", which is now "Leipzig is growing sustainably!" (Stadt Leipzig, 2019).

The increase in population means that there is a smaller area per capita for parks and other public green spaces. Even so, the total area of public green spaces and urban woodlands has expanded.

Figure 23: Access to public green spaces in 2009 and 2016 (Stadt Leipzig, 2019)

EnRoute's- Mapping green infrastructure

For the project, to determine the key indicators for ecosystems and their services, two different spatial scales were considered. Within the Enroute project, the scale of the entire city was important to draw comparisons. In this, the key indicators at the metropolitan scale were drawn out, which include population density, land cover of green spaces, canopy coverage, and the share of urban GI to the total area of the city. The second spatial scale was at the district level, comprising all 63 local districts that represent the urban scale in Leipzig, where the differentiation was observed, mapped, and quantified.

Leipzig experiences flooding due to heavy rainfall and the urban heat island effect, like many other European cities. Therefore, crucial factors include the shading effects of mature trees and the root penetration of vegetation, such as from shrublands and young trees. Another important indicator for root penetration and shading is the number of trees per local district per resident. It was noted through analysis that some local districts lack GI provision, while others have a good amount of vegetation cover. Differentiating the vegetation cover is another way to raise awareness of the need for more shrubs and/or more shade from large trees.

In order to better identify where urban GI was under stress, the Leipzig city lab measured the amount of urban green space at high resolution and integrated it with comprehensive population data. The mapping exercise was an essential foundation for the Green Master Plan. The "double inner development" model was adopted as the basis of the city's master plan (City of Leipzig 2018). Leipzig's city government is currently working to maintain green spaces and control usage pressure. Regarding the GBI in the city, the following question was the focus:

"How can the City of Leipzig maintain or even enhance ecosystem services of green and blue infrastructure under the conditions of dynamic urban growth, land use pressure, and re-compaction?" (Oppla, 2019).

KEY POLICY/ STRATEGY

Many steps have been taken in German cities to conserve and maintain urban nature; well-established tools like nature conservation areas and land use plans have been around for a while. In Germany, GI has gained more attention in recent years in both planning and policy. The Federal Government evaluated urban nature with the "White Paper on Urban Nature", and it provided municipalities with recommendations for future development with the "Green Paper on Urban Nature"(BMUB, 2017). These have been bolstered by action targets and key metrics for measurement from the Federal Institute for Research on Building, Urban Affairs, and Spatial Development (BBSR, 2016)

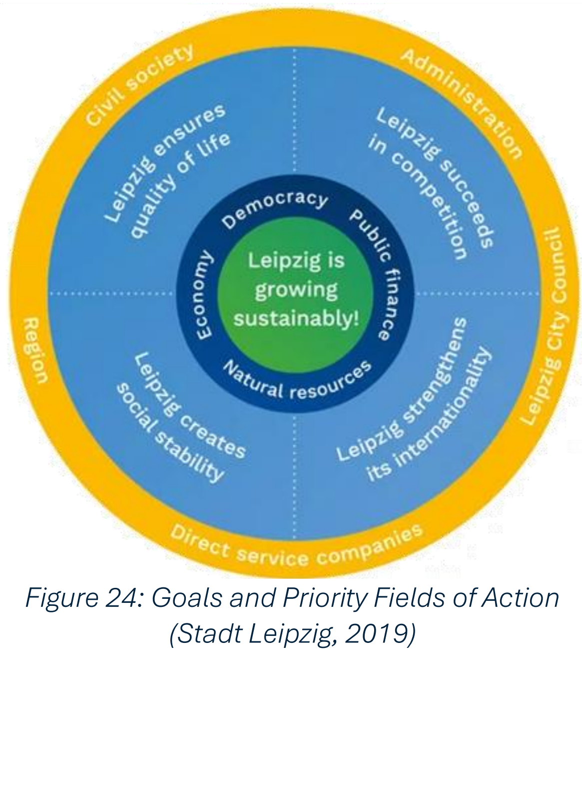


Figure 24: Goals and Priority Fields of Action (Stadt Leipzig, 2019)

The EnRoute project started with the establishment of cooperation structures -the City Lab Leipzig. This included participation from the City of Leipzig's representatives of the Department of Urban Green Areas and Watercourses and the Department of Environmental Protection, along with Senior scientists of UFZ (Department of Urban and Environmental Sociology).

The group focused on contributing to the city of Leipzig's Green Master plan, which had been prepared since 2017. The working group developed an analysis of the green infrastructure of the city based on the data obtained through high-resolution digital orthophotos, a Digital Surface Model (DSM), and ancillary vector data, and mapped green and grey structures for the year 2012. The mapping results and the study's progress were discussed at the transdisciplinary working group meetings and were then incorporated into the Green Master Plan. Mapping and tracking GI is a central desideratum in many cities. The quantitative survey of all current green spaces was the primary goal, along with the qualitative assessment of GI. Mapping, and particularly continuous monitoring, is essential to planning because it is used for evaluation (Oppla, 2019). The 'Concept for Leipzig 2030' also identifies improving 'Green spaces in the city and quality of the built environment' in lieu of the growth of the city and promises to address the issue through sustainable planning [Figure 24] (Stadt Leipzig, 2019)

OUTCOME

As a sort of follow-up project mapping Leipzig's GI for 2018, the Department of Urban Green Areas and Watercourses expressed a great deal of interest in a collaborative monitoring procedure. The project's success depended on the accurate referencing of the City of Leipzig's current plans. Apart from mapping, the city's interest lies in establishing a GI monitoring system that goes beyond the EnRoute scope.

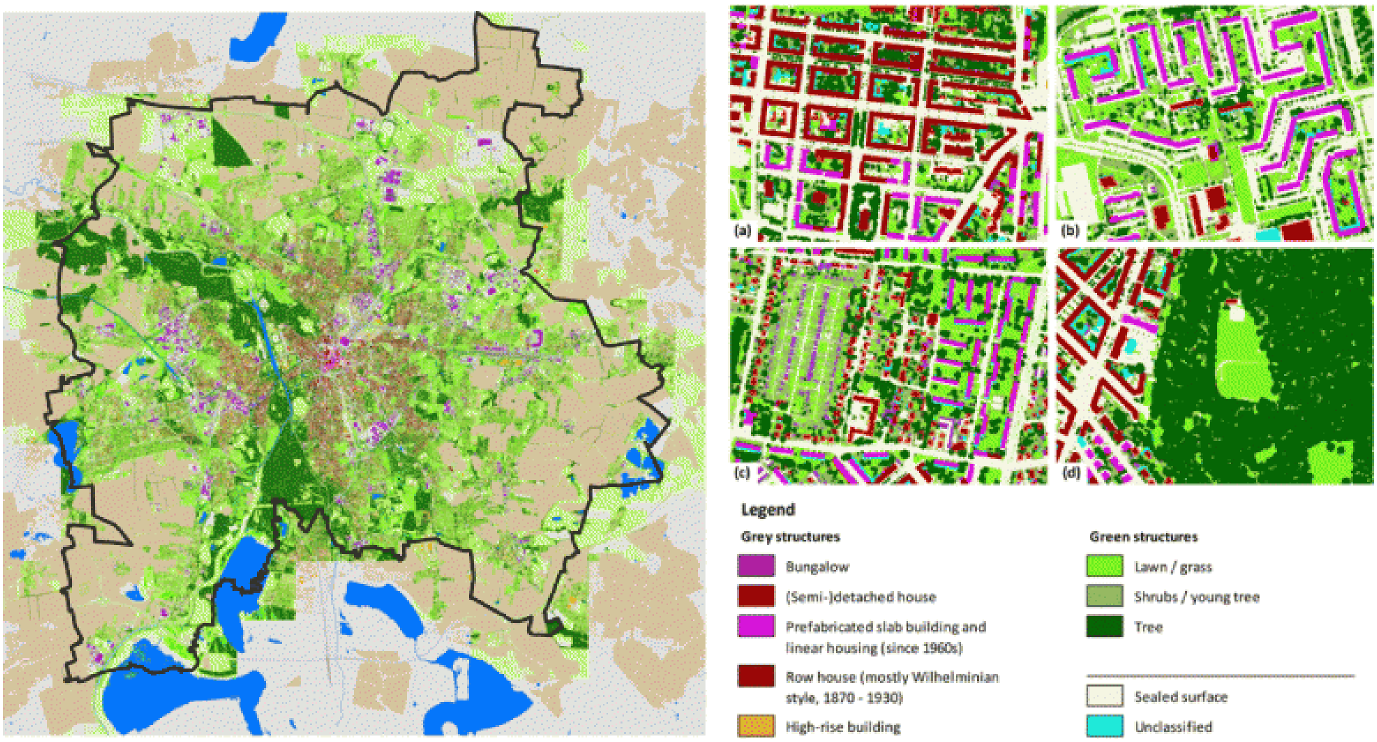


Figure 25: Mapping grey and green structures Leipzig (Rink et al., 2019)

The mapping of green infrastructure for 2012 established a crucial basis for increased cooperation, joint learning, and comprehension between planners and scientists, and as the baseline for the establishment of a monitoring system. Since this data and modelling approach is based on data from remote sensing, it can be used in any European city.

LIMITATIONS

Within this approach, a major factor was the accuracy of the digital ortho photos used by the UFZ team. Since remote sensing techniques mapped from above tend to overlay, many features are not detected. Because of this, ground-level GI features like lawns, meadows, and blue structures were undervalued if they were surrounded by large trees or a lot of shrubland.

Another limitation was the population statistics available up to the district level. The mapped data offers detailed information at a 60 cm scale. As a result, it is evident that the information available in the analysed data differs significantly, and aggregation is required. Therefore, costly neighbourhood-level population statistics would provide a far more sophisticated understanding, particularly in local districts where there is a greater demand for GI- this was also a financial constraint during the study. Leipzig's "growing city" pressures could be better visualised in a monitoring procedure, and only data for the 2012 time step could be examined until the project's conclusion due to data availability. To document changes in urban green and grey structures, further mapping is needed, which is of great importance to policymaking.

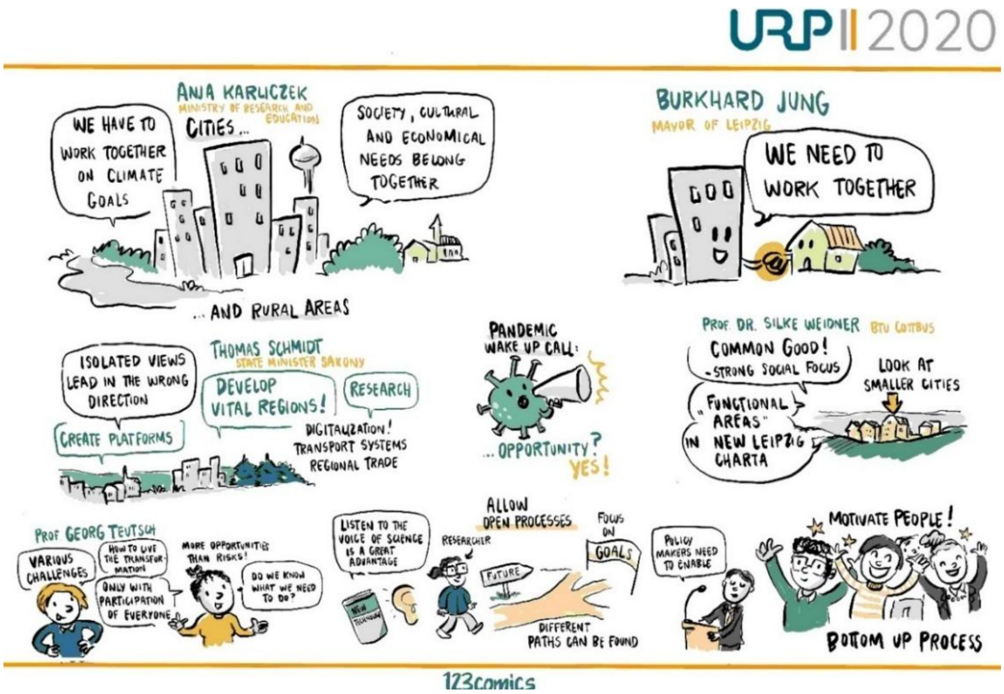


Figure 26: Comic strip- URP2020 Opening Ceremony (Source: 123comics)

b. Preserving BiodiverCities under the pressure of infill development

Location: Helsinki Metropolitan Area, Finland

Year:

Scale: Multi-City level

Main Instrument: Creation of Pollination maps

BACKGROUND

The cities of Helsinki, Espoo, Vantaa, and Kauniainen make up the Helsinki Metropolitan Area, which is situated on Finland's south coast. There are roughly 1.1 million people living in the 772 square kilometre Metropolitan Area. By Finnish standards, the area's housing density is high, with roughly 19% of the nation's population living in just 0.2% of its total land area. There are sizable green spaces and recreational areas in the area despite the land's substantial occupancy. The cities of Helsinki, Espoo, and Vantaa are covered by EnRoute City Lab (HEV).

Helsinki, like many European capitals, is expected to grow denser over time. Compared to other European capitals, Helsinki still had a comparatively high percentage of green space in 2014 (47% of the total area). Similarly, Espoo is the fastest-growing city in Finland and the country's second-largest city. Thus, one of the issues associated with the rapid yearly population growth is maintaining ecological connectivity (Helsinki, 2019). The fourth-largest city in Finland, Vantaa, has led the way in implementing nature-based solutions, such as stormwater management. The city wants to prevent urban flooding, develop the River Vantaa Njoki for migratory fish, and expand the opportunities for outdoor recreation along riverbanks (Helsinki, 2019).

KEY INITIATIVE

In Helsinki, Espoo, and Vantaa, the primary policy concern was "how to accommodate the constantly growing population and the consequent continuous need for construction in a sustainable way." In the HEV area, the urban development policy is to keep new construction inside the dense urban structure and prevent urban sprawl. Since infill development frequently occurs in green spaces, the problem is how to place it without critically harming biodiversity and ecosystem services. All HEV cities has the green space network and ecological links mapped. Additionally, they also have a partial assessment of ecosystem services (Helsinki, 2019).

The most well-known ecosystem services to HEV's environmental specialists and urban planners are the recreational opportunities offered by nature. Pollination was chosen as the primary service because there was no prior knowledge on the topic. From the perspective of biodiversity and pollination service provision, the question was whether ‘pollination maps could be used to prioritise urban green spaces and protect the most significant ones’. Pollination maps emphasise the importance of even small green spaces, as well as private gardens and flower-filled yards, in terms of infill development within the already dense areas. Planners and practical managers of green spaces can benefit from using pollination potential maps, as pollinator-friendly urban green spaces bloom continuously throughout the summer. All efforts to maintain appropriate habitats for wild pollinators are crucial in light of the disappearance of pollinators. This falls within the purview of policymaking in cities as well (Helsinki, 2019).

OUTCOMES

The primary indicator to be mapped in the EnRoute project was the suitability of the current green spaces to support pollinators. Additionally, several other indicators deemed significant by the HEV city lab were mapped as part of SYKE's self-funded activity, namely:

- Built-up area of all land area (%)
- Land taken for construction (new built-up areas) between 2006 -2012
- Impervious and pervious land cover (%)
- Accessibility to green areas from kindergartens (as an indicator of urban cultural ecosystem service)
- Land areas suitable for nature-based recreation
- Accessibility to close-to-home recreation areas

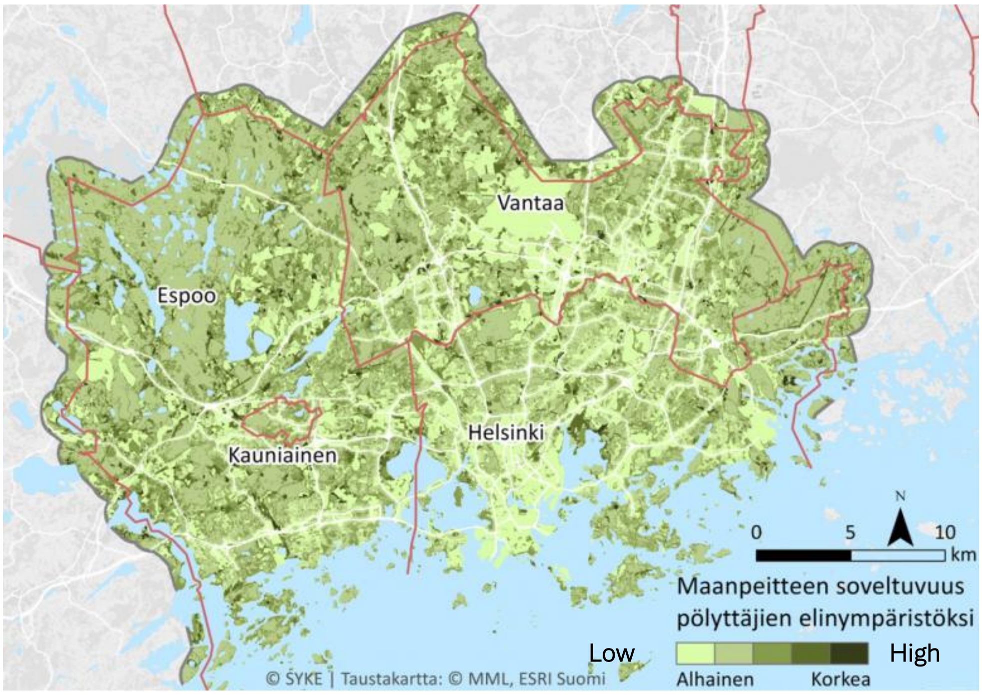


Figure 27: Suitability of the land types for pollinators, i.e., pollination potential map of the Helsinki Metropolitan Area (Helsinki, 2019)

The map of the suitability of existing green areas to support pollinators was made for the area [Figure 24]. Naturally occurring nesting and foraging locations for the most significant wild pollinators, particularly bumble bees, were depicted on the pollination potential map. These include meadows, flowering gardens, green strips, forest edges, and park areas with bushes and trees. There are numerous locations along the water's edge where the habitat types appear to favour pollinators, even though the waterside itself does not improve suitability for pollinators. Hot spots were typically identified as areas with minimal management (almost wasteland) and meticulously maintained areas like cemeteries and public gardens with rigorous management. Areas that support pollinators appear to primarily align with established green spaces when compared to the coarse-scale green area maps of HEV cities, though the situation may be different on a finer scale (Helsinki, 2019).

LIMITATIONS

The model reported that the use of local data obtained from multiple cities was limited by the fact that it was inconsistent in terms of content, spatial scale, quality, etc. Furthermore, due to the fine scale and temporal variability of the phenomenon, a large amount of data that would enhance the model does not exist. For example, the data on the location of flowering plants that are preferred by wild pollinators. Maps created by a model may not always accurately depict spatial reality, which further requires fieldwork to validate the generated maps; that is, wild pollinators observed in the field in the event of pollination. There are only a few isolated, dispersed studies on wild pollinators in HEV cities (Helsinki, 2019).

c. A local, collaborative, natural capital approach to enhance the value of nature in Manchester

Location: Manchester, United Kingdom

Year: 2017

Scale: City

Main Instrument: The Local Action Plan (LAP)

BACKGROUND

For many years, Manchester's success has been attributed in part to its green infrastructure (GI). The City Council acknowledged in 2015 that both new and existing GI will need to remain an integrated part of the city's growth as it continues to expand over the ensuing decades. They created the now-award-winning City of Manchester Green and Blue Infrastructure Strategy in 2015 (CIEEM, 2018). The strategy outlines how this will be accomplished over the next decade, combining the progress made thus far with the commitments already made on GI. Through consultation with local stakeholders and using data and evidence specific to the area, the framework was intended to be co-created, improved, and customised.

The EnRoute Project in the City of Manchester was built on the work done for the Local Action Plan (LAP) through a series of workshops with policymakers, practitioners, and other professional stakeholders. The technical research team and the City Council policy lead worked together to develop the EnRoute strategy that was implemented in the city. Four goals are outlined in the GI Strategy to help realise the vision:

1. Improve the quality and function of the existing GBI to maximize the benefits it delivers.
2. Use appropriate GBI as a key component of new developments to help create successful neighbourhoods and support the city's growth.
3. Improve connectivity and accessibility to GBI within the city and beyond.
4. Improve and promote a wider understanding and awareness of the benefits that GBI provides to residents, the economy, and the local environment (Manchester City Council, 2019).

KEY POLICY/ STRATEGY

During the Local Action Project (LAP) and the EnRoute CityLab, a straightforward but meticulously studied framework was created for evaluating the benefits of ecosystem services and natural capital in the city. The goal was for the framework to be co-created, refined, and tailored in consultation with local stakeholders, as well as with locally specific data and evidence, so that it could be a powerful enabler for people attempting to deliver local actions in urban environments. In order to create a baseline of the net-benefits that residents of a particular community or a number of communities experience, the assessment method describes a set of 12 indicators that are represented by a 'net-wheel graphic' [Figure 25]. This was done for 32 wards in the city of Manchester.

"*The LAP approach includes a simple, but consistent and robust framework for the assessment of natural capital- and ecosystem services-derived benefits in urban landscapes has been developed. The multi-indicator graphics produced have been referred to as Ecosystem Service Benefits 'Wheels'."(Manchester City Council, 2019)*

By providing a highly visual and interactive multi-parameter assessment of need/opportunity for action, the Wheels encourage informed discussion among decision-makers, practitioners, and local stakeholders. This should aid in fostering a shared vision and a consensus for a more informed decision-making process at the local scale.

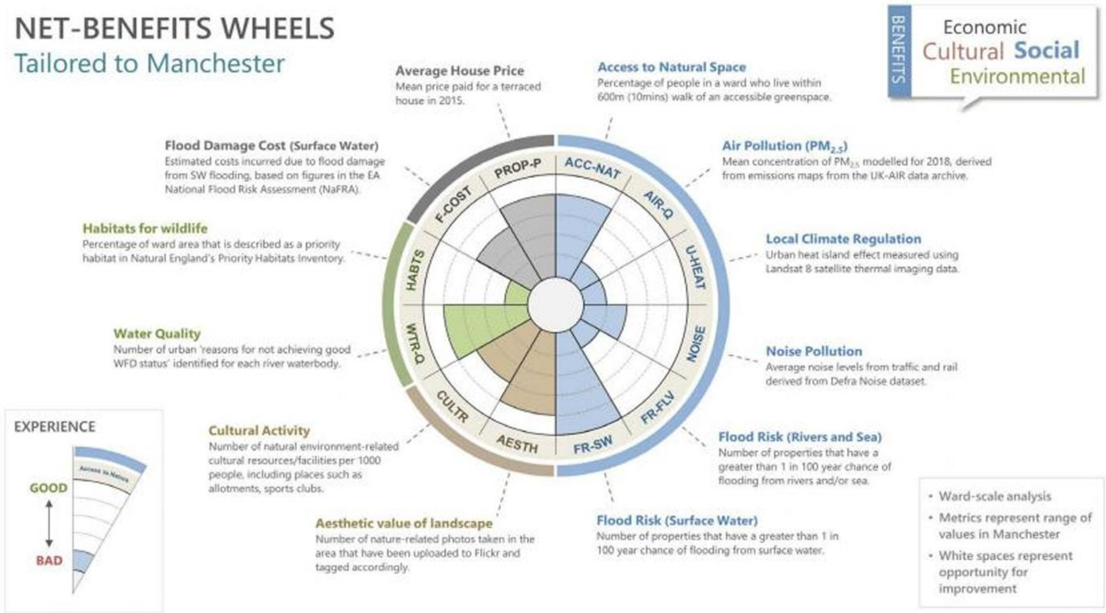
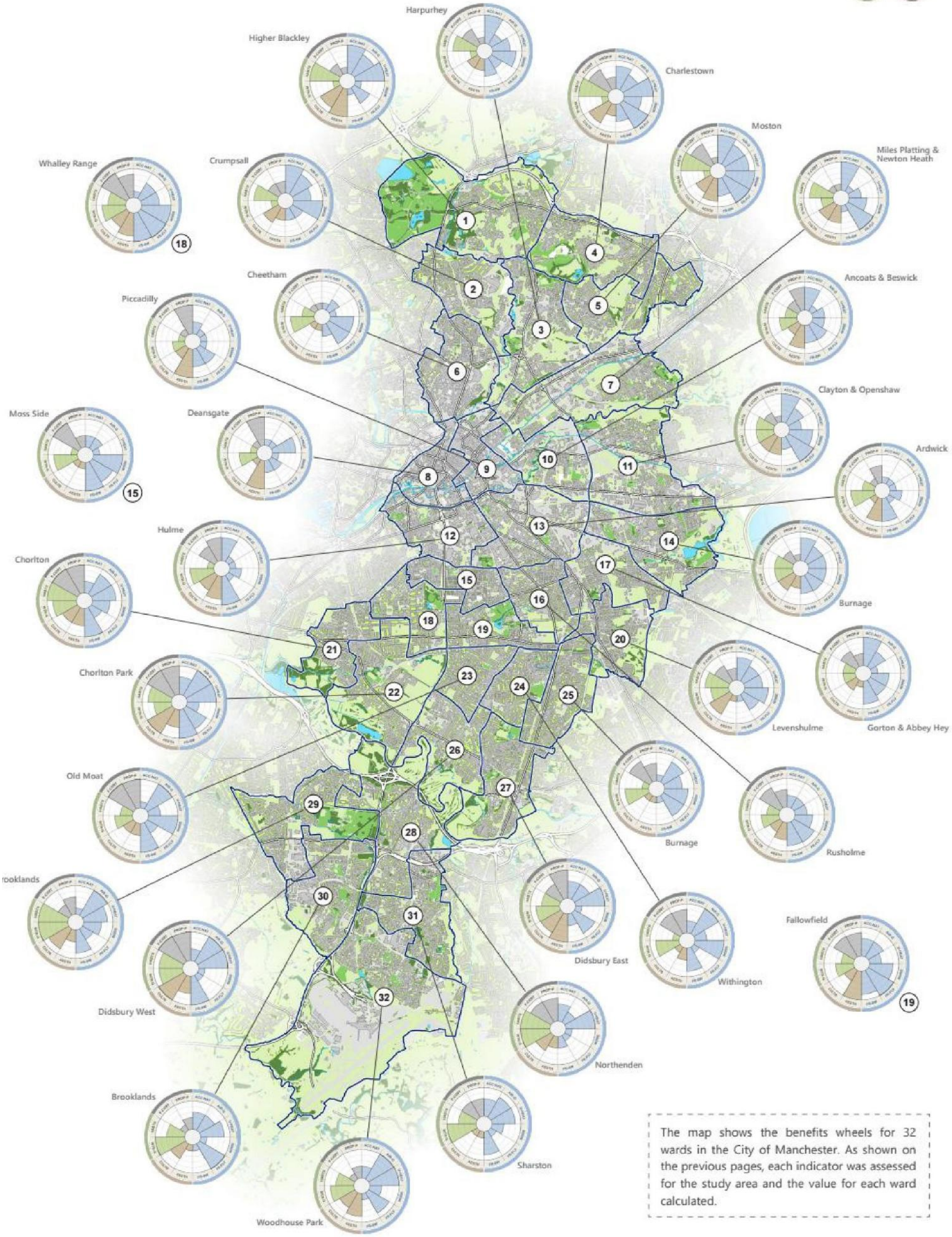


Figure 28: Net Benefits Wheel (Manchester City Council, 2019)

When it comes to emphasising the value of GBI for cities, Manchester's Great Outdoors (MGO), the GBI Strategy, sets the standard. It aligns the GBI agenda with other city-specific thematic concerns, such as economic growth and health and well-being. The EnRoute CityLab approach enables presenting a convincing argument in an accessible manner: GBI is the modern city's life support system and a major factor in achieving the liveability goals of the 'Our Manchester Strategy', seeking to facilitate better decision-making.

INDICATOR SUMMARY

Ward-Level Assessment



The map shows the benefits wheels for 32 wards in the City of Manchester. As shown on the previous pages, each indicator was assessed for the study area and the value for each ward calculated.

OUTCOMES

MGO serves as the strategic backdrop for a number of initiatives, such as monitoring of GBI activities throughout the city, highlighting best practices, influencing master planning in a positive way, and assisting with funding bids. The strategy was created 'for the city, by the city,' with 32 partner organisations contributing to its development and execution. MGO now serves as a benchmark for effectively achieving important aspects of the city's long-term 'Our Manchester' vision (Barlow & Paling, 2018). The CityLab project under this was an innovative project that examined the general operation of the city's GBI and assisted in identifying potential interventions that could enhance the functionality of the landscape at the ward level. To guide its analysis, the CityLab has combined data from a variety of in-depth, state-of-the-art research outputs. The 'My Back Yard' project, for instance, fundamentally changed the city's perception of Manchester's garden spaces(Manchester City Council, 2019).

Furthermore, the LAP-EnRoute strategy was created especially to support the goals outlined in the 25-Year Environment Plan (25-YEP) of the UK Government. Several fundamental principles form the basis of the 25-YEP. It is intended to support local, cooperative adaptive management of the environment by empowering and engaging local communities in preserving and enhancing the value of natural capital in their landscapes to improve the economy, the environment, and quality of life (Manchester City Council, 2019).

Throughout the EnRoute project, various organisations in Manchester worked together to produce detailed datasets that describe the location and character of the natural capital assets throughout the city. Additionally, the EnRoute CityLab project gave an assessment of GBI functionality, which was improved and refined using the most recent datasets and analysis tools.

LIMITATIONS

The quality and accessibility of the spatial data needed for the evaluation of indicators are the approach's biggest drawbacks. Additionally, there are a number of essential and high-quality datasets in the UK that may be used in this evaluation of natural assets, but their availability is constrained by commercial interests. Another limitation within the project was the data showing the condition or quality of the natural assets to carry out their ecosystem services activities and produce the potential benefits (Barlow & Paling, 2018).

This data is harder to get and is where problems with data quality and spatial resolution are most evident. In light of this, the project calls for new approaches to monitoring to be taken into consideration in light of the steadily declining public resources (Barlow & Paling, 2018).

III.2. 3. The Interreg North Sea Region project BEGIN (2017-2021):

Through the BEGIN project, ten cities and six research institutes partnered to better address extreme weather incidents in their metropolitan areas. A major issue for many cities is the increased frequency and intensity of rainfall brought on by climate change. In order to share best practices and experiences, the cities are working on projects that will involve transnational exchange and city learning networks.

A unique strategy that is employed throughout the project- 'City-to-City learning', facilitates transnational interaction between these Local Authorities. Pilot initiatives will be co-created, co-financed, or self-organised by BEGIN, as contrasted to standard approaches that only inform or consult stakeholders. In practice, cities begin with planned investment initiatives and use the best technique from the Social Innovation toolbox to invite stakeholders (*BEGIN*, 2020).

Instead of adopting a restricted financial strategy, BEGIN employs two methods:

1. <u>Value-based decision-making.</u>

The delivery of conventional grey infrastructure has mostly focused on technical and spatial values (Raymond et al., 2017). GBI spatial claims tend to be complex since they also claim space for social values, sustainable values, and other spatial values, along with the technical aspects like underground facilities, roads, waterways, etc. BGI adds new geographical values, sustainability, and social values to the mix.

There are various types of value integration, from alignment to true/full integration. It has to do with the kind of value produced. Three stages of value generation can be identified when applied to management practices: aligned, coordinated, and integrated (Jørgensen et al., 2006).

Fragmented	Aligned	Coordinated	Integrated
Separation	Corresponding	Coherent	Inherent
Single value (either/or)	Combined value	Balanced value	Added value
			
Values are achieved separate. Division in time: first one then the other/ Division of tasks: we do this, you do that.	Values are added as an extra objective to existing ambitions and are then trade-off amongst each other. There are always winners and losers.	Values are combined, do not get in each other's way significantly so that each value reaches at least a basic standard.	Added value is achieved when the integration of values leads to enhanced value for each objective within the integration.

Figure 29: Levels of value integration (Kuitert & Van Buuren, 2022)

Although values are combined to this extent, distinct processes still exist. The wider advantages of BGI are frequently added as a goal to preexisting objectives, which are then somewhat overshadowed by other objectives, like construction and financial viability (Rauken et al., 2015). Within BEGIN, two ideal typical extreme governance methods to value integration were distinguished: top-down bureaucratic/ institutional innovation followed by implementation, and bottom-up social innovation with the goal of creating organisational support during the project delivery. In bureaucratic innovation, value integration frequently takes the shape of policy integration. Policy integration occurs at the level of strategic decision-making; therefore, value integration, which is bureaucratic innovation, must then find a way through the organisation to be implemented. For example, existing aims for climate adaptation can be complemented with new goals aimed at improving health and well-being (Kuitert & Van Buuren, 2022).

On the contrary, value integration as social innovation can occur at various levels but is more bottom-up, occurring either inside the organisation or in an internal-external network. Its goal is to make sure that the organisation adopts the value integration being pursued and mainstreams it across the organisation. By integrating diverse stakeholders and interacting with a range of value systems, bottom-up social innovation generates shared public value that transcends governmental boundaries. All in entailing, the policy brief emphasizes 'there is no one-size-fits-all solution' (Kuitert & Van Buuren, 2022).

Value Integration Pathways' primary lessons are reinforced by the BEGIN initiatives. In order to accomplish climate adaptation goals at the intersection of government, market, and society, these integration routes entail governance innovation through the creation of public value in the form of GBI. The BEGIN policy brief lays out recommendations to guarantee value integration in the delivery of GBI:

i. From business as usual to early involvement of actors from other domains
ii. From a product to a process understanding of value integration
iii. From the project perspective to the district/neighbourhood perspective.
iv. From a procedural focus on integration to a professional approach towards integration
v. From 'lead' value to multiple value perspective
vi. From integration as non-committal to formal safeguards (Kuitert & Van Buuren, 2022)

2. Socially innovative governance processes.

Social innovation, according to the European Commission, is "the development and implementation of new ideas (products, services and models) to meet social needs and create new social relationships or collaborations." (EC, 2013)

The policy brief was supported by the key takeaways from the social innovations initiatives created throughout the BEGIN project. It makes four recommendations to guarantee that BGI and its implementation are incorporated into policy.

1. Identify the beneficiaries and their interests when making the case for BGI
2. Link the BGI to communities by demonstrating the value to them
3. Stimulate multi-departmental and multi-stakeholder collaborations for BGI delivery
4. Develop asset management principles and processes for BGI (Willems et al., 2022)

The BEGIN project explored the social innovation needed to create a more effective, multipurpose GBI that offers a variety of social, economic, and environmental advantages. The social innovation seen in BEGIN involved interacting directly with local communities, fostering new cooperative partnerships, and collaborating across organisational and disciplinary barriers.

A GBI Business case- In essence, a business case offers the rationale for a project or initiative. It can show financial organisations and other beneficiaries, such as local communities and the stakeholders, the worth or value of GBI. Business cases that clearly explain the reasoning behind the intervention should be organised and concise; Figure 29 shows what should be included within them.

Figure 30: What should a business case cover (left)

Figure 31: Recommendations for developing business cases for BGI (right)

BEGIN focuses on capitalising on social innovation opportunities, which entails finding new and alternative ways to offer BGI that engage communities and people. Managing water and applying BGI on the surface opens up a plethora of new BGI-related alternatives for bringing about change in cities. For instance, the COVID-19 epidemic has re-emphasized the growing interest in providing health and well-being effects from high-quality green space during the past ten or more years. In order to facilitate the delivery of these results, this gives BGI an 'open door' (Carmona, 2019). BEGIN policy brief determines four recommendations for creating business cases for BGI [Figure 28]

The above recommendations have been backed by published research and literature, as well as interactions with BEGIN beneficiaries. The four suggestions were accompanied by helpful guidance and evidence from the BEGIN partners' pilot initiatives (Horton et al., 2021).

a. Antwerp, Belgium

"The Water Plan highlights the spatial potential and qualities that blue and green infrastructure can provide for dense urban fabrics. It also tells the story of Antwerp as a historic water city and provides a narrative glimpse into Antwerp as a future water-sensitive city." (Interregg, 2020a)

BACKGROUND

Within the city of Antwerp, local authorities are working to expand green spaces and optimise quality, accessibility, and utility value as part of the Spatial Structure Plan for Antwerp green and blue network implementation, prioritising water management whenever feasible. In addition to creating space for Antwerp's rivers and brooks in the lowlands, the ecological value of the water elements present is highlighted.

Between 2007 and 2012, the city aimed to establish a green project in each district, giving special consideration to the harmony of sports, recreation, and the environment. Within the city, the 'Urban development in Antwerp, Designing Antwerp' was also published to guide the expansion of the city. The document also sets a base for the development of the green-blue network within its guidelines. (City of Antwerp, 2012).

In the city, several area-oriented programs are presently being implemented at the level of the structural plan's strategy. One of the significant ones was a large-scale spatial figure along the River Scheldt, which connects the historic port areas from north to south and includes the ancient city core in the centre (City of Antwerp, 2012).

The city also has a specific water plan published, where 3 'watercities' are described: The artificial watercity (current sewage system of the city), the hidden watercity (the historical, often disappeared traces of water in the city) and the natural watercity (the natural water channels and green areas in and around the city). Its primary goal is to shift the emphasis from the artificial watercity to the natural one and, if possible, restore historical water traces. Together, the three water cities serve as the foundation for the Waterplan vision map's layers [Figure 29] (*Waterplan Antwerp*, 2019).

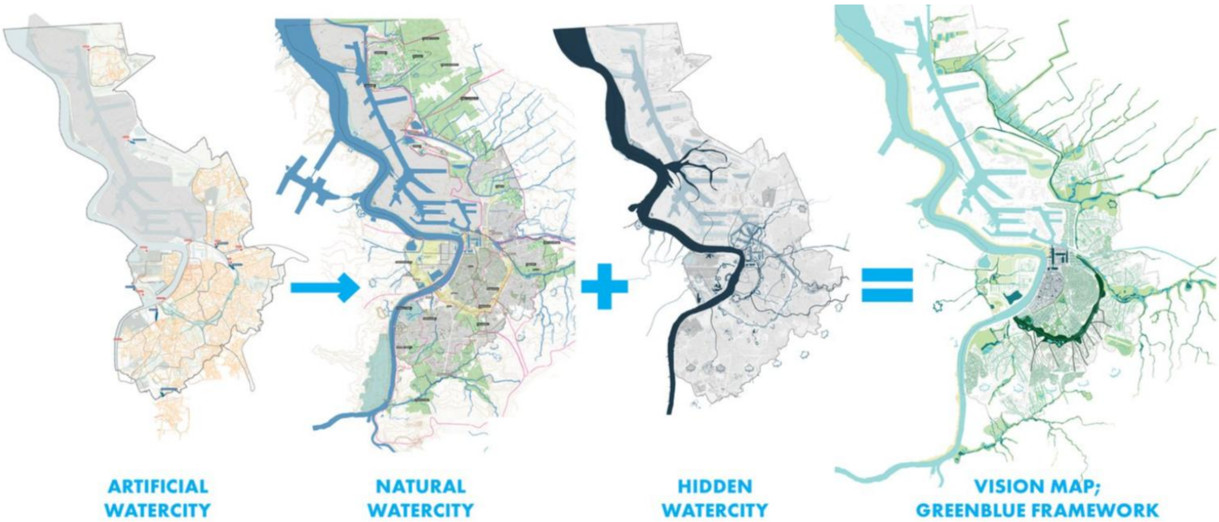


Figure 32: Watercities forming the components of Antwerp's green-blue framework (*Waterplan Antwerp*, 2019)

KEY INITIATIVES

Within the framework of BEGIN, two pilot projects were undertaken:

Reconnecting the Schijn and Scheldt rivers

The river Schijn was a part of the vast Scheldt estuary in the 18th century. Tidal forces influenced the river's discharge and the ecology that followed, leading to the river being forced underground by centuries of urbanisation and the construction of docks for Antwerp's ancient port.

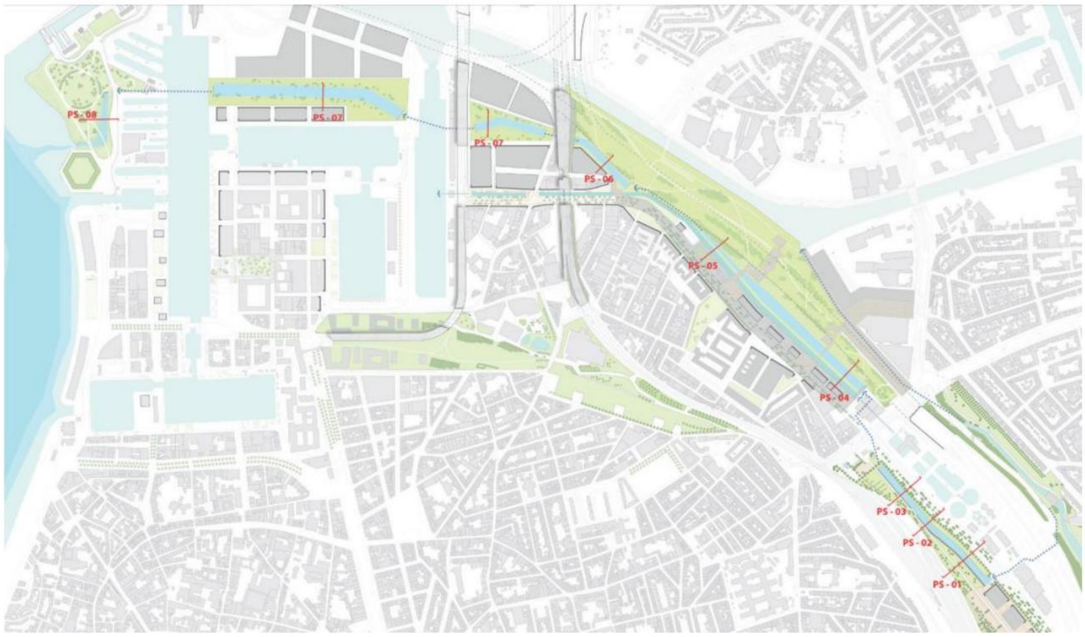


Figure 33: Schijn-Schelde connection along with planned parks (*Olthof et al., 2018*)

To re-establish the historical link between the two rivers, a feasibility study was carried out. The results showed the lack of recreational green space near the city centre, the need for greater ecological connectivity, protection against heat stress, resilience to urban flooding caused by heavy rains and climate change, etc, are some of the main drivers for this reconnection project. This was identified by the Antwerp Green Plan, Climate Plan, and Heat Plan, as well as multiple flood studies (Interreg, 2020a).

Antwerp's climate adaptation plan could include re-establishing connections between the two rivers because the new river would serve as a barrier to retain stormwater in the city. Furthermore, connecting the new river to expansive green spaces has three advantages: it can provide protection from heat stress, serve as a new ecological link, and address the city's green scarcity. Various spatial models were designed and technically assessed within the feasibility study based on several factors, including the proposed ambitions, the impact on ongoing projects, the impact on direct and indirect costs and benefits, the quality of the space, and the degree to which they can be integrated into already-existing projects [Figure 30] (Interregg, 2020a).

Re-designing the left riverbank

The second Antwerp pilot project intends to revitalise or build nearby parks and squares while reshaping the river Scheldt's natural banks and dykes. By increasing the amount of additional rainwater collected, the initiative aimed at lowering the city's mean radiant temperature. The project's social goal was to increase public space usage so that people could escape the heat and re-establish a connection with the waterfront. The planning was done through a collaborative process, which is the project's strength. The idea was to build the landscape as an open, ever-changing structuring figure in order to redesign the left riverbank into a recreational, open, residential, and sustainable landscape (Interregg, 2020a).

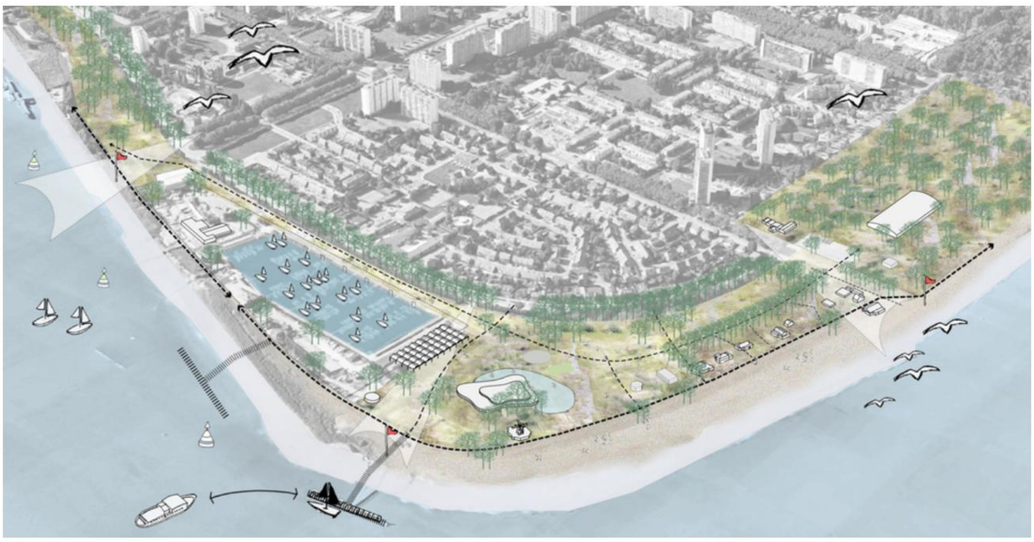


Figure 34: Simulation image of Sint-Anneke Plage (Interregg, 2020a)

The goal of the residential and recreational development was to create a vibrant and attractive neighbourhood. Sustainable mobility was included in the design by providing the best possible accessibility for cyclists and pedestrians and by connecting the left and right riverbanks with water taxis [Figure 31] (Interregg, 2020a).

OUTCOMES

The BEGIN city experiences related to policy encapsulate four policy recommendations:

1. Identifying beneficiaries for making the case for GBI- [**Antwerp Waterplan, towards a future-proof water city] -** Within this, it is highlighted that only a water city's government/s, corporations, and community organisations working together can make it a reality. In addition to providing a hydrological and spatial blueprint for the city, it also outlines how current design methods and execution procedures will change over the next several decades (*BEGIN*, 2020).
2. Relate the BGI to communities by demonstrating the value to them. **[Garden Streets, Climate Robust Neighbourhoods] -** Garden streets were suggested as an experiment to find ways to mitigate the effects of climate change (heat stress, flooding, etc.) by collaborating with residents to find ways to green and blue the streets. To strengthen climate adaptation within the neighbourhood, the suggested path was for businesses, clubs, and citizens to collaborate to establish projects (*BEGIN*, 2020).
3. BGI requires interdisciplinary municipal partnering. **[City Lab Sint-Anneke Plage: Design Sprint and Deep Dives] -** The recommendation encompassed inducing a different mindset through the city lab by analysing the success factors and barriers of the design (*BEGIN*, 2020).
4. Develop asset management principles and processes for BGI. **[Experimenting, Monitoring and GIS Analysis]-** The recommendation chalks out the various ways the city has planned parts of the GBI and what further plans can enhance this network (*BEGIN*, 2020)

LIMITATIONS

Despite the vision for the GBI programme, the project was largely expected to remain merely strategic and visionary. A lot of factors have contributed to this, some of which include the limited political support for GBI and the volatile political climate. Also contributing to the limitations of the project are its limited insights and the exclusion of future uncertainties. The programme also lacks a narrative and branding within the social scenario of the city (Veerbeek, 2018).

Dordrecht, Germany

b. ***"…Dordrecht is taking its ambition a step further by developing a broader integrated blue-green vision, to become a more resilient city with a robust infrastructure. This vision not only tackles flooding but incorporates other vital aspects such as biodiversity, health, recreation, mobility, the spatial quality of the city, and even agriculture."*** (Interregg, 2020b)

<u>BACKGROUND</u>

One of the most devastating floods in the history of the Lowlands occurred 600 years ago at Dordrecht. When Dordrecht was Holland's capital in 1421, an intense storm broke some of the dykes. Up to thousands of people were killed, and about 20 villages surrounding the city were destroyed. Dordrecht lost a lot of its importance because the city was an island that could only be reached by boat for decades after that. The city is still susceptible to flooding today (Interregg, 2020b).

The island city has seen severe flooding for more than 600 years; Dordrecht has a long history of water management and is aware of both the benefits and risks involved. In order to become a more resilient city with a strong infrastructure, Dordrecht created a more comprehensive integrated blue-green vision. In addition to addressing flooding, this vision considers other important factors like mobility, biodiversity, health, recreation, and the city's spatial character (McCready, 2021).

<u>KEY POLICY/ INITIATIVES</u>

Dordwijkzone City Park

The Dordwijkzone is a pilot initiative of BEGIN. The Dordwijkzone was planned to be expanded into a City Park XXL, which is envisioned to be bigger than Central Park, New York. The vision was to make the park with amenities that help the citizens interact with nature and offer a space for recreation and culture (Interregg, 2020b)..

The Municipality of Dordrecht made investments in ecological corridors, sustainable traffic routes, green space ecological reinforcement, and public space enhancement. The pilot project recognised that increasing citizen participation and engagement in the initiative was essential. The City Park XXL aimed at being a park of and for the people of Dordrecht, where they can enjoy a variety of social and sporting events. The addition of green spaces is anticipated to improve health, physical activity, and quality of life while lowering CO2 emissions and heat stress (Interregg, 2020b)..

De Staart – A Safe Shelter on High Ground

Another BEGIN Pilot Project in Dordrecht was De Staart. It was a remote region with few opportunities and a lot of issues. Nonetheless, it was anticipated to play a significant part in achieving the Dordrecht water safety agenda. This is due to its location on 'high ground,' which is the highest ground on the island of Dordrecht relative to sea level. Surrounded by water and adjacent to the National Park, the Biesbosch, De Staart boasts a unique location that presents a multitude of opportunities. The region was expected to begin serving as a refuge in case of (water) emergencies and as a new, sustainable living space (Interregg, 2020b)..

The project called for using water safety as a leverage to achieve equitable and sustainable urban development, making opportunities for creating a multi-use public space. The leveraged strategy necessitates De Staart's easy and quick accessibility, and making access to water and flora easier. New, positive relationships with the city, as well as between the city and the region, are necessary for this approach. The Wantij is proposed to be designed as a Tidal Park, which would be good for the environment, leisure, and standard of living on De Staart. Thereby, making living on the ocean, in and with space for nature, becomes a viable alternative (Interregg, 2020b).

In the event of a flood disaster, De Staart is the ideal location to take shelter due to its relatively high elevation. The significance of De Staart as a possible shelter was covered by Dordrecht TV in an article about the exhibition The High Ground.

A Blue-Green Vision

BEGIN has also played a role in developing the Blue-Green Vision for the Island of Dordrecht. *"The vision combines a healthy living environment with climate adaptation, biodiversity, and the island's rich cultural history."* (Interregg, 2020b).

In the upcoming years, Dordrecht will continue to grow and densify. More homes typically translate into more traffic and parked vehicles. The city hopes that the anticipated increase in car movements may be offset by cycling and public transit, integrating high-quality GBI with a network of bike lanes that are connected to public transport. The vision banks on the fact that GBI will keep the city healthy and attractive while also preparing it for climate change, also resulting in improved social, cultural, and economic conditions (De Urbanisten, 2020).

The Island of Dordrecht, aimed to invest in stronger blue-green connections. The two most notable green areas in the city, Wantij and Dordwijkzone, serve as the primary axes. In addition to these two areas, almost every resident has access to all that green through a tightly knit system of parks, lanes, canals, and dykes (De

Urbanisten, 2020). The Blue-Green Vision proposes the reinforcement of four GBI:

1. The tidal landscape forming the rich shores of the island, the Wantij riverbanks in particular
2. The historical network of dykes that surround the city like rings
3. The creek landscape with all the meandering waterways
4. The Dordwijkzone, which will be reinvented as 'Central Park' and climate buffer (De Urbanisten, 2020) [Figure 32]

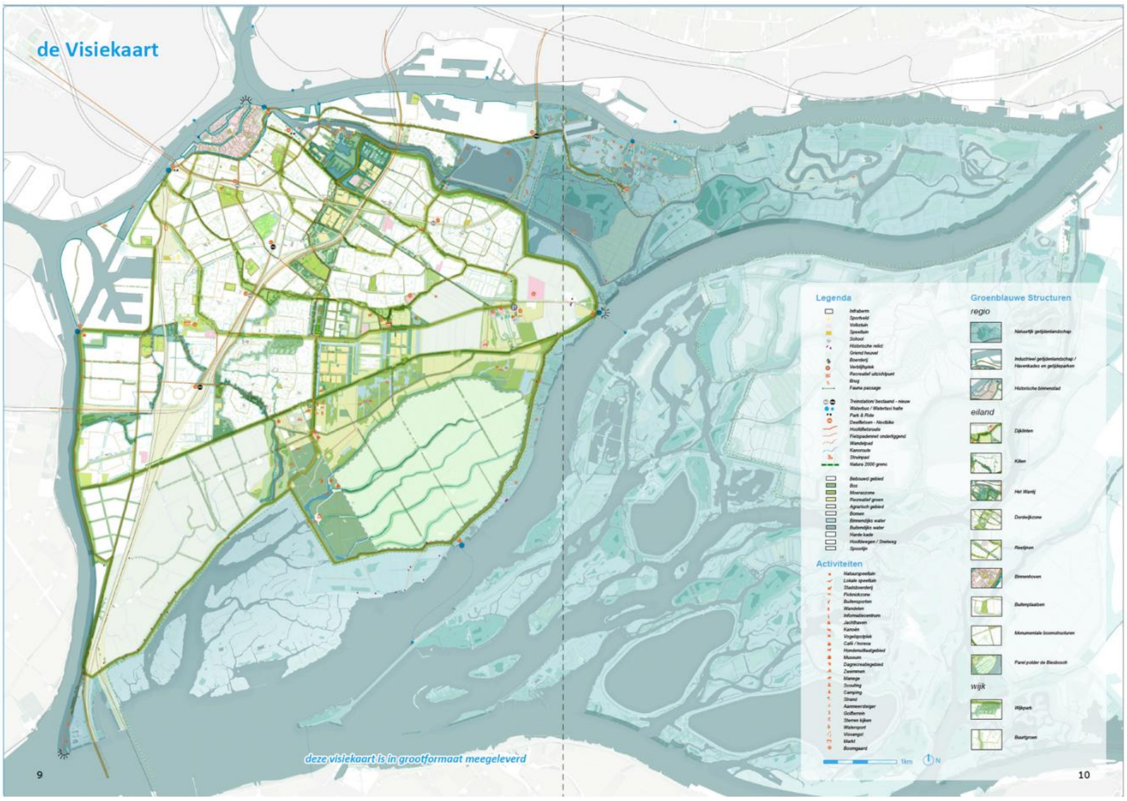


Figure 35: Blue Green Vision Dordrecht (De Urbanisten, 2020)

OUTCOME

The BEGIN city experiences related to policy, encapsulates four policy recommendations:

1. Identify the beneficiaries for making the case for BGI- [**Create a broad and integral blue green vision]** - This recommendation focuses on the development of the Integral blue-green vision which includes climate adaptation, biodiversity, health and recreation with stakeholder ambitions in consideration. It has two proposed blue green zones:
    a. Dordwijkzone: a combination of sports fields and parks.
    b. Wantijzone: a green corridor from the city centre to the Biesbosch National Park along the Wantij river.

2. Relate the BGI to communities by demonstrating the value to them- **[Branding and involve citizens in order to create a resilient city] -** Engaging citizens and other stakeholders in the development of the vision is important for its success. A suggestion was to showcase blue green solutions along a citywide art path in collaboration with locals. Additionally, stakeholder engagement in the creation of green areas with plans to launch campaigns and providing websites for information and guidance.
3. BGI requires interdisciplinary municipal (and other) partnering- **[Create an interdisciplinary team that works on a blue green city]** - The recommendations call for working in a Bluegreen team that comprises of experts from city development, city maintenance, strategy, communication, citizen engagement and other teams. Advocating for a large network that expands outside one single team and mainstreaming strategies to the entire community. The suggestion is to establish zones as citywide beneficial to health, recreation, small businesses with high quality green spaces. The new suggested zones have garnered broad political support.
4. Develop asset management principles and processes for BGI- **[Use maintenance and investments projects to create blue green spaces]** - Executing the vision of the blue green programme, along with asset management principles and process for GBI. The vision measures in short terms to improve and maintain performance. Considering this insight, the aim is to develop a green investment fund.

<u>LIMITATIONS</u>

Dordrecht faces many challenges in implementation of the long-term vision, with the on-going pilot projects having to yet translate into a concrete action. Another major issue identified is the lack of clear prioritization regarding the projects of focus. This has also led to limited implementation of measure on ground with many initiatives stuck in the planning stage (Veerbeek, 2018).

The city has not overcome the implementation barrier and is stuck in an endless plan development cycle, often influenced by opportunistic decision making. Furthermore, the presence of challenging neighbourhoods and the socioeconomic disparity within the city complicated the efforts of integrating GBI solutions effectively (Veerbeek, 2018).

c. Ghent, Belgium

"The city of Ghent is working on the realisation of 8 green climate axes that connect the outer city with the inner city. This blue-green system includes 8 axes, an inner-city system, a green recreational ring and green nodes at the crossing points of the several elements within the system…" *(Interregg, 2020c)*

BACKGROUND

Situated in the industrial heart of Europe, the Belgian city of Ghent offers both prosperity and environmental concerns. The city has previously experienced high levels of fine dust particles, contaminated streams and soils, and nearly obsolete forests. By greening public areas and reducing the number of cars in the city centre, these concerns have been addressed over the past few decades, making the city more liveable. In addition to addressing the issue of soil contamination, the city's new green urban zones are enhancing biodiversity and serving as climate buffers, reducing heat stress and increasing water percolation (Troch et al., 2021).

In addition to these two primary purposes, green spaces contribute significantly to the recreation and well-being of citizens. In order to make sure that the city is climate resilient by 2030, Ghent is actively preparing for the anticipated consequences of climate change. The Ghent Climate Plan for 2020–2025 shows the city's efforts to create a resilient climate (Troch et al., 2021).

KEY POLICY/ INITIATIVE

At the end of 1980's, the idea of "green axes," which serve as connecting components within a citywide green system, was first proposed by the City of Ghent. The axes were designed to distribute current and new recreational elements, residential recreation, allotment gardens, and larger and smaller GI at the neighbourhood level as efficiently as possible.

In order to ensure continuous, segregated bike and pedestrian routes along these axes, underpasses and bridges was then planned. Eight green climate axes span more than 50 km throughout the city, creating a unified ensemble with the city's green recreational rings and five enormous green poles at the periphery (Kelder, 2018).

Green Axe Project- BEGIN

Eight green axes, or climate-proof green spaces, are planned to be developed throughout the city as part of the Ghent project. The project is based on the fact that the green axes can be used to reduce the municipal infrastructure's vulnerability to the effects of climate change. The first social or urban goal is to remove as many urban-administrative obstacles as possible that make this green axe more difficult.

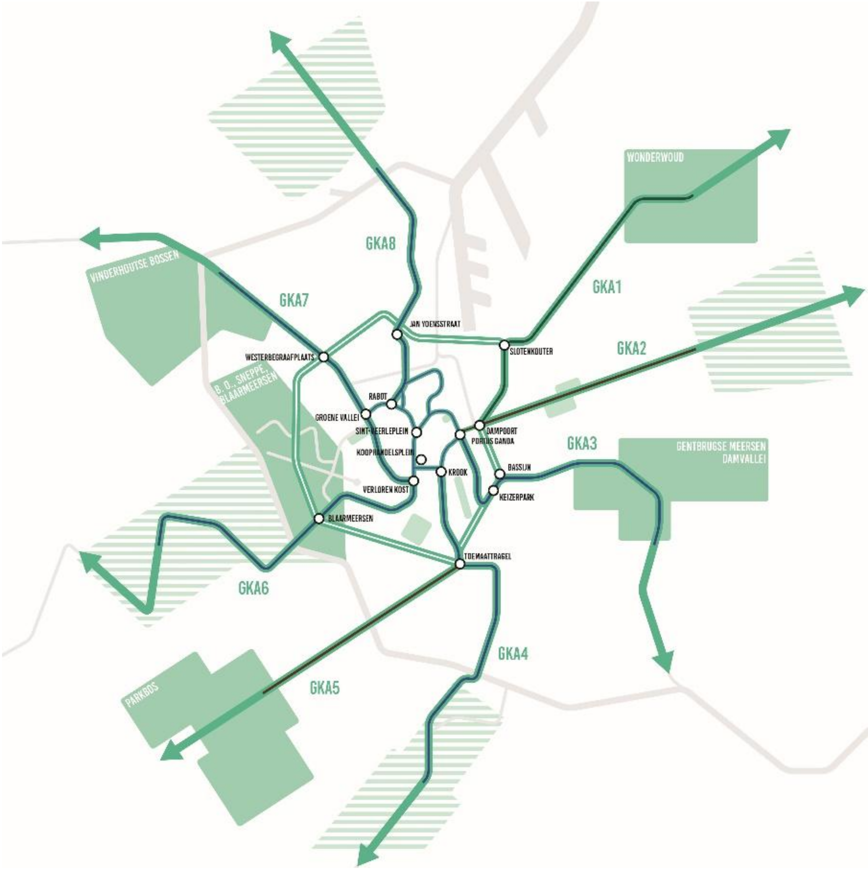


Figure 36: Eight Green Axes of the Ghent (Troch et al., 2021)

The second aim of the project was to establish a community-based participatory method for infrastructure upkeep (Troch et al., 2021). The vision consists of a map of the 8 green climate axes, along with 6 spatial targets outlined:

i. Planting as many trees as possible to reduce heat stress and increase biodiversity.
ii. Lowering pavements to create space for water infiltration.
iii. Protecting existing green spaces and building new high-quality green spaces.
iv. Prioritising pedestrians and cyclists.
v. Reducing the number of cars on the road and parking spaces.
vi. Making public services accessible through the green climate axes (Troch et al., 2021).

The next stage is to create a design plan for each segment (region) and convert the overall vision into a structural map for each green climate axis. Numerous city agencies, including those for urban planning, roads and rivers, mobility, vegetation, climate and environment, the city architect, and policymakers, worked together to create this vision. The city of Ghent developed a communication plan in 2017 to persuade Gentians to de-pave their private outdoor areas and make them greener. By substituting tiles for vegetation, the soil more readily absorbs rainfall and raises the groundwater table, avoiding overflowing sewers, while also lowering heat gain. De-paving residents' front gardens was the subject of the city's initial experimental operation (Troch et al., 2021).

Figure 37: Detail of a structure map (part of green climate axis 7) *(Troch et al., 2021)*

<u>LIMITATIONS</u>

Within Ghent, the GBI initiatives do not have an appraisal of multiple benefits (MBs) and insufficient insight into the actual performance of implemented GBI measures. While the city has developed a comprehensive vision, it grapples with the absence of concrete projects to bring this vision to life. Additionally, there is a lack of clear assessment of climate induced risks like flooding, drought and heat which greatly hampers effective adaptative planning. These climate change adaptation measures, mainly within the inner city are fragmented and are isolated rather than one integrated strategy.

Furthermore, the city is committed little to revitalizing the GBI masterplan, which also makes it tough to remain focused across the separate eight green axes. This complicates efforts to implement a cohesive and effective green infrastructure strategy (Veerbeek, 2018).

III.2. 4. Green Grid and Natural Signatures

Location: London, United Kingdom

Year: 2007, 2011

Scale: City-wide

Main Instrument: Creation of a strategic environmental strategy, and the green grid project

BACKGROUND

According to the EIU Global Liveability report of 2024, London, the capital of the United Kingdom, was ranked as the 45th most liveable city in the world (EIU, 2024). The government of London values its geology and ecology of 'London's Natural Signatures'- which is the network of green spaces, parks, woodlands, rivers, and its wetlands. The city recognises this network as an integral part of creating a sense of local identity and its role in promoting the healthy living of its residents.

Acknowledging the fact that there is disparity in access to green spaces in the city, the Mayor of London aims to have more than half of the city be green by 2050 and to integrate the economic and social value of GI into the decision-making for the city.

KEY POLICIES

London's Natural Signatures

The framework published by Natural England aims to re-establish the relationship between the built and the natural aspects of the city. It is designed to be a tool to aid planners and developers to be conscious of the natural landscape. The report is divided into sections, owing to the size of the city, covering twenty-two Natural Landscape Areas. The framework promotes healthier living, providing spaces for physical activity and relaxation. It aims to cool the city and absorb stormwater to lessen the impacts of climate change. It acknowledges the role of the GI to filter pollutants to improve air and water quality. Furthermore, it calls for creating better quality and better-connected habitats to improve biodiversity and ecological resilience. The vision of the framework is to align with the existing policy of the city, enhancing the local identity (Baxter, 2011).

London Environment Strategy

The city of London's environmental strategy is an attempt aims to make sure that the city is '**greener, cleaner** and **ready for the future'.** It hopes to tackle urgent environmental challenges like toxic air, noise pollution and the adverse effects of climate change. The strategy draft had a strong stakeholder involvement- it was open for a public consultation and had the widest reach of any of the 8 previous environmental strategies of London. It involved 370 technical stakeholders with many suggested amendments to the strategy's policies and proposal (London Assembly, 2023).

Figure 38: London environmental Strategy Executive Summary (Greater London Authority, 2018)

The goals outlined for GI include making London the first 'National Park City', improving the existing green space distribution, and protecting the London Green Belt from further development. The city will use Urban Greening factor to make sure new construction is greener and set up London Green Spaces commission to fund and manage green spaces. Furthermore, the city aims to use the planning system to protect biodiversity by making up for any losses brought about by new construction that cannot be repaired on-site with gains elsewhere (London Assembly, 2023).

The strategic framework for decision-making throughout the city is provided by the London Plan's policies on GI as well as those regarding open spaces, biodiversity, woodlands, and other natural habitats. The '*All London Green Grid' (ALGG)* [2011] Supplementary Planning Guidance offers spatial guidelines along with a number of ALGG Area Frameworks that highlight potential and priorities for local green infrastructure. The ALGG is on its way to being replaced with a new '*London Green Infrastructure Framework (LGIF)'* (London Assembly, 2023).

In order for nature and green space to thrive and be available to all Londoners, LGIF is anticipated to offer a new spatial framework and vision to target and prioritise GBI throughout the city. The ALGG and the Green Infrastructure Focus Map will be replaced by the LGIF, which was suggested in the London Climate Resilience Review. The London Local Nature Recovery Strategy (LNRS), which will serve as the LGIF biodiversity/nature layer, will be developed in tandem with it. It is anticipated to be finished by the summer of 2025 (London Assembly, 2023).

The LGIF is said to include a supporting framework document that outlines strategic priorities for London's GBI as well as interactive, digital mapping that is based on the best available data on environmental, social, and economic variables. Numerous stakeholders, including local government agencies, landowners, land managers, environmental organisations, and community representation organisations, will be consulted during its development (London Assembly, 2023).

OUTCOMES

All London Green Grid

In 2006, 'A Summary for Decision Makers' was published in which London introduced the idea of heat stress as a crucial factor in spatial planning. This was a starting point of the Green Grid project in East London. In response to the urban heat island crisis and the impact of the heat waves on the economy, the city of London planned to take measures as three different levels of scale: Building/ street (1-10m), the urban design (10-1000m) and the city plan (1-50 km) (Greater London Authority, 2006)

The ALGG framework, launched in 2011, integrates GI policies that include the core strategies, local plans, and regeneration policies. It includes three elements- GI-related planning policy within the city's master plan, the ALGG supplementary planning guidance, and eleven ALGG area frameworks that give a more detailed assessment of opportunities for GI. It addresses the challenges the city faces of biodiversity depletion and sustainable food production.

By 2014, more than half of London councils had incorporated the ALGG into their policy. These boroughs made a specific policy commitment regarding the ALGG and demonstrated a strong dedication to the ALGG principles, as shown by the recognition of the significance of green connectivity and the numerous advantages of more strategically managing green spaces. According to a mid-term evaluation report, the ALGG began to encourage improved planning, coordination, and optimisation of GI operations across London and backed a wider political adoption of the GI idea. The ALGG encouraged collaboration between the local community (schools, housing organisations, and resident groups) and the London boroughs. A comprehensive approach to GI design, the ALGG serves as a bridge connecting several municipal and sub-local policy initiatives. To guarantee local uptake, the Grid made it a requirement for the London boroughs to develop open space initiatives that are connected to their local biodiversity action plans (Interlace, 2023).

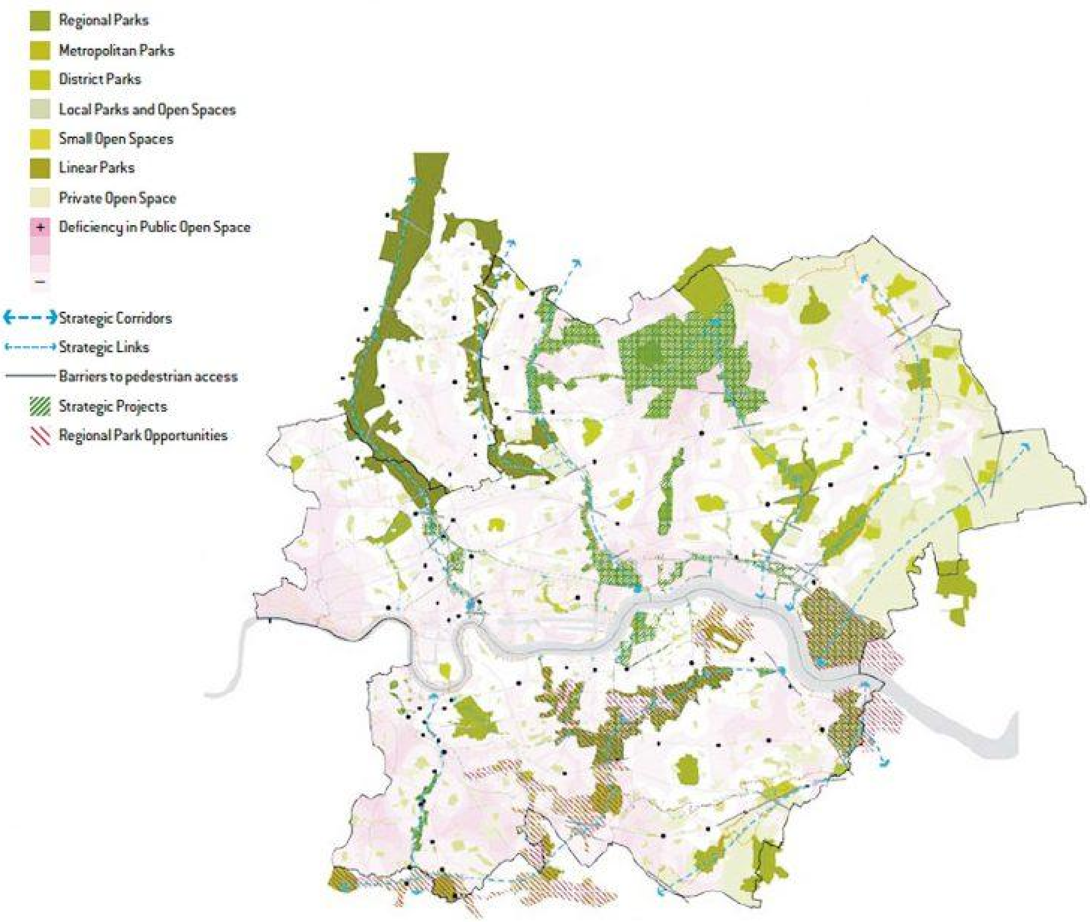


Figure 39: East London Green grid (Greater London Authority, 2006)

East London is veined with green-blue buildings as part of the East London Green Grid proposals. The strategy aims to establish natural urban systems and create links between the Thames, the Green Belt surrounding London, public transport hubs, and the neighbourhoods where people live and work. These green-blue structures are specifically employed to improve air quality, buffer water, and reduce air temperature.

The 'Green Grid Master Plan' lists 300 projects to be implemented in three stages. The city believes that a relatively well-meshed GBI is essential to realising a sustainable metropolis. The goal of a healthy urban environment has been closely associated with the existence of green buildings. Therefore, the city is certain that the green-blue networks will develop into robust conduits for future developments, including economic growth (Greater London Authority, 2006).

LIMITATIONS

To guarantee that it is implemented as efficiently as possible, coordination between the boroughs and the ALGG Area Frameworks, as well as with new partners such as local enterprises and housing associations, must be strengthened. This includes combining resources and putting projects together. Additionally, more investment is needed to effectively implement GI goals, especially in areas where less progress has been made (e.g., food production projects, green infrastructure skills development, and blue/green space plans along the Thames) (CPRE, 2014).

Along with a tendency towards political adoption and strategic GI planning, the ALGG Supplementary planning guide has placed more attention on the various advantages and opportunities that may be obtained from GI. Furthermore, GI audits need to be conducted by London boroughs and Area Framework partners in order to provide a strategic baseline audit. Regular updates are missing to promote efficient management (CPRE, 2014).

III.2. 5. Water squares

Location: Rotterdam, The Netherlands

Year: 2011

Scale: Neighbourhood

Main Instrument: Creation of public recreational spaces that are doubled as stormwater infrastructure

BACKGROUND

Large-scale environmental infrastructure projects are common to the Netherlands, especially those relating to land reclamation and sea level protection. Likewise, Rotterdam has always been particularly vulnerable because to its location on a delta. Rising tides brought on by climate change continue to threaten the sea. Since the city suffered significant damage during World War II and rebuilt with a lot of concrete, roads, and hard-surfaced public areas, it is particularly susceptible to flooding from the increasingly frequent heavy rain fronts.

The municipality of Rotterdam commissioned seven large scale public space projects across the city. These projects are expected to contribute to the urban greening and climate resilience. Car lanes are being limited at the inner-city Hofplein, a famous gathering spot, to give priority to bicyclists and pedestrians. On the Maas River delta, a new tidal park is being planned next to the Feyenoord football stadium, which has been moved. The city's GBI will be greatly expanded by the six projects, including the Hofbogenpark, which will create a new "green axis" that runs through it (Rob Wilson, 2024).

In the Annual Report, the official document commissioned by the Municipality of Rotterdam, they not that 15 squares will be renovated with new and better greenery and measures to combat flooding. The city plans to turn five of the 15 squares into “climate squares” by introducing water storage measures (Gemeente Rotterdam, 2023).

KEY INITIATIVE/ POLICY

WATERSQUARES

In 2011, water squares were proposed as water storage areas that double down as quality urban public spaces. Proposed as a two-fold strategy of investing capital in water storage while makes these spaces aesthetically pleasing as well as enjoyable.

The water square was designed to be an often-dry recreational space with two areas: a sports area and a hilly playground. A lush frame of trees and grass encapsulates the area. Rainwater gathered from the neighbourhood will flow into the water square during periods of heavy precipitation, only a portion of the square will be filled during cloudbursts. More and more areas of the water square will progressively fill with water if the rain continues. Before entering the square, the rainwater is filtered, and rainwater will remain in the square until the city's water infrastructure can handle it once more. The water can then flow to the closest body of open water. As a result, the water square is also a way to enhance the quality of open water in cities.

The water square is cleaned after being used as buffering area which is why the design employs fluent slopes. In 2006–2007, a typological study and design on water squares was conducted. Subsequently, the "Rotterdam Waterplan 2" made the water square an official civic strategy in 2007 (De Urbanisten, 2008).

<u>OUTCOMES</u>

Water square Benthemplein, completed in 2013, is a project designed by De Urbanisten and commissioned by the municipality, has been replicated multiple times around the world. The square has three recessed, stepped spaces that can be used as small performance auditoriums, places to sit, or places to skate for 70% of the year. However, during rainy periods, these sunk portions transform into basins, which are surface attenuation tanks that store extra precipitation runoff and give the square a water feature appearance (De Urbanisten, 2013).

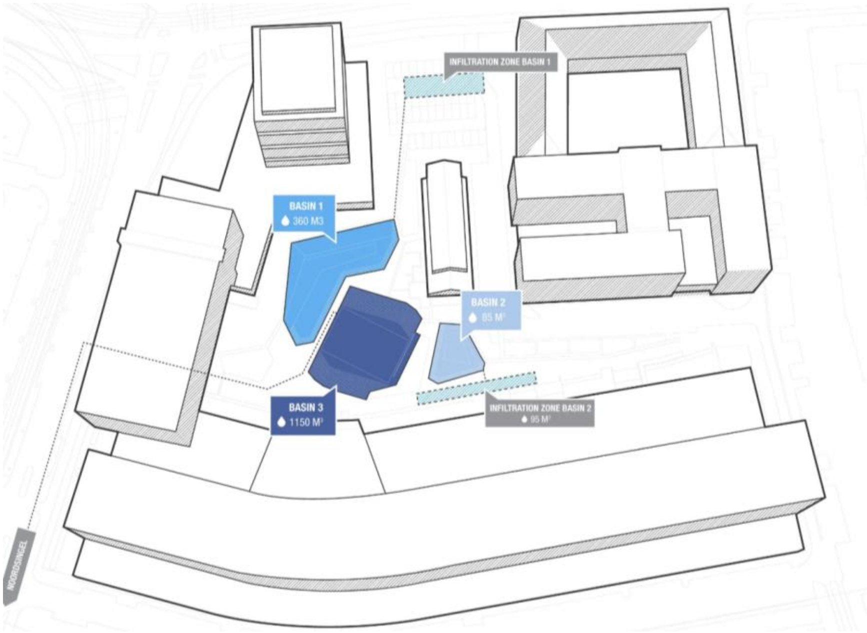


Figure 40: Water square Benthemplein basins (De Urbanisten, 2013)

Three basins catch rainwater: one deeper basin only gets water when it rains continuously, while the other two shallow basins for the adjacent area get water anytime it rains. Water from the wider region surrounding the square is collected here. Large stainless-steel gutters carry rainwater from the square over to the basins. When dry, the three-stepped ponds are utilised for skating, unofficial theatre, or simply lounging. Locals, students, and members of the nearby church, youth theatre, and gym collaborated to create the design to focus on a youth centric stakeholder involved project (De Urbanisten, 2013).

Figure 41: Plan of Water square Benthemplein, Rotterdam (De Urbanisten, 2013)

"All that can flood is painted in shades of blue. All that transports water is shiny stainless steel. The space is gently defined and subdivided by a green structure of high grasses, colourful flowers and the existing large trees. Our water square creates a new context for the great modern building of Maaskant and the fantastic giant artwork of Karel Appel."(De Urbanisten, 2013)

The existing trees have also been retained on site and are also now surrounded by newly designed gardens and concrete benches. The facilities designed in a way that serve both the public and the rainwater demand are a good example of how GBI can bring dynamism to the space and the versatility can bring a central meaning to public life.

LIMITATIONS

For the water squares, ground level is important and considering the design aspects of the structure, generally the square’s lowest point is situated below the groundwater level. To prevent the square from filling with groundwater, the square’s buffering facility needs to be waterproofed which adds considerable costs. Similarly, the constructions need to be equipped to handle the load when it is full of water and also the upward forces that work on the structure which tend to be expensive too (Bravo, 2013).

The water squares maintenance and management are crucial since the water enters the square from above the ground and is therefore unpurified. This implies that once the water has been pumped away, contaminants like mud, debris, leaves, and branches are still present. In order to restore the square's aesthetic appeal and usability, these contaminants must be removed as soon as it dries (Bravo, 2013).

III.2. 6. Active, Beautiful, Clean Waters Programme

Location: Singapore

Year: 2006

Scale: City-wide

Main Instrument: Active, Beautiful, Clean Waters Programme

BACKGROUND

Singapore is a densely populated country with a limited amount of land, and despite this has been constantly recognised for a high standard of living. Being an island city/state, Singapore has always had water at the forefront of its national policies. From the 1960s water scarcity faced by the city, the discourse of water regarding its utilisation has shifted from a basic necessity to now enhancing liveability (CLC, 2013). The city hopes to develop its identity as a City of Gardens and Water and thereby uses 'The Active, Beautiful, Clean Waters (ABC) Programme' as an initiative to do so.

The city has an organisation, Centre for Liveable Cities (CLC), that researches urban systems and has developed a liveability framework within which the city identified three intersecting outcomes for a liveable city encircled by three complementary systems that create the conditions to sustain these outcomes [Figure 42]. This framework identifies key domain areas and aims to answer how the city transformed itself into a highly liveable city within the last 5 decades (Centre for Liveable Cities, 2017).

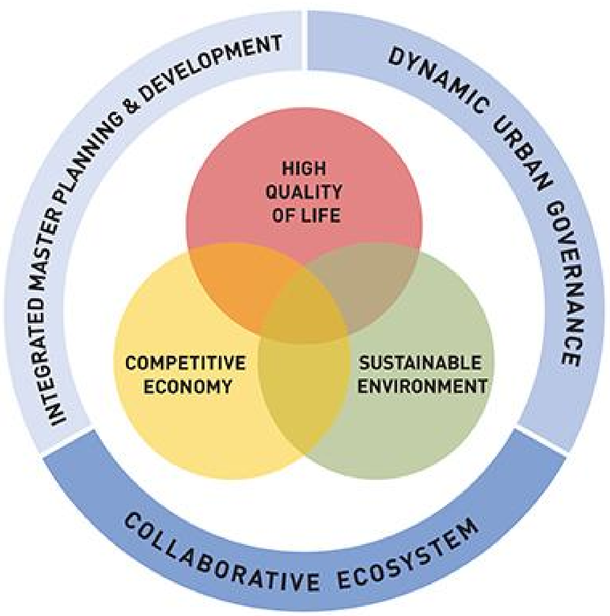


Figure 42: Singapore Liveability Framework (CLC, 2013)

KEY INITIATIVE

The Active, Beautiful, Clean Waters (ABC) Programme

The physical and climatic conditions of Singapore made it important to have a strong network of drainage infrastructure to alleviate flooding historically. Thus, the backbone of the water structure was recognised as an environmental asset to enhance the liveability of the urban environment.

ACTIVE	BEAUTIFUL	CLEAN
Creating new recreational and community spaces while bringing people closer to water.	Transforming concrete waterways into vibrant and picturesque waterscapes that are well integrated with the urban environment.	Improving water quality through holistic management of our water resources and public education by fostering better people-water relationships.

The efforts post 1990's in the island city have shifted towards making the entire island into an urban catchment area while making the water management process more sustainable. The ABC Programme, launched in 2006 is long term, island-wide attempt to access the potential of multi-functional waterways with Singapore's National Water agency. The programme aims to transform waterways and waterbodies into urban assets and bringing citizens closer to water. The unique thing about this programme lies in its approach towards community engagement and aims to inculcate a sense of stewardship within citizens towards water resources (Centre for Liveable Cities, 2017).

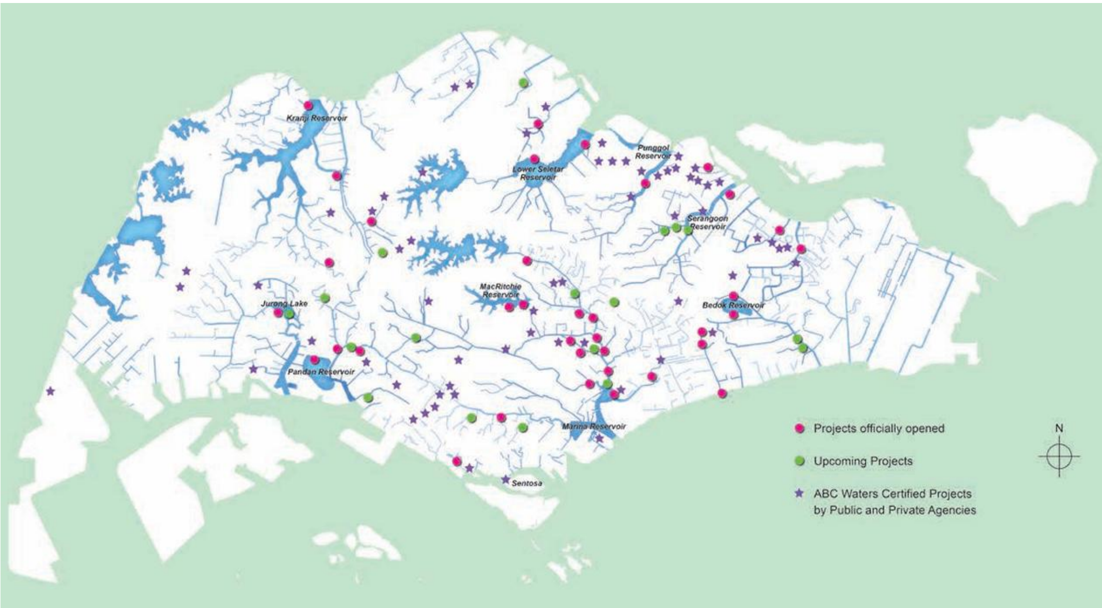


Figure 43: Singapore's Blue Map (Source: Singapore's National Water Agency)

"LET'S GET IN FORMATION!": SETTING UP THE 3P NETWORK

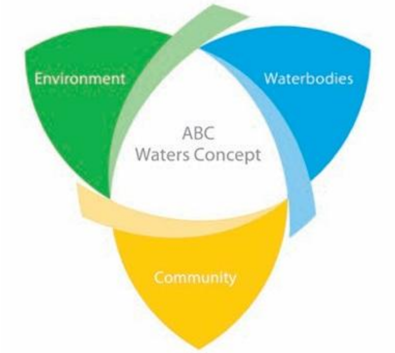


Figure 44: The ABC Waters Concept

The Programme's focus displays a shift from a utilitarian to a social approach, showcasing the tangible value of blue spaces in the city. The project hoped to enhance the urban space by beautifying the concrete waterways within the island and activating waterbodies as recreational spaces. In 2008, demonstration sites started in parts of the city and were highly successful. A contributing factor to this was the adaptability of the plans according to site conditions.

The Programme used unique communication methods to create awareness and build a rapport with the citizens. The ABC Waters 6-day exhibition was launched, along with a lifestyle magazine 'PURE', and a game show 'ABCs of Water'. The backbone of the ABC Programme is the 3P (Public, Private, Public) Network created to engage people, private and public sectors for the city's water management projects (Centre for Liveable Cities, 2017).

OUTCOMES

Rejuvenation of Bishan-Ang Mo Kio Park

As a flagship ABC Waters project, within Bishan-Ang Mo Kio Park, a decision was made to naturalise the linear canal into a meandering river to create a green-blue network and design community spaces. Extensive greenery was planted along the path of the river, and the canal acts like a stormwater conveyance channel.

The approach included combining natural systems with engineering, which uses a range of plants and bedding materials within the bioengineered river edges to stabilise the riverbanks. To provide natural cleaning mechanisms, a cleansing biotope made out of wetland plants was also introduced. The park also includes other GBI, like vegetated swales and green roofs, that slow down the flow of water. The design elements of ABC Waters, which are planned to mimic natural processes, should eventually prove to be cost-effective and self-sustaining (Centre for Liveable Cities, 2017).

The canal and the park were concurrently rejuvenated to create an integrated landscape. Many community-proposed spaces were designed like areas for Tai Chi, better lawns for picnics and sports, and other lifestyle activities. The new design created a connection to the river directly where citizens can go to the edge of the water directly. A community initiative was a butterfly habitat where flora that sustains their population was planted. Additionally, the biodiversity the park boasts has increased, along with various species of birds sightings increased since the rejuvenation. Another aspect of the initiative is that the ABC Waters

Certification Scheme was introduced in 2010 to recognise and encourage public organisations and commercial developers who incorporate ABC Waters design elements into their projects. Four design criteria—active, beautiful, clean, and inventive elements—are used to evaluate projects (Centre for Liveable Cities, 2017).

LIMITATIONS

The ABC Waters Design Features (ABCWDFs), like rain gardens and swales, are effective in removing particulates from stormwater, but perform poorly in nutrient removal, mainly total phosphorus (TP) and total nitrogen (TN) (Lim & Lu, 2016). This requires a better strategy to address nutrient pollution. Furthermore, there is a scarcity of field monitoring studies that categorise the performance of the ABCWDFs, which hampers the widespread implementation of these systems(Neo et al., 2022).

Additionally, since the program has completed 60 projects, it is in dire need of an ongoing post-project evaluation and monitoring to ensure that the programme is meeting its goals (Lim & Lu, 2016). Overall, the limitations have been minor compared to the success of the programme, like stormwater management, enhancing biodiversity, enhancing the living environment, etc.

III.2. 7. Grey to Green initiative (G2G)

Location: *Portland, Oregon, USA*

Year: *2008-2014*

Scale: *City-wide*

Main Instrument: *Introducing subsidies, public awareness, and goals towards a greener city with more eco-roofs*

<u>BACKGROUND</u>

Leading the way in sustainable stormwater management and green development, Portland has stepped up its efforts to finance green infrastructure for stormwater management. The city's annual average rainfall creates about 10 billion gallons of stormwater runoff. Considering that, the city has made it its focus to replace its traditional grey infrastructure with green alternatives through the Bureau of Environmental Services (BES) Grey to Green initiative (G2G). However, by developing G2G green infrastructure, BES is not only lowering stormwater runoff and enhancing habitat and water quality, but it is also offering services and advantages linked to energy, health, and community livability (Entrix, 2010).

<u>KEY INITIATIVE</u>

Grey to Green initiative

The G2G Initiative's goal was to expand the City's green infrastructure, which includes the following elements, or Best Management Practices (BMPs): building eco roofs and green streets, planting trees in urban areas, removing invasive species and revegetating, removing culverts, purchasing undeveloped land, and planting in natural areas.

Eco roofs are living, breathing vegetation roof systems that take the place of traditional roofing materials. Infiltration basins (rain gardens), vegetated curb extensions, or streetside planters are examples of green streets that catch stormwater runoff from roadways. Because they prevent erosion, which preserves habitat and water quality, and absorb rainfall, which restores hydrology, trees contribute to the health of watersheds. Invasive vegetation removal and native plant restoration cool the air, pavement, and streams while lowering stormwater volume, filtering stormwater pollutants, and creating a more diverse ecosystem.

The G2G initiative also outlined 5-year goals, which include:

- Adding 43 acres of eco-roofs.

- Constructing 920 green street facilities, emphasizing partnerships with other city bureaus and agencies such as the Portland Water Bureau, the Portland Bureau of Transportation, and the Portland Development Commission.
- Planting 33,000 yard trees and 50,000 street trees.
- Removing invasive plants from 1,900 acres of city parks and controlling invasive plants on an additional 840 acres citywide.
- Purchasing and protecting 419 acres of high-priority natural areas.
- Restoring 70 acres of habitat per year for a total of 350 acres (Entrix, 2010).

The initiative was planned with aspects of liveability at the centre and has an elaborated section on how the initiative would aspire to improve air quality, enhance physical and mental health, community cohesion, environmental equity, and access to nature, among other things.

Figure 45: Mt. Tabor Middle School Rain Garden (City of Portland, Environmental Services, 2009)

OUTCOMES

The initiative was deemed a huge success, and Portland now has 172 eco-roofs, which cover almost ten acres, helping control runoff, enhancing air quality, conserving electricity, and creating habitats for birds and pollinating insects. Towards the end of 2009, there were about 700 green street facilities in Portland, which together manage an estimated 48 million gallons of stormwater runoff annually. 32,300 plants were planted in the city over these five years. It is anticipated that these trees would filter 18 million gallons of stormwater as they get older. The city also offers incentives of up to $5 per square foot to add new eco-roofs, along with 'tree bates' to encourage people to plant eligible yard trees (Entrix, 2010).

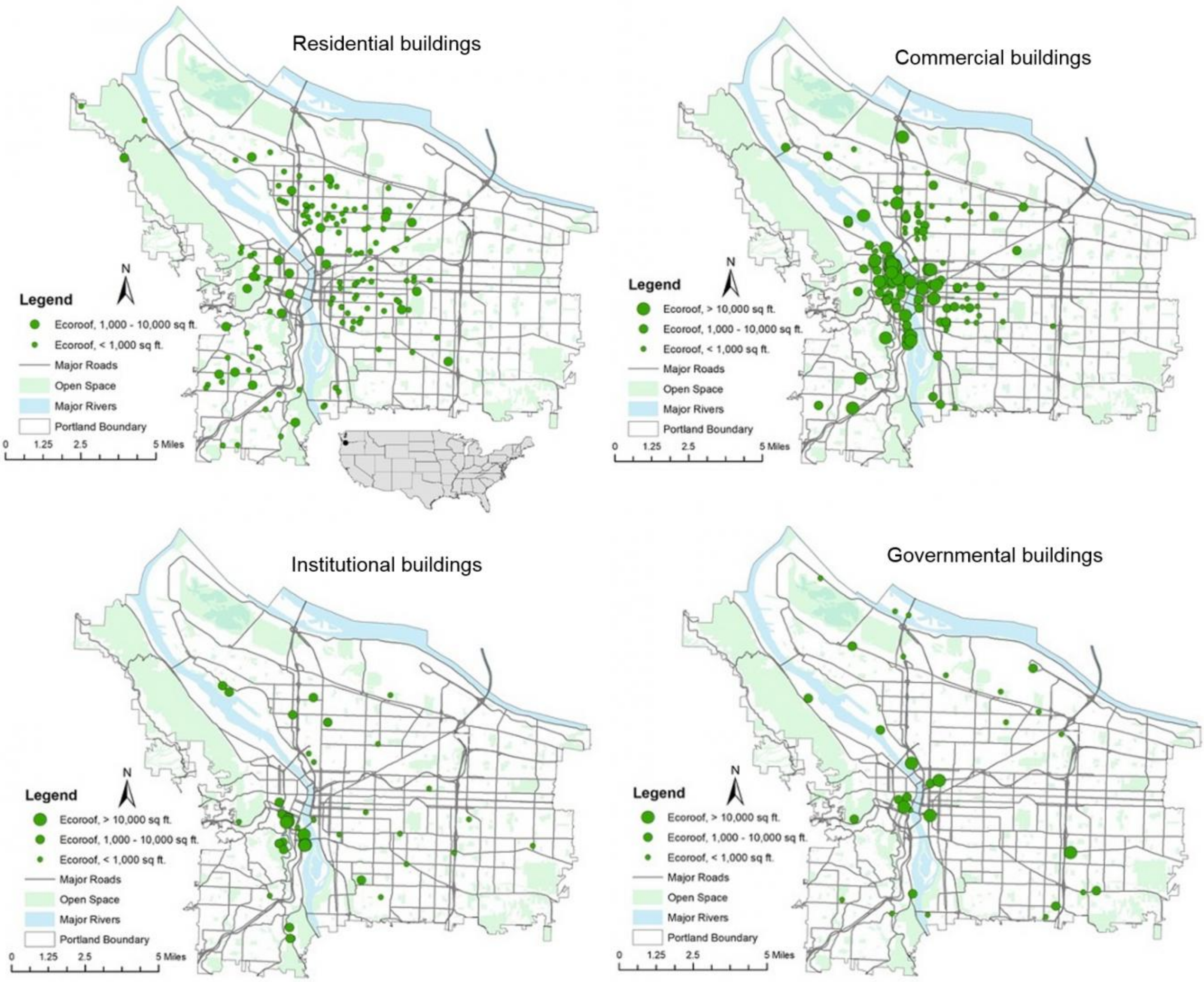


Figure 46: Eco roofs on various buildings in Portland (Netusil & Thomas, 2019)

In order to protect the storm drains, control and filter runoff, and enable rainwater to return to the soil, the city constructed 867 green street planters. The goal of planting 83,000 trees was aimed at removing about 8.5 tonnes of PM10 annually, and an estimated 333 pounds of PM10 would be eliminated annually if 43 acres of green roofs were installed and the city managed to achieve 1/3rd of their goal, approximately (Friends of Trees, 2012).

The city cleaned 7.400 acres for invasive plants with the assistance of volunteers and staff from Portland's Parks & Recreation. They fixed 17 culverts that were lowering the quality of the water and keeping fish from swimming through (Entrix, 2010).

LIMITATIONS

Although it was not assessed, the overall impact of the G2G Initiative's enhanced vegetation on Portland's air quality is anticipated to have a negligible impact on respiratory illnesses overall. Few studies have measured the direct correlation between greenness and improved physical health, both on its own and in combination with other facilities that encourage physical exercise (Entrix, 2010).

Although air pollutants harmful to human health may also be released by vegetation, these impacts are anticipated to be negligible and were not calculated for this study. The large differences in results could be explained by variations in the climate, leaf area index, pollution levels, and the relative capacity of grasses to absorb PM10. Despite the difficulties of determining cause-and-effect links with some health benefits, the health subgroup identified air quality, mental health, and physical health benefits as the three key health benefits that G2G BMPs may provide to the citizens (Entrix, 2010).

III.2. 8. Sabarmati River Front

Location: Ahmedabad, India

Year: 1998

Scale: State-wide

Main Instrument: Developing a sustainable and interactive riverfront area

BACKGROUND

Ahmedabad is the 8th largest city in India and houses a population of approximately 9 million people. It is the capital of the state of Gujarat and one of the economic powers of India. The city has developed with the Sabarmati River at the centre and is an integral part of the landscape, running north to south, dividing the city into two halves. The river has often been used for cultural and recreational uses and offered a place for various informal economic activities for the citizens. Despite the central role the river played, it was neglected and abused by dumping untreated sewage and industrial waste for many years. The river ecology was fragile due to the intensive use and was prone to flooding. These developments made the river unusable. The riverfront's potential to be transformed from its dilapidated status into a significant urban asset had long been recognised. Since the 1960s, there have been proposals to accomplish the same, and the city eventually envisioned and started this multifaceted project in 1998.

KEY INITIATIVE

Sabarmati Riverfront- Reconnecting Ahmedabad to its River

The Sabarmati Riverfront Development Corporation Limited (SRFDCL) was established by the Ahmedabad Municipal Corporation in May 1997. It was given a seed capital of Rs. 9 crore and given the task of building the riverfront on a 'Build, Maintain, Operate, and Transfer' basis. The project aims to reconnect the citizens with the river but creating a socially stimulating waterfront environment and redefining the identity of the city around the river. The projects aim to do this by developing the neglected areas at the waterfront of the river. The project classifies its objectives into three:

1. **Environmental Improvement:** The objective umbrella strategies are formulated for the improvement of the environment. This includes detailed strategies to reduce erosion and flood protection along the banks. New sewage treatment facilities and a water management system to reduce flooding and clean up the river are major points of the design. Since the river is not a perennial river, a strategy to maintain water throughout the year was

worked out. To increase marine biodiversity, SRFDCL monitors the water's quality and oxygen content, and the amount of dissolved oxygen in the river is maintained (SRFDCL, n.d.).

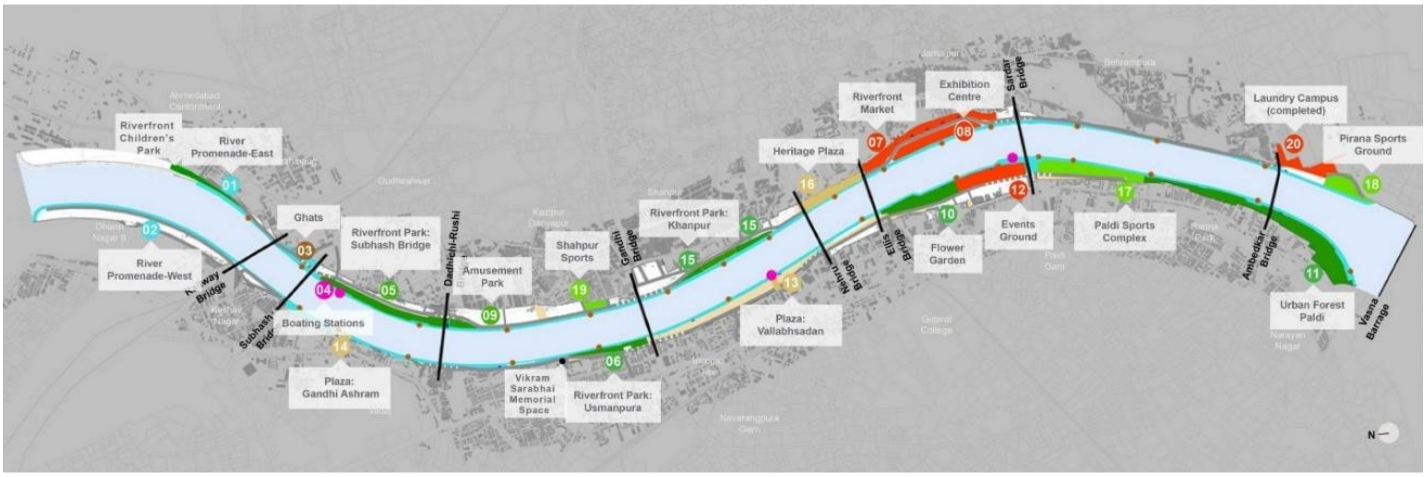


Figure 47: Recreational masterplan showing two-level continuous promenade (SRFDCL, n.d.)

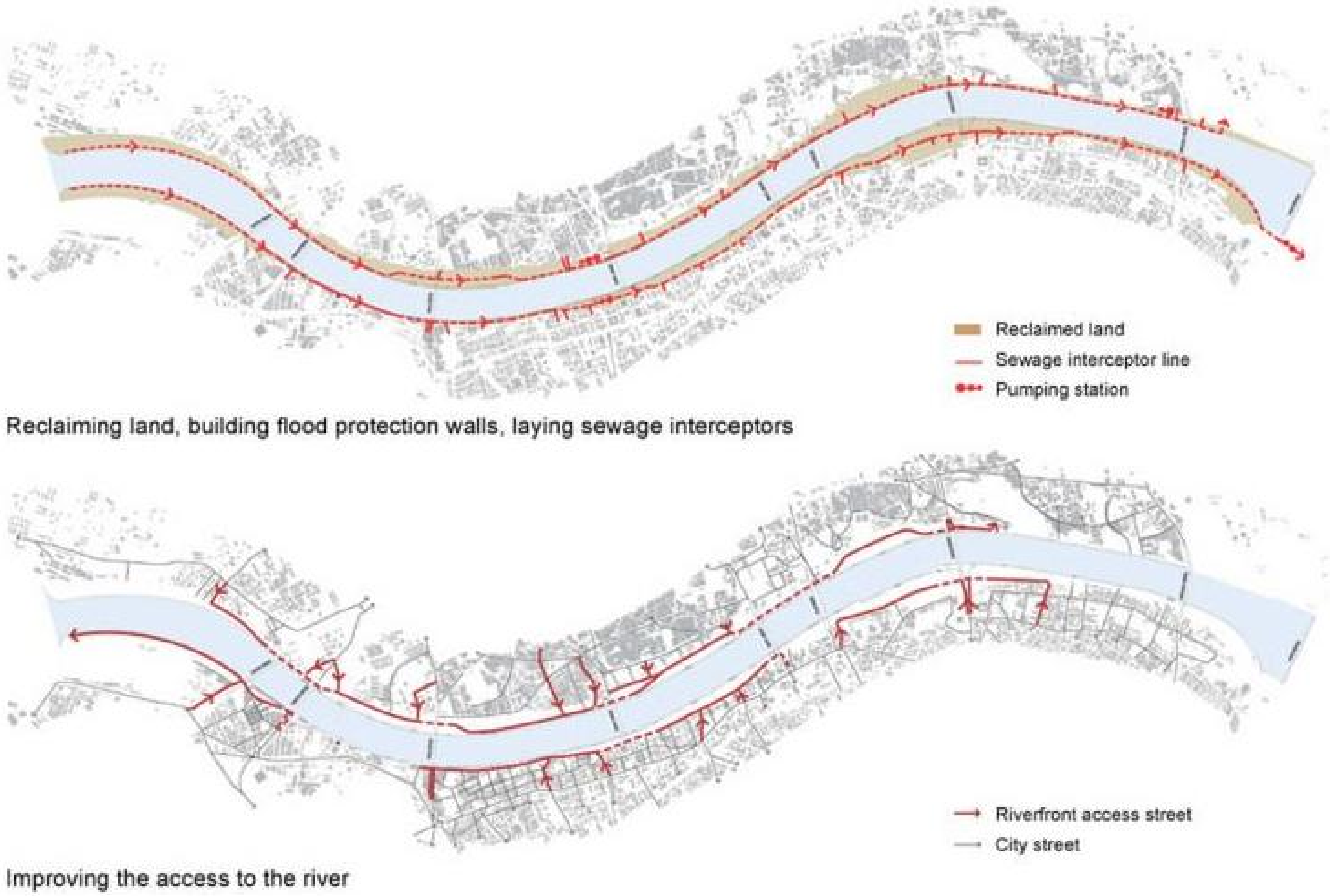


Figure 48: Sabarmati riverfront project achievements (Source: HCPDPM)

2. **Social Upliftment:** Over 10,000 households that previously resided in slums along the riverbanks are to be resettled as part of the project; these residents have been moved and given secure tenure permanent homes. To assist traditional occupations, facilities have been developed, such as the Riverfront Market for sellers from the weekly 'Ravivari' flea market and a Laundry Campus for the cleaning community. In order to establish a public space with a continuous 11.5 km promenade along both riverbanks, the project reclaims over 202 hectares of riverbed land. This comprises green open spaces, parks, and plazas that are intended to benefit nearby communities and improve the city's green network (SRFDCL, n.d.).

3. **Sustainable development:** The project is meant to be self-financing; to achieve this, a limited amount of the reclaimed land will be sold for commercial development. To guarantee that the built environment along the riverfront is harmonious and has a striking skyline, the private developments that will be constructed there are to be strictly regulated by laws. The project's goals are to revitalise the city centre and encourage a more widespread revitalisation of the neighbouring suburbs, encouraging integrated, high-density growth, with an emphasis on public transport and walkability (SRFDCL, n.d.).

OUTCOMES

The project has yielded significant results towards the goals outlined. The project has rehabilitated over 10,000 families that were living in slums by the riverside and allotted them modern housing. Gurjari Bazaar has now become a developed informal market housed in a structured facility and allows 1,600 vendors to operate, creating economic opportunities in the area. To accommodate the washer community of the area, the modern Dhobi Ghat with a utility area of about 6000 sq.mt. was made with facilities that don’t pollute the river anymore. The riverfront also sees people from the Jain community gathered in considerable numbers to practice the group ‘Parna’ (Rite of releasing fast) (SRFDCL, 2014).

Parks and garden space for cultural institutions are constructed on 27% of the project site. The project has constructed 36 ghats that foster a sense of community among the residents. The river has been cleaned up, and the ecology has returned to its lush state with a variety of migrating bird species. To increase marine biodiversity, SRFDCL is monitoring the water's quality and oxygen content (SRFDCL, 2014).

Figure 49: Before and after Images of Riverfront development (Source: Darshan Pathak)

LIMITATIONS

The project was supposed to be a trailblazer for GI, which is why the funds allotted for this project were state-level rather than city-level to raise the visibility of Ahmedabad nationally. The potential value of this project was envisioned to have a cascading effect on the daily lives of the citizens. The project had state support and was not possible at the city level. Despite the good things mentioned in the 2014 report, the project remains unclear about the green space development and its investment.

The promenade's well-kept layout may have limited the ecological functionality of the on-site GI because a strict management program reduces the possibility of ecological diversification. Few chances for community-led projects have been suggested when investments in GBI have been made; instead, funds have typically been directed towards formal green areas like the two riverbank parks. Some academics in Ahmedabad have also suggested that the removal of the existing ecological resource base (including trees, grasses, and shrubs) has caused more harm to the ecosystem than the replacement GI development will deliver. Other criticism of this investment in formal parks focuses on the requirement of an entrance fee, which makes the project exclusionary (Mell, 2016).

III.2. 9. Sponge City Program

Location: Wuhan, China

Year: 2015

Scale: City-wide

Main Instrument: Sponge City initiative

BACKGROUND

The 'sponge city' concept was created in 2013 to solve China's urban water management issues and restore a harmonious relationship between the city, water, and people. Known as the 'city of one hundred lakes', Wuhan is the capital of Hubei Province and is situated in central China. The city is liveable because of its vast water systems and ample sources of water, which also create beautiful landscapes and pleasant city vistas (*Grow Green Project*, n.d.).

On the flip side of the coin, so to speak, Wuhan also faces difficulties with flood prevention and water management. China is vulnerable to floods and has faced 15 floods in the span of a decade from 2004 to 2014 (Oates et al., 2020). Waterlogging has plagued Wuhan for years, due to the uneven distribution of precipitation and the fact that the city's built-up region is situated in a low-lying terrain, and the urban area's elevation is typically below the flood level. Urban discharge capacity is limited since the Yangtze River and its tributaries flood season falls during the monsoon season. By filling lakes and increasing impermeable surfaces, rapid urbanisation has made waterlogging issues worse by decreasing natural drainage. To combat this, the sponge city demonstration project was initiated in Wuhan in 2015 (Peng & Reilly, 2021).

KEY INITIATIVE

Sponge City Programme

The Wuhan sponge city programme is interdependent with urban plans, namely the Wuhan Comprehensive Planning and the ecological planning framework. To aid in the execution of municipal sponge city initiatives, the Ministry of Housing and Urban-Rural Development released the 'Technical Guide' for Sponge City Construction in 2014. The Technical Guide provides guidance for implementing the sponge city concept throughout the planning, design, building, and maintenance phases. The "1+6" urban development pattern and the broader ecological framework—"two axes, two rings, six wedges, and multiple corridors"—were proposed in the comprehensive planning of 2010.

Figure 50: Six green wedges in Wuhan development Plan *(Li et al., 2023)*

From 2015 to 2020, sponge city initiatives were being developed to carry out the Wuhan Plan, with an emphasis on preventing waterlogging during the initial stages of construction. Rain gardens, green roofs, permeable pavements, grass swales, bio-retention facilities, depressed green areas, pervious concrete pavements, built wetlands, and rainwater-fed wetlands are some of the sponge infrastructures utilised in Wuhan sponge infrastructure. GBI is essential for preventing waterlogging, and source reduction techniques like 'infiltration' and 'retention' are used in conjunction with low-impact development (LID) to reduce rainwater drainage and ease the strain on urban pipe networks. To help participation, the district and municipal governments were urged to find a way to link stormwater fees and the sponge sites, as well as to create a special

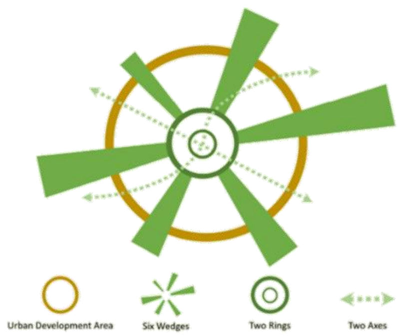


Figure 51: Wuhan ecological planning framework (Peng & Reilly, 2021)

investment fund for the building or subsidy and reward of sponge city projects (Peng & Reilly, 2021).

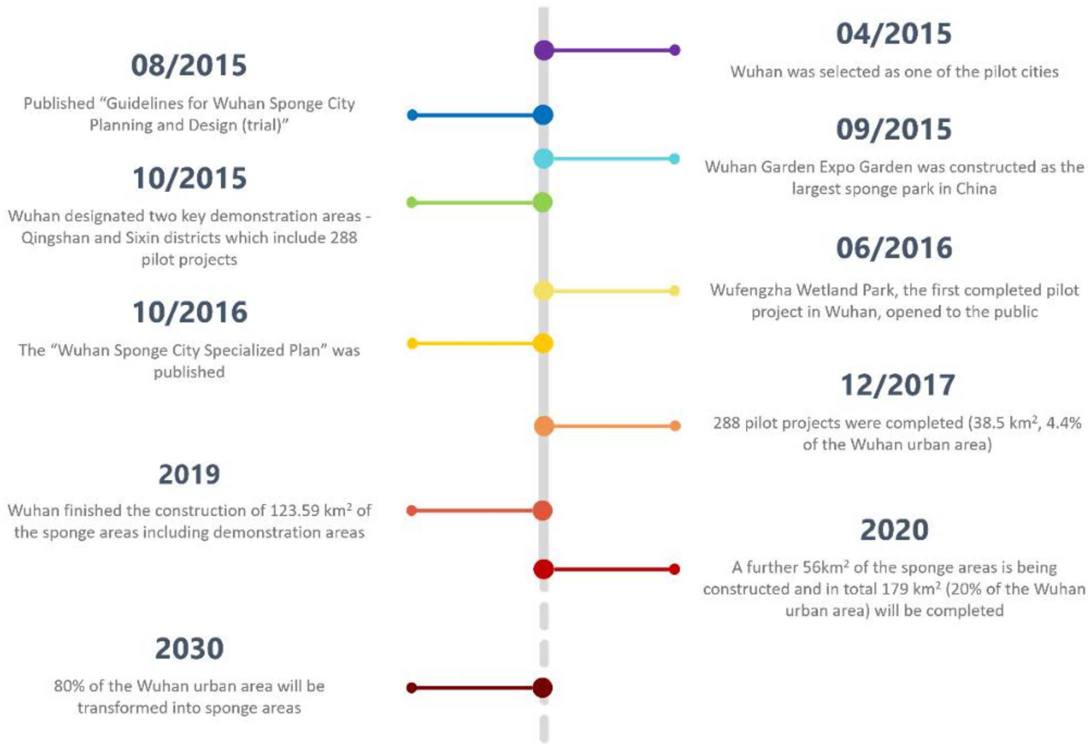


Figure 52: The timeline of the Wuhan Sponge City Programme (Peng & Reilly, 2021)

OUTCOMES

The objective of the programme complies with the national guidelines that state set the objective of 20% and 80% of the urban area should achieve the sponge city requirements by 2020 and 2030 respectively. Wuhan launched sponge city construction demonstration projects in 2015 and released the 'Wuhan Sponge City Pilot Implementation Plan' in 2016 to kickstart the citywide sponge city initiatives. For sponge demonstration projects, a "2+N" mode was used to create 38.5 km2 of sponge-like areas. The "2+N" method includes two demonstration areas, Qingshan (23 km2) and Sixin (15.5 km2), as well as 288 pilot projects focused on renovating the old town and developing the new city region. For this, both government and social funding contributed CNY 11 billion (EUR 1.4 billion) to the building of the demonstration projects. The pilot projects were of various types, including roadways, green spaces, and residential quarters. As local sponge technical standards were being compiled, hundreds of sponge projects were being carried out (Peng & Reilly, 2021).

The city's waterlogging points decreased from 162 to 30 (after the rain stopped over 90% of the waterlogging points vanished). Additionally, the area of waterlogging spots was greatly decreased, and the maximum period of waterlogging was cut from one month to six hours. In lieu of this, waterlogging's negative effects on traffic and the public were significantly reduced, demonstrating the sponge city program's enormous potential. The conservation plan also designated 166 lakes to ensure their water regulation and storage capacity, especially during the flooding season. When Wuhan saw many rounds of heavy, record-breaking rains during the rainy season in 2020, the city was mainly unaffected (Peng & Reilly, 2021).

To efficiently manage data and monitor sponge projects, a monitoring and evaluation platform was created that combines sponge maps, information management, and performance evaluation into a single solution. This initiative promoted the growth of the sponge industry, which has since grown to include teams involved in product development, design, construction, and research. With the establishment of multiple new building material production lines that aided in the growth of the Wuhan green building materials industry, the sponge sector also exhibits significant promise in the field of green building materials (Peng & Reilly, 2021).

<u>LIMITATIONS</u>

Despite the water drainage capacity and waterlogging avoidance calculations take climate change into account, greater consideration of various climate scenarios is necessary. Air quality, biodiversity, and carbon emission reductions are other environmental issues that have not been considered when evaluating sponge projects (Peng & Reilly, 2021).

One essential element of urban management that might not only meet social requirements but also speed up project procedures is stakeholder involvement and public participation. To guarantee social involvement, financial incentives like tax deductions could be made available. Opportunities for improved sponge project management and execution could include research, training, and capacity building (Peng & Reilly, 2021).

Opportunities to expand the Sponge City Program are further limited by basic budgetary and governance problems, especially the rising municipal debt. In situations when there is no immediate or even long-term yield, it is challenging to motivate private investment. Tasks are currently divided up among municipal agencies and handled as handovers; for instance, projects are designed by one subdivision and then moved to another for construction, with no one body involved in the program from start to finish (Oates et al., 2020).

The sponge city model has also received some criticism because projects are rarely located in densely populated urban areas, where they are especially needed. Furthermore, criticism levelled against the sponge city concept is that it lacks the adaptability necessary to support site specific priorities and objectives.

As a result, while water-related issues vary from city to city, the solutions employed are guided by the same set of principles. Although they are a crucial starting point, the national government must provide for flexibility so that cities can create initiatives that are appropriate for their unique socioeconomic and environmental features. Another factor is the newness of the programme- due to which long term data of its performance is not yet available which makes the prediction of operation & maintenance costs tough (Oates et al., 2020).

IV. COMPARITIVE ANALYSIS OF STRATEGIES AND INITIATIVES

IV. Comparative Analysis of Urban Strategies and Initiatives

IV. 1. Identification of indicators

Considering the impact GBI has on liveability, we have identified indicators for an impact analysis of the GBI initiatives and programmes within the case studies. Considering the aspects of daily urban lives, the classification of the indicators that impact liveability falls under four main categories:

A. Ecological Indicators
  - A1. Air Quality
  - A2. Urban Heat Island Effect Mitigation
  - A3. Stormwater Management Efficiency
  - A4. Green Cover and Permeability
  - A5. Increased biodiversity

B. Physiological Indicators
  - B1. Increased Physical Activity Levels
  - B2. Access to Green and Blue Spaces
  - B3. Increased Social Cohesion and Community Interaction

C. Economic Indicators
  - C1. Business Growth and Tourism
  - C2. Employment in Green Sectors
  - C3. Sustainable Transport Benefits

D. Governance and Policy Indicators
  - D1. Public Participation in Green Initiatives
  - D2. Institutional Capacity for GI/BGI Implementation
  - D3. Policy Incentives for Private Sector Involvement

To understand the impact in a better way the classification of the indicators is done considering the three ways of impact.

(green)	- Achieved
(pink)	-Partially Achieved
(grey)	-Not Mentioned

IV. 2. Impact analysis

Based on the case studies and the data provided by them, an impact assessment is carried out within the case studies chosen.

Indicators	A1	A2	A3	A4	A5	B1	B2	B3	C1	C2	C3	D1	D2	D3
Stockholm														
Oslo														
Barcelona														
Leipzig														
Helsinki														
Manchester														
Antwerp														
Dordrecht														
Ghent														
Rotterdam														
London														
Singapore														
Portland														
Ahmedabad														
Wuhan														

IV. 3. Insights

Based on the case studies, several key insights are obtained regarding how various places have adopted GBI according to their local contexts for their climates and particular problems of urban life. The comparative analysis of the impacts helps us understand which aspect of liveability is addressed and which remain overlooked. The distinct divisions created between indicators, namely ecological, physiological, economical and governance give an insight into how GBI strategies affect each realm of impact individually and together as well. The analysis helps us ascertain the issues that are frequently addressed when GBI initiatives are proposed in the recent time. Some of these include:

- Climate resilience
- Ecological sustainability
- Public health and well-being
- Social Inclusion & green space equity
- Economic sustainability

The key issues outlined all share common objectives of relieving the pressures of urbanization and help in adapting to the changing climate. Furthermore, they highlight the importance of adoption of GBI initiatives from the bottom up and not just top-down approaches. Additionally, an analysis of the case studies offers a comprehensive view on the connections between GBI planning and people-driven design, aiding in the extraction of useful design and planning strategies and initiatives.

IV. 4. Best Practices & Policies

Multi-value integration of GBI

Prioritizing designing GBI in a way that they serve multiple functions and contribute to ecological, social and economics purposes is essential. GBI needs to be perceived beyond its environmental value, and recognised for the multi-purpose solution that it is, given its multiple benefits. For example, the BEGIN project highlights the importance of shifting from 'lead' values like flood management to multi-value purposes where GBI supports health, recreation and business growth.

Stakeholder engagement and community driven initiatives

Many case studies have active and early involvement of stakeholders of diverse types including governments, businesses, students, community members, etc. These case studies show that co-creation with stakeholder involvement fosters a stronger community and helps create a user driven design. For example, The ENABLE project focuses on understanding the perceptions and preferences that people have of GBI through surveys and using participatory techniques.

The success of a GBI initiative also depends on citizen awareness and perception of their benefits. In some cases, there might be some resistance to change and their implementation, therefore stakeholder awareness and arranging educational campaigns is also equally important.

Climate responsive and data driven design

Many cities adopt GBI to mitigate the effect of climate induced stress like flooding, UHI effect, and biodiversity loss. Within the case studies, many project display a climate sensitive design that integrates storm water management and public space development like the Rotterdam water squares and Antwerp's Schijn-Scheldt River reconnection project. Additionally, using devices like IoT sensors to obtain real time data about the environment like water quality, and air quality helps maintain GBI and use its maximum potential. AI driven analytics like in the case of Manchester can help predict the effectiveness of GBI and optimize cooling strategies.

Economically sustainable models

Many GBI projects have problems with funds for maintenance and management over the long term, especially when the benefits of GBI are not immediately quantifiable in financial numbers. Therefore, developing a clear business plan or outline for securing funds is essential for successful GBI and its viability. Case studies showing the tangible benefits like reduced healthcare costs, increased property values, and tourism growth make a strong financial argument for investments. Some mechanisms adopted by the case studies involve using public-private partnerships (Rotterdam water squares), tax incentives (Portland's Grey to Green), and self- funding plans (Sabarmati Riverfront development).

Policies for Institutionalizing GBI

Since GBI design is context based and not a one-size-fits-all policy, it is important for adaptive governance to consider the local socio-economic and environmental contexts. Multi scalar integration of GBI at micro (street/house), meso (neighbourhood) and macro (city) level is important to have a successful framework for a larger impact. These could include integrating GBI into climate adaptation and land-use policies and developing legal mandates for stormwater fees along with incentives. Furthermore, embedding GBI in national, and local policies ensures multi-level coordination for effective long term urban planning. For example, Singapore's ABC waters program shows long term commitment with institutional backing effectively integrates the benefits of water management and liveability.

IV. 5. GBI Process Framework

After in depth analysis of case studies, to ensure a streamlined process, this thesis proposes a step-by-step model to ensure systematic, scalable and adaptive approach to implementing GBI

PHASE	ACTION PLAN	CASE STUDY EXAMPLES
Phase 1: Assessment	1. Conducting a thorough assessment ecological, social, and climate vulnerability; 2. Using GIS and remote sensing to map potential GBI sites. 3. Engaging stakeholders from the inception stage to define goals and co-benefits.	**Dordrecht' Blue green Vision** (Climate risk assessments)
Phase 2: Policy Integration and Financing	1. Developing a legal framework integrating GBI into existing urban policies and goals; 2. Defining zoning laws that regulate minimum GBI standards; 3. Creating a financing model along with opportunities for tax incentives and grants for private-sector participation.	**Singapore's ABC waters Programme** (Govt backed incentives)
Phase 3: Planning and Implementation	1.Using sustainable materials and retrofitting existing grey infrastructure with GBI elements according to local context.	**Wuhan Sponge City Programme** (ecological connectivity),

	2. Ensuring interconnected green and blue spaces to form ecological corridors; 3. Promote community-led GI projects (rain gardens).	Rotterdam Water squares (multi-functional)
Phase 4: Monitoring and Evaluation	1.Ensuring long- term sustainability of GBI by establishing monitoring protocols (IoT sensors). 2. Setting Key performance Indicators for evaluation of benefits like tracking urban cooling, biodiversity, and public health improvements. 3. Use adaptive management strategies and adjusting based on the performance.	Singapore's ABC Programme (AI-driven maintenance), Helsinki & Leipzig GBI models (GIS-based evaluation)
Phase 5: Capacity Building and Public Awareness	1. Training local government officials and citizens on GBI maintenance (volunteer-based programs); 2. Developing public engagement programs to raise awareness about GBI benefits. 3. Encouraging community led projects.	ENABLE Project (participatory planning), Barcelona Superblocks (public-driven)
Phase 6: Scaling and adaptability	1. Expanding successful pilot projects and replicating them on a city-wide scale, adapting them to the specific context; 2. Future proofing cities by ensuring regular policy updates to keep up with innovating techniques for maximum GBI impact; 3. Promoting international co-operation and funding mechanisms. 4. Establishing ties with other cities for knowledge exchange.	Dordrecht's Blue-Green Vision (scalable flood resilience model), London Green Grid (expanding connectivity of green spaces)

IV. 6. Challenges and Barriers

Even with the multiple benefits provided by GBI, mainstreaming it faces many challenges. Understanding these barriers is essential to ensure effective integration of GBI, especially when it is needed the most right now. Even though implementation of GBI projects is context specific, they have many common barriers, which are:

Institutional Barriers

Between administrative units there is a lack of responsibility regarding aspects of GBI. For example, in Stockholm ENABLE project many different departments working on conservation and natural reserve management separately caused inefficiencies in management. Additionally, political support also plays a major role despite having ambitious goals. For example, in Wuhan the lack of strong local political backing caused the project to have administrative hurdles. Also, in Portland the GBI policies were overshadowed by economic centric development which delayed the widespread adoption.

Financial Constraints

One of the most frequently faced problem is insufficient funding for GBI. For instance, the Sabarmati riverfront project in Ahmedabad faced several budget constraints which led to insufficient maintenance and along with an entrance fee charged in certain places creating a barrier for accessibility. The presence of limited financial incentives also exacerbates this problem, as seen in the case of Barcelona's ENABLE project and Rotterdam's Water squares where private sector was reluctant to invest in GBI due to the absence of tax benefits or financial support mechanisms.

Environmental challenges

While GBI strategies help in alleviating climate stress, they have their limitations. As seen in the case of Stockholm's green wedges some of the proposed GBI suffered with drought conditions and that vastly affected vegetation. Additionally, the conflicting interest with other environmental priorities also proves to be a challenge like the case of London's ALGG the city faced challenges balancing conservation efforts along with urban expansion, that lead to tough trade-offs.

Socio-economic considerations

If green infrastructure projects are not carried out with an equity-focused plan of action, they may unintentionally make social inequality worse. Access to green spaces may be restricted in some places, which could result in disparity in general quality of life, health, and well-being. Efforts to address these equity issues and guarantee that GBI projects benefit all urban dwellers actively need to be done (Young, 2011).

<u>Technical barriers</u>

There is a gap in integration of GBI with urban master plans like in the case of Ahmedabad's riverfront development in which GBI is added as an afterthought and only proposed to create a better image of the city rather than being integrated into the city's urban plan. Another technical barrier is the limited spatial data and hydrological data, like faced by Dordrecht while mapping blue-green corridors and was met with inconsistent data availability.

IV. 7. Future Directions

The case studies analysed suggest a need for addressing the challenges to achieve a more sustainable and liveable city through GBI. The future direction should focus on making stronger institutional capacity by embedding GBI into mainstream urban plans and policies. To support this, governments and local authorities both need to ensure equitable access to them. Community driven approaches have been recognised to be quite beneficial to bring GBI to the neighbourhood level, but raising the general public awareness is essential. To do this creating strong financial incentives and tax benefits would help greatly.

Integrating new technologies such as IoT and AI, will help optimizing GBI monitoring and performance tracking. The analysed case studies suggest a need for data driven approach consisting of GIS and hydrological models for efficiency and placement of GBI. Furthermore, leveraging GBI to help enhance liveability by addressing urban heat, physiological health, biodiversity loss, etc can help in attracting better private- public partnerships and encourage investments.

V. GBI INTERVENTION STRATEGIES

VI. 1. Planning system in India

India, officially the 'Republic of India' is the seventh-largest country by area, and currently also holds the title for the most densely populated democracy in the world. India commands an important strategic position on the globe with respect to trade and a strong cultural significance. The country has been amongst the fastest growing economies in the world for almost two decades. Faster growth has obvious implications for the pace and nature of urbanization (Ahluwalia, 2019). The challenge Indian planners and politicians are facing is how to improve the quality of life in cities so that they can continue adapt to future growth while ensuring better living conditions for its residents and cooperation rural sector development.

India encompasses various states with diverse cultures and traditions of their own. Owing to this, the constitution of India preamble states that the country is a 'Sovereign Socialist Secular Democratic Republic'. The 74th constitutional amendment provides a three-tier federal structure, which consist of the union governments, the state governments and the urban local bodies (which are further divided into rural and urban). The country has 28 states and 8 union territories, of which New Delhi is the latter.

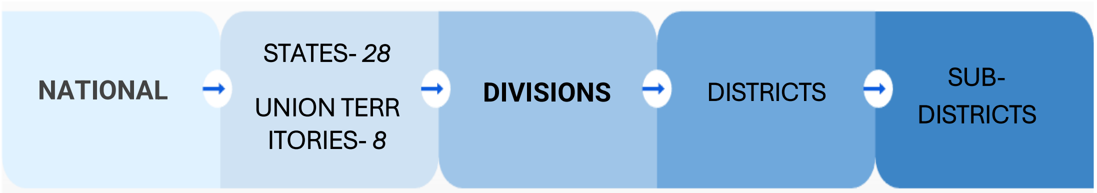


Figure 53: The Nation's governance Structure of India (Source: Author)

Due to the distinct diversity, the competencies of the urban planning and development system are primarily at the state level, as stated by the 74th Constitution Amendment Act. The state bodies then further assign the duties to local municipal bodies. The most prominent body is the Ministry of Housing and Urban Affairs (MoHUA), formerly known as the Ministry of Urban Development at which national level provides the state government with financial support and policy guidance. The ministry is established to exercise a larger influence that will shape the policies and programmes of the country cohesively (MoHUA, n.d.).

Therefore, the state governments have a significant role to play in ensuring an enabling environment through institutional and legislative reform to transfer funds, functions, and functionaries. Municipal functionaries are often workers of the state government who are assigned to specific cities by the state governments (Ahluwalia, 2019).

India gained independence from the British in 1947, and the newly minted nation used the foundation of the Town and Country Planning Act of 1947 from the United Kingdom for India's current urban planning system, which is focused on land use zoning. India issues a master plan that usually spans around 20 years and provides a roadmap from the current state of the city to its desired goals, complete with spatial details for the last year. In the case of state governments, urban national policies generally flow from national plans themselves. Overall, the planning and development stem from cooperation between the government bodies and the people. Post-independence, the country adopted a top-down approach where the planning organisation formulates a development plan for cities and authorises it from the respective state departments. The process of legalising a development plan includes suggestions and objections from the citizens, and it is legally only approved when it addresses all of these.

Urbanization is not only a consequence of faster growth and development but also an instrument in promoting development through the economies of agglomeration, which characterize cities. The cost of unplanned urbanization is borne not only by the cities but the whole economy. The Urban and Regional Development Plans Formulation and Implementation (URDPFI) Guidelines were prepared in 1996, and updated in 2015, undertaking the task of inclusive planning, integration of the land use and transport, disaster management as well as the networks of the communication, electricity, roads, water supply, sewage and solid waste.

A participatory approach was considered in the 2015 update, to fully comprehend the proactive involvement of state governments and the Government of India Ministry in directing urbanisation. The URDPFI guidelines, which offer the framework, required methods, norms, and standards, as well as options for resource mobilisation, including land assembly approaches and land development regulations, are meant to be comprehensive to promote a balanced and orderly regional and urban planning and development (URDPFI, 2015).

According to the URDPFI Guidelines, urban and regional planning in India is divided into two categories:

1. Core Area Planning
2. Specific and Investment Planning

The URDPFI describes the process of spatial planning as “a continuous, time-oriented, cyclic process” that should be viewed and used as a dynamic process that includes planning, implementing, monitoring, reviewing, and updating plans. It outlines a general process of planning [Figure 53].

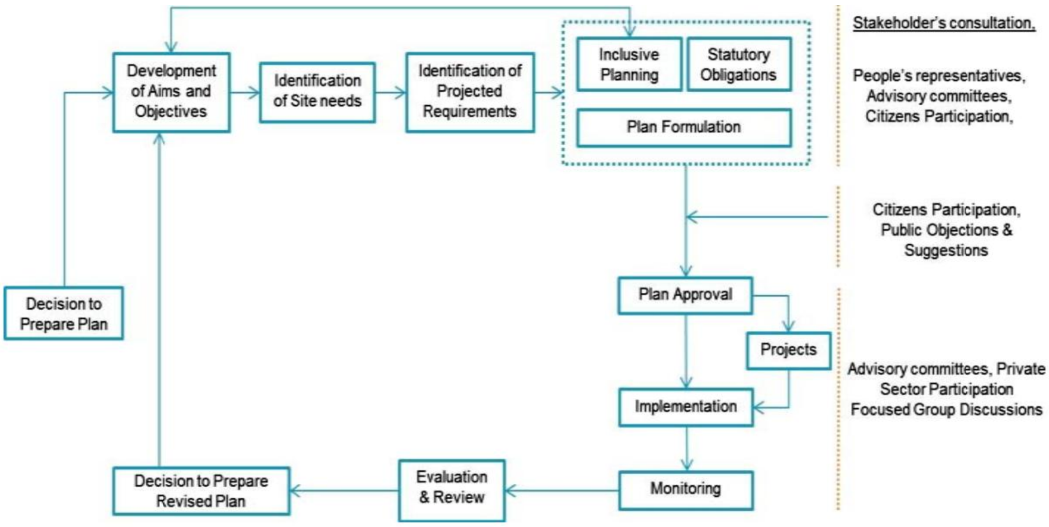


Figure 54: General process of planning (URDPFI, 2015)

Over the past ten years, the Indian government has adopted a variety of proactive measures to revitalise its cities. Launched in December 2005, Jawaharlal Nehru National Urban Renewal Mission (JnNURM) was designed to help urban renewal with partial investment support from the government (JNNURM, 2005). Several new projects were announced in 2014 and 2015, including the Smart Cities Mission, the Atal Mission for Rejuvenation and Urban Transformation (AMRUT), the Clean India Campaign (Swachh Bharat), and Housing for All. These projects are presently in various phases of planning and execution (Ahluwalia, 2019).

VI. 2. Green Blue Infrastructure and Liveability India

Between 1901 and 2018, India's average temperatures rose by 0.7°C as a result of excessive greenhouse gas emissions. India's temperature will still rise by 2.7°C by 2099, even with the best possible rate of immediate emissions mitigation, and in the worst-case scenario, it will rise by 4.4°C by the end of the century (MoES, 2020). Therefore, GBI has evolved as an answer to the rapid urbanization and environmental degradation associated with it. The assessment of current blue-green initiatives in India and around the world emphasises the necessity of a multifaceted, carefully planned approach to GBI.

As established in the previous section, the multi-level governance structure of India and the sheer size of the country make way for GBI policies to be initiated at every level. The approach to GBI includes a mix of ecological preservation, climate resilience, and urban planning. These efforts involve various ministries and organisations in charge operating at respected levels.

In an early discussion of India's environmental policy in the Fourth Five-Year Plan (1964–1969), green infrastructure was first brought up. The plan simply described environmental protection as a key tenet of a healthy lifestyle and discussed how environmental issues affected nations all over the world. Several years later, the environmental ministry was formed and undertook several issues such as preservation of forests, mangroves, and other vegetation, and controlling air and water pollution (Driver & Mankikar, 2021) .

The major policies and initiatives at the National level include:

1. National Action Plan on Climate Change (NAPCC)

In response to the UN Framework Convention on Climate Change and the UN's "Green Economy Initiative," (UNEP, 2009) India created the National Action Plan on Climate Change in 2008. The effort outlined the poverty-reduction, sustainability, and macroeconomic effects of green investment in fields like sustainable agriculture and renewable energy. It also offered recommendations for encouraging further investment in these fields. Twelve missions make up the NAPCC, within which the missions for sustainable habitat, water, agriculture, and forestry are multisectoral and cross-departmental:

1. National Mission for Green India
2. National Solar Mission
3. National Water Mission
4. National Mission for Sustainable Agriculture
5. National Mission on Sustainable Habitat

6. National Mission for Enhanced Energy Efficiency
7. National Mission for Himalayan Ecosystem
8. National Mission on Strategic Knowledge on Climate Change
9. National Wind Mission
10. Mission on Health
11. National Coastal Mission
12. Waste-to-Energy Mission

Each of the missions had deliverables outlined along with a thematically planned team consisting of specialists trained climate change researchers with specializations in various domains. Deliverables for the mission also comprise the stated technical aims, which are codified in the strategic knowledge mission objectives. The main NAPCC Principles encompass using a climate change-sensitive, inclusive, and sustainable development approach to protect the poor; Reaching goals for poverty reduction and national growth while maintaining ecological sustainability; Widespread and quick implementation of suitable technologies for mitigation and adaptation, etc (NAPCC, 2008).

2. <u>Smart Cities Mission (2015)</u>

Launched on 25th June 2015, the Smart Cities Mission’s objective is to promote sustainable and inclusive cities by providing core infrastructure for a decent quality of life by the use of ‘smart’ solutions. The Smart Cities Mission's strategic elements include city extension (greenfield development), city renewal (redevelopment), and city improvement (retrofitting), as well as a pan-city project that applies smart solutions to a wider area of the city (MoHUA, 2015b).

Through extensive work on the city's social, economic, physical, and institutional pillars, the mission seeks to promote economic growth and enhance quality of life. By developing replicable models, the emphasis was on equitable and sustainable development, for which 100 cities were chosen to become Smart Cities. Owing to the various cultural and geographical diversity, the mission is based on six fundamental principles [Figure 52] (MoHUA, 2015b).

Figure 55: Principles of Smart City Mission (MoHUA, 2015b)

Within the Smart Cities Mission, several initiatives are proposed, one of which includes the Ease of Living Index (EOL). The EOL, launched in 2017, has an objective of framing an index to enable a shift to data data-driven approach to urban planning and management. It encompasses four pillars to assess the ease of living of the citizens: Institutional, Social, Economic, and Physical. These are further divided into 15 categories across 78 indicators. The EOL is strongly linked to the country's path to achieving the SDGs.

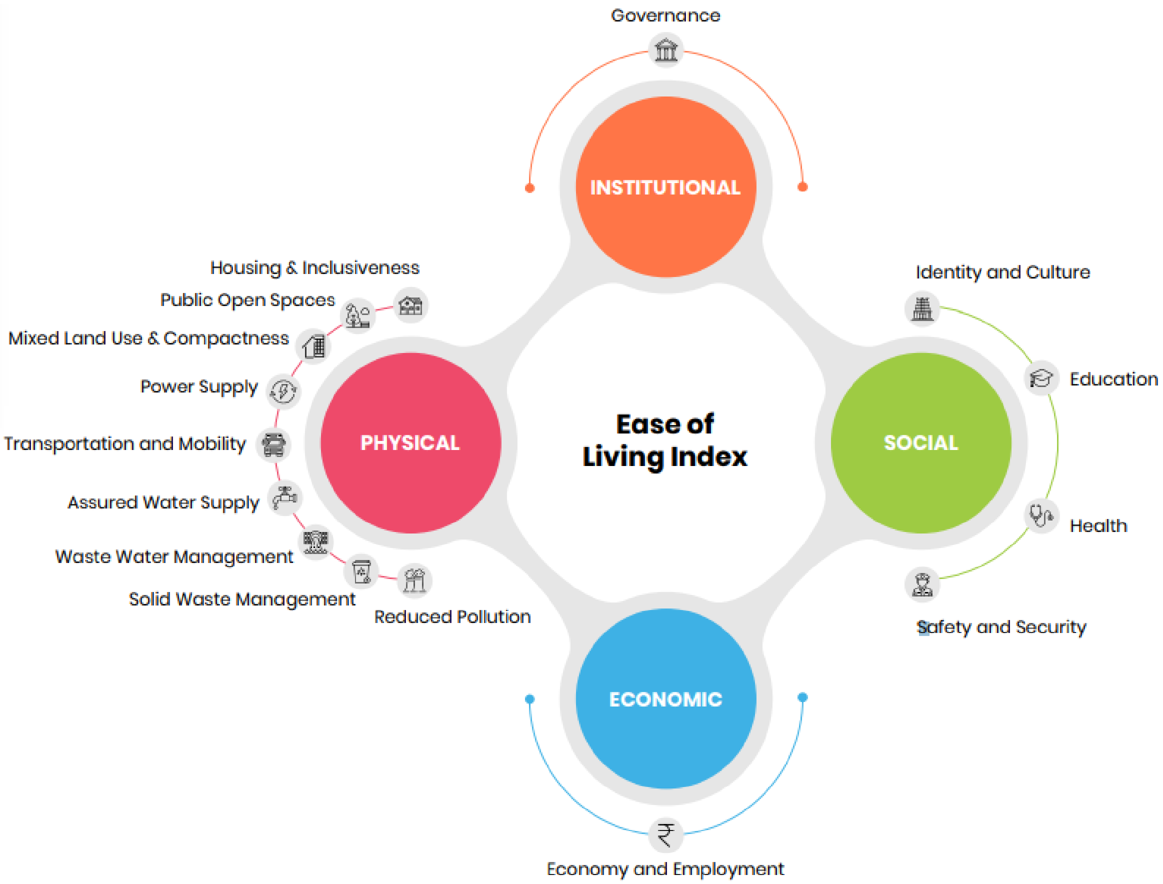


Figure 56: Ease of Living Index and its categories considered (SMARTNET, 2018)

In the EOL report of 2018, Delhi was placed at 65 among 111 cities considered, ranking low in the social, economic, and physical sub-indices, but ranking high in the institutional sub-index (SMARTNET, 2018).

3. <u>Atal Mission for Rejuvenation and Urban Transformation (AMRUT)</u>

AMRUT was started by the government of India with the goal of providing basic civic amenities like water supply, sewerage, urban transport, and parks in order to improve the quality of life, especially for the poor and disadvantaged, across 500 cities. The mission focuses on building infrastructure that contributes to delivering better services to the citizens. The three main purposes of the AMRUT mission include guaranteeing that every household has access to a tap with a guaranteed supply of water and a sewer connection; elevating the amenity value of cities by creating parks and other green spaces; and to lower pollution by implementing public transportation or building infrastructure for non-motorized transportation, such as walking and bicycling (MoHUA, 2015a).

VI. 3. Introduction to the study area

Cultural Relevance

Delhi, located in northern India, has served as the country’s capital for a century, is currently among the top ten megacities worldwide, and continues to become more significant internationally. Historically, when the capital of British India shifted from Calcutta to Delhi, the city needed appropriate infrastructure as the imperial city, for which the task was entrusted to architects Edwin Lutyens and Herbert Barker.

Lutyens finalised the layout of the city in 1915, for which the plan was inspired by the European Renaissance and included an intricately planned plantation scheme that consisted of indigenous varieties. The layout included public buildings and compounds and now houses the seat of the national government of India, and includes buildings like the official residence of the President of India, the Prime Minister, and all other Union ministers, members of Parliament, among others.

Figure 57: Google Satellite images showing (left) Lutyens Layout for Delhi, and (right) Chandni Chowk (Source: Google Earth (17/05/2025))

Post-Independence, the partition brought an influx of immigrants from the other side of the border and caused a sudden increase in the inhabitants to 12 million, which led to Delhi expanding in all directions, encircling the centre planned by Lutyens. In contrast to Lutyens' layout, the new constructions were densely populated and constructed to radically different standards. Public discussion on the need to alter the British imperial heritage was sparked by the disparity between these two sets of standards.

Geographical Context

Situated between 76.84°E, 28.41°N, by 77.35°E, 28.88°N, Delhi is located in the Ganges plain and is distinguished by the Aravalli Hills (Delhi Ridge) and the Yamuna flood basins (Ahmad et al., 2013). The Ridge marks the end point of the 15-million-year-old Aravalli, which forms the "Western Ghats" that run along the country's west coast from the deep south to Delhi. The Yamuna River, which rises in the Yamnotri glacier and joins the Ganga in Prayagraj, is the greatest tributary of the Ganga River. A system of ponds, lakes, and canals was created by the river and the Ridge.

Furthermore, the city is currently traversed by several natural drains that were originally used as freshwater overflow canals to absorb the river's backflow during monsoon floods (NIUA, 2020). Located within the NCR region, Delhi is divided into nine districts and twenty-seven subdistricts at the administrative level [Figure 54b] (Ahmad et al., 2013). Delhi's urban agglomeration—which includes the satellite cities of Ghaziabad, Faridabad, Gurgaon, Noida, Greater Noida, and YEIDA city—is the largest metropolitan area in India and the second largest in the world. It is also collectively known as the National Capital Region (NCR) [Figure 54a].

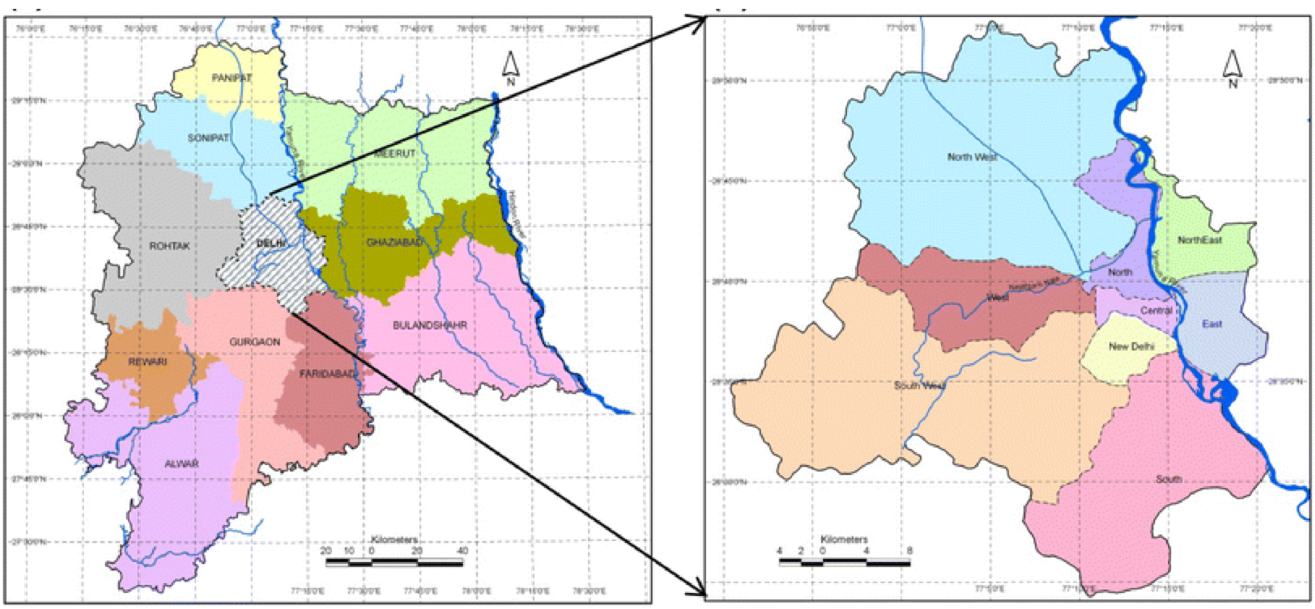


Figure 58: Maps showing (left) the NCR region and (right) the 9 administrative districts of Delhi (M. Jain et al., 2016)

With the rapidly increasing population, the city faces multiple challenges such as traffic congestion, worsening air quality, heat waves, unplanned urban growth and an overall worsening of the environment.

DEMOGRAPHY

Population - 16,752,235 (Census-2011)

Density - 11297 persons/sq.km. (Census-2011)

Decadal growth (Between 2001 and 2011) – 21.2% (Census-2011)

Current population (2025) - 34,665,600 (Approx.)

Delhi had significant geographical expansions as a result of the flood of migrants brought about by two significant historical events in India: the partition of India in 1947 and the re-establishment of Delhi as a capital city in 1912. Furthermore, during the past 60 years, Delhi's gross population density has grown from 1176 people per km2 to 11,297 people per km2, with some subdistricts having more than 40,000 people per km2 [Table 6] (Ahmad et al., 2013).

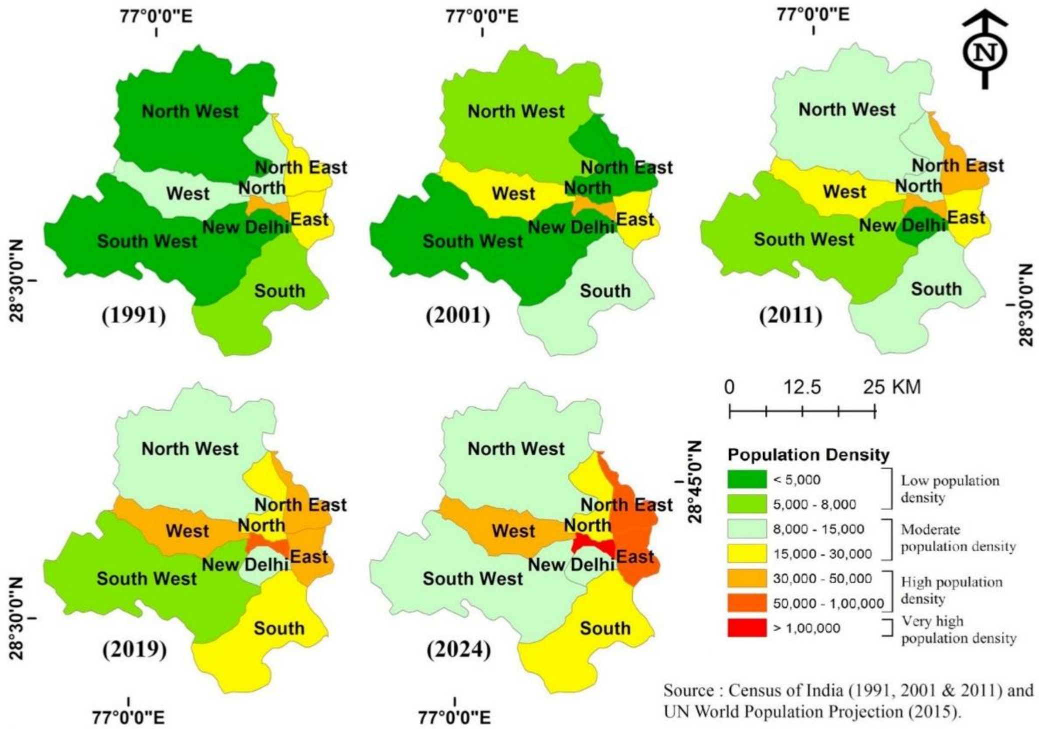


Figure 59: District Population density Variation Delhi (Tripathy & Kumar, 2019)

The 2011 census showed that there were over 11 million people living in Delhi, while a population of over 16.8 million lived across the NCT. Also, in terms of land area, Delhi has grown from 201km2 to 792km2 since 1951. Additionally, natural growth, net in-migration, and the extension of the physical boundaries are the main causes of population growth in any urban region. Although, according to Delhi's predicted yearly population growth, net in-migration is contributing to a marginally higher rate of population growth than natural growth (Ahmad et al., 2013).

Table 6: Population Growth of Delhi 1951-2011 (Ahmad et al., 2013)

Years	Total Population	Density (Person/km2)	Total Urban Population	Urban Population %	Annual Urban Growth %
1951	1,744,072	1176	1,437,134	82.40	-
1961	2,658,612	1793	2,359,408	88.75	5.08
1971	4,065,698	2742	3,647,023	89.70	4.45
1981	6,220,406	4194	5,768,200	92.73	4.69
1991	9,420,644	6352	8,471,625	89.93	3.92
2001	13,782,976	9340	12,819,761	93.01	4.23
2011	16,752,235	11297	16,333,915	97.50	2.45

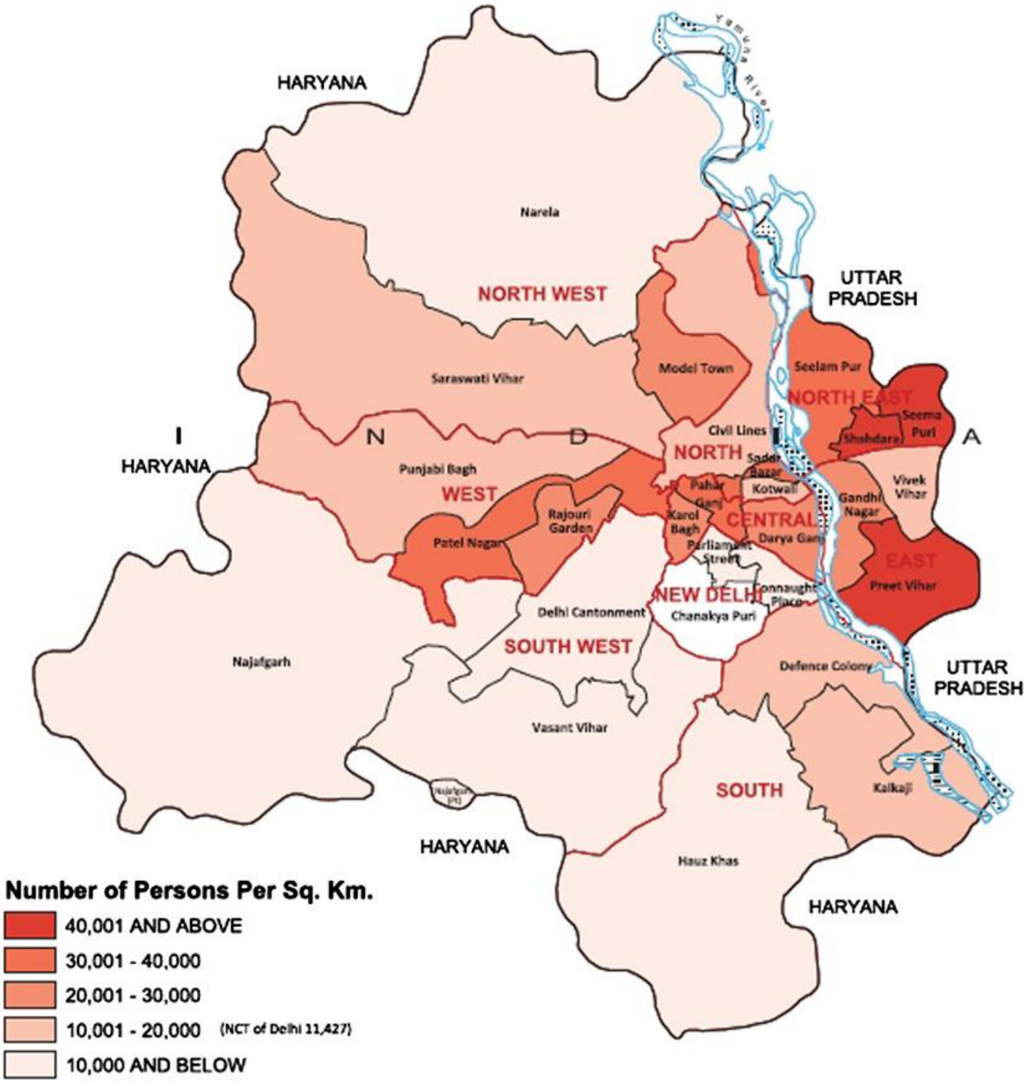


Figure 60: Density of Population as per Census 2011 (Ahmad et al., 2013)

VI. 4. Delhi Planning Framework and Green Blue Initiatives

Since Delhi has a unique status in the country as the Nation Capital Territory (NCT), the city has various bodies that have specific roles related to land use, environment, infrastructure, etc. Some agency mandates are centred on creating and overseeing regulations pertaining to various facets of environmental management while others are in charge of implementation and upkeep of those policies. An overview of the roles played by the major agencies in relation to three environmental aspects- pollution control, enhancing green areas, and protecting and conserving natural resources and features, is shown in Figure 57(NIUA, 2020).

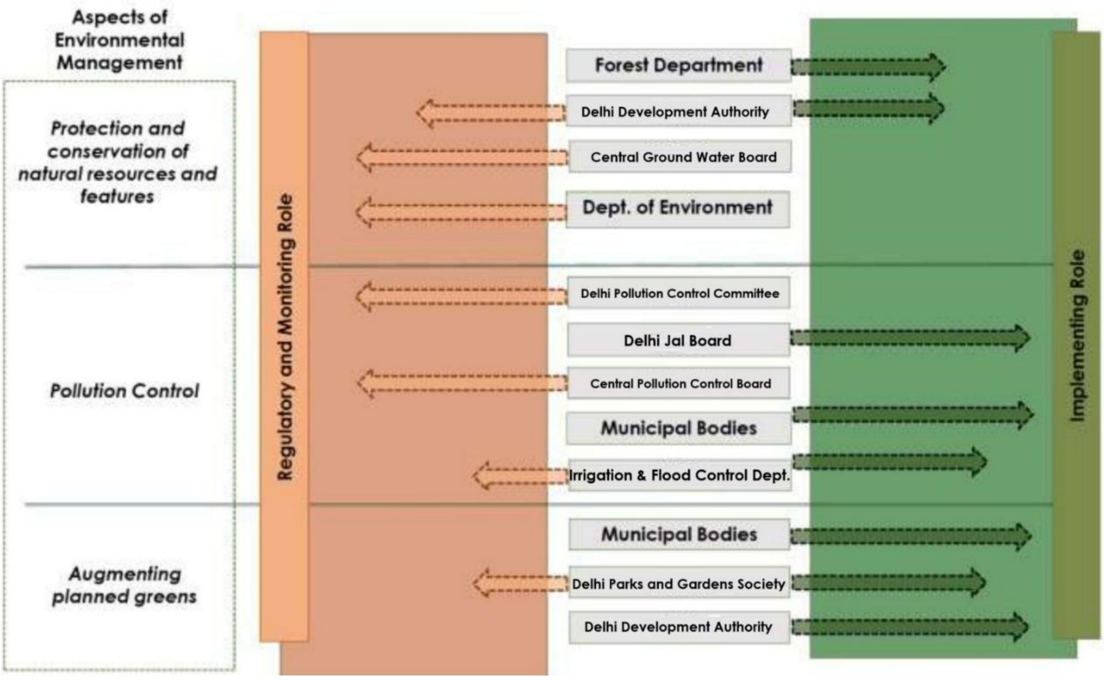


Figure 61: Roles of major environment related agencies in Delhi (NIUA, 2020)

One of the main obstacles within the landscape of governance in the city is the overlapping competencies of the various agencies. As project stakeholders, Delhi Development Authority (DDA) seeks to unite many organisations, including the Delhi Jal (Water) Board (DJB), the Flood and Irrigation Department, and municipal corporations. This will be a challenge in a city where even waterlogging becomes a dispute between authorities, especially given that the DDA has no supervisory authority over these bodies (Rajput, 2020).

Delhi has consciously moved towards integrating sustainable practices into urban planning policies and initiatives, introducing GBI initiatives to improve urban resilience and enhance liveability.

Some of the steps taken by the planning authorities include:

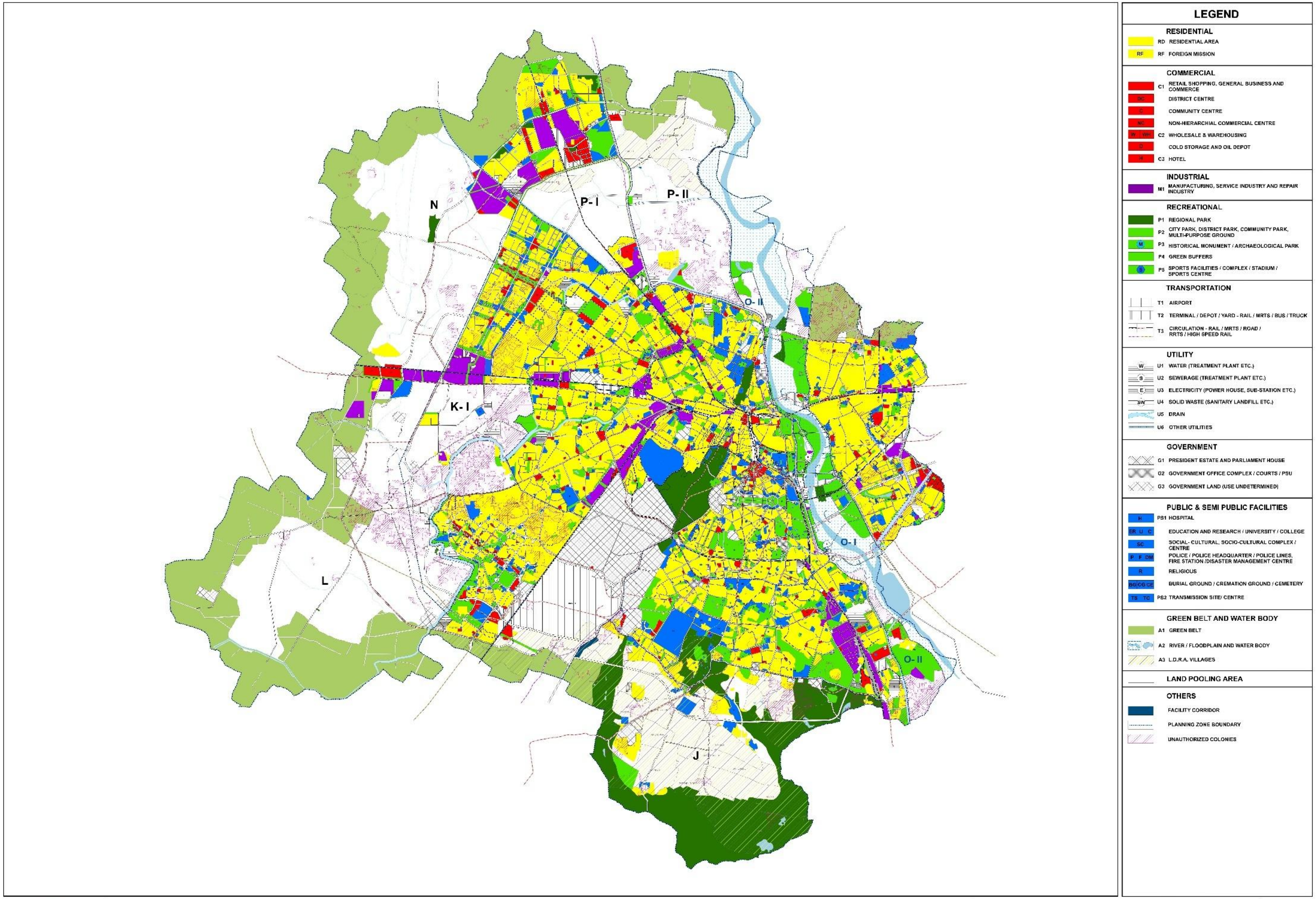
4. <u>Master Plan for Delhi 2041</u>

The DDA is a central authority established in 1957 who's primary role is master planning and land development also leads the green infrastructure development in the city. DDA is in charge of developing the 20-year Master Plans for the city and is currently preparing the Master Plan for Delhi (MPD) 2041, making it one of the first cities in India to integrate GBI in its masterplan. The vision of the MPD 2041 is to "**Foster a Sustainable, Liveable and Vibrant Delhi**". The MPD has six objectives [Figure 58], out of which the first one is Environmental sustainability, under which the plan recognises "all green and blue assets and their inter-connected network as essential infrastructure layer of the city that provide open spaces for citizens to enjoy and facilitate larger network benefits for biodiversity, microclimate and flood management" (MDP- 2041, 2024).

Figure 62: Six objectives of MPD 2041 (Wangchuk, 2022)

A framework for integrated management of GBI in the city is provided by the master plan, which has a vision for the growth of net area under natural green-blue assets and planned green spaces provided as part of new city developments. MPD is expecting to follow a Four-pronged approach over the period of the plan which will integrate initiatives to protect and improve already-existing natural assets, develop new city-level assets, and raise the built environment's green-blue quotient. The following benefits are expected by the MDP 2041:

a. Environmental – enhanced per capita greens, richer biodiversity, reduced heating and flooding, reduced pollution, improved resilience to climate change.
b. Health – cleaner living environments, active lifestyles, reduced burden of ailments and diseases (including mental health) and improved quality of life.
c. Socio-cultural – higher environmental awareness and closer connection of people with nature, availability of spaces for leisure, physical and social activity.



DRAFT LAND USE PLAN FOR DELHI 2041

DELHI DEVELOPMENT AUTHORITY

Km 0 2.5 5 10 15 Km

d. Economic – improved attractiveness as an investment destination, better productivity, reduced expenditure on health care, boost to green economies like urban farming, etc.

Additionally, some of the major features of the plan are:

- Encouraging people-nature interaction by marking specific areas and trials as ‘interactive Zones,’ and permitting activities like yoga, nature classes and exercise.
- Preparation of a tree directory to identify unique tree corridors or precincts, heritage trees, precincts with high carbon storage & sequestration rate which will be protected
- A 300m green buffer along the banks of Yamuna with 75-100m greenways planned for walking/cycling trails
- Creation of green mobility corridors for an interconnected network of GBI connected through pedestrian/cycle paths.
- 80% of each surface parking lot must be pervious or covered with pervious paving, along with landscaping in the areas beneath flyovers, along water pipelines, on unpaved road segments, etc.
- Restoring the ecosystem by de-silting the current wetlands and establishing new wetlands.
- Introducing a Green Blue Factor (GBF) for all new projects and developments that will be computed by the planned green and blue features on site, along with incentives and disincentives for achieving the minimum BGF.
- Creation of a database of Green-Blue Infrastructure mapping the existing and potential sites as a part of the Delhi Spatial Information System (MDP- 2041, 2024)

5. City of Lakes Project

Delhi is home to about 1,140 man-made and natural water features. Today, the city's surface water area makes up about 24.35 km^2 of its entire geographic area, a significant decrease from 6.6% to 1.6%. Few of these resources are bordered by open, forest, or green spaces; the majority are surrounded by densely populated areas (S. Singh & Biswas, 2024).

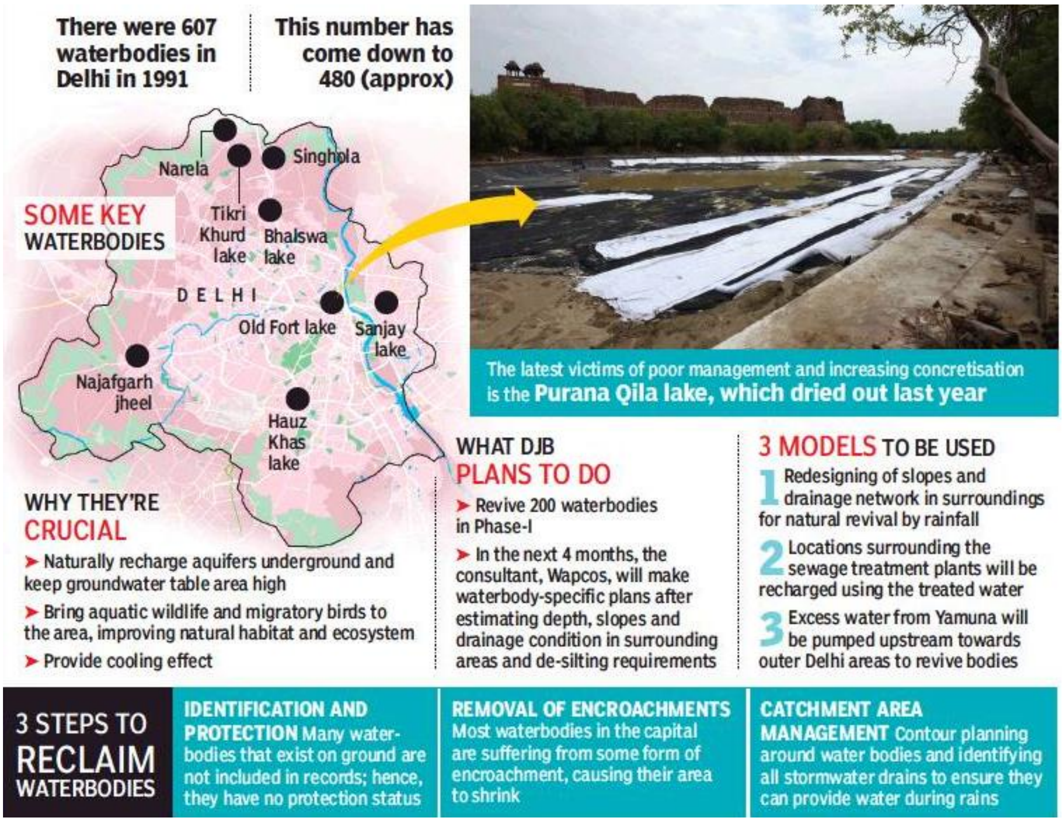


Figure 63: Waterbodies in Delhi in 1991 and 2018 (P. Singh & Gandhiok, 2018)

The City of Lakes was a Project announced by the DJB in 2019 in an attempt to rejuvenate around 250 water bodies, out of which 48 have been revived. The Project was a response to wetlands gaining an important status, and in 2022, 10 water bodies in the city were identified in the 1st phase to be labelled as Delhi's wetlands. A Delhi Wetland authority was established to oversee the reviving of the water bodies and wetlands. Additionally, there are a number of plans and policies in place for protecting urban water bodies, including the National Plan for Conservation of Aquatic Ecosystems (NPCA) (2016), the Delhi Water Policy 2016 (Draft), the Wetland (Conservation & Management) guidelines (2017), and the Delhi Master Plan 2041 (S. Singh & Biswas, 2024).

Some of the successful projects under the city of lakes initiative are:

A. **The Okhla Bird Sanctuary**- Once threatened by encroachments and fast urbanisation, has now become a popular destination for ecotourism and a refuge for migratory birds (S. Singh & Biswas, 2024).

B. **Najafgarh Drain**- Afflicted by pollution and trash disposal, has been converted into a wildlife oasis. In terms of catchment area, it is the largest basin and manages water that is released from Delhi's urban and rural areas (S. Singh & Biswas, 2024).

C. **Yamuna Biodiversity Park (YBP)**- Once an arid and degraded floodplain has been successfully restored. As a primary goal to encourage community participation, in environmental conservation, YBP places a high priority on nature education. YBP was a test project for creating biodiversity parks throughout the city (S. Singh & Biswas, 2024).

6. Miyawaki Urban Forest Initiative

Delhi, known for its vibrant culture and a horrible AQI, has taken inspiration from the Japanese botanist Akira Miyawaki for a green revolution in the city. The initiative aims to transform urban landscapes into lush and vibrant ecosystems by planting dense native forests. These forests act as essential lungs, enhancing air quality and offering habitats for indigenous species in a dense metropolis like Delhi. Many organisations and community groups in Delhi have adopted the Miyawaki technique, which has resulted in the creation of multiple forests throughout the city. These forests are essential in reducing the negative impacts of urbanisation. The Grow Billion Trees campaign is one of the main forces for the promotion of Miyawaki forests in India (Grow Billion Trees, 2024).

With an emphasis on sustainable techniques and community involvement, this organisation is committed to planting trees all throughout the nation. In Delhi and other cities, the organisation has effectively carried out a number of Miyawaki forest initiatives. The creation of a Miyawaki forest at Delhi's Chhawla School with 1200 saplings is one of Grow Billion Trees' most notable initiatives. This program fosters a sense of environmental stewardship in addition to giving students a practical learning experience (Grow Billion Trees, 2024).

7. Master Plan of Greens

The DDA developed the Master Plan of Greens in the city to create and maintain green spaces and recreational areas within the city for the citizens. The governmental organization classified the type of green spaces and subjected them to different levels of protections.

The plan integrates green and blue spaces by preserving and growing green spaces, such as city forests, biodiversity parks, and ridge forests, along with wetlands, ponds and natural drains. The plan emphasizes peri urban green zones in an attempt to counter the urban heat island effect created [Figure] (DDA, n.d.).

The master plan includes five categories:

A. Regional parks

Act as lungs of the city and are protected under the Indian Forest Act 1927. The physical boundary areas are owned by various agencies- DDA, Central Public Works Department, New Delhi Municipal Council, Forest Department and the Ministry of Defence. Many recreational activities are permitted in these areas, and the area has provisions like picnic huts, shooting ranges, zoological garden, bird sanctuaries, botanical gardens, open air theatres, orchards etc (DDA, n.d.).

B. Protected forests

Large tracts of land have been forested by DDA to create a variety of huge, protected forests throughout the city. They serve as the city's natural lungs, preventing pollution and environmental damage while restoring equilibrium. DDA currently oversees 25 of these protected forests, greatly contributing to increasing liveability (DDA, n.d.).

C. Community Parks

These parks are aimed are offering active and passive recreation, and the most important feature of these are its proximity to residential areas. Located at 1.5km form residential areas, these parks serve residents directly acting as recharge zones, regulating ambient temperatures and acting as carbon sinks. They have generally have an area of 5-25 hectares and serve the city ecologically by serving as shelter for wildlife. They have provisions of space like open lawns, pathway for walking/ cycling, food kiosks, and areas for socialising and congregating (DDA, n.d.).

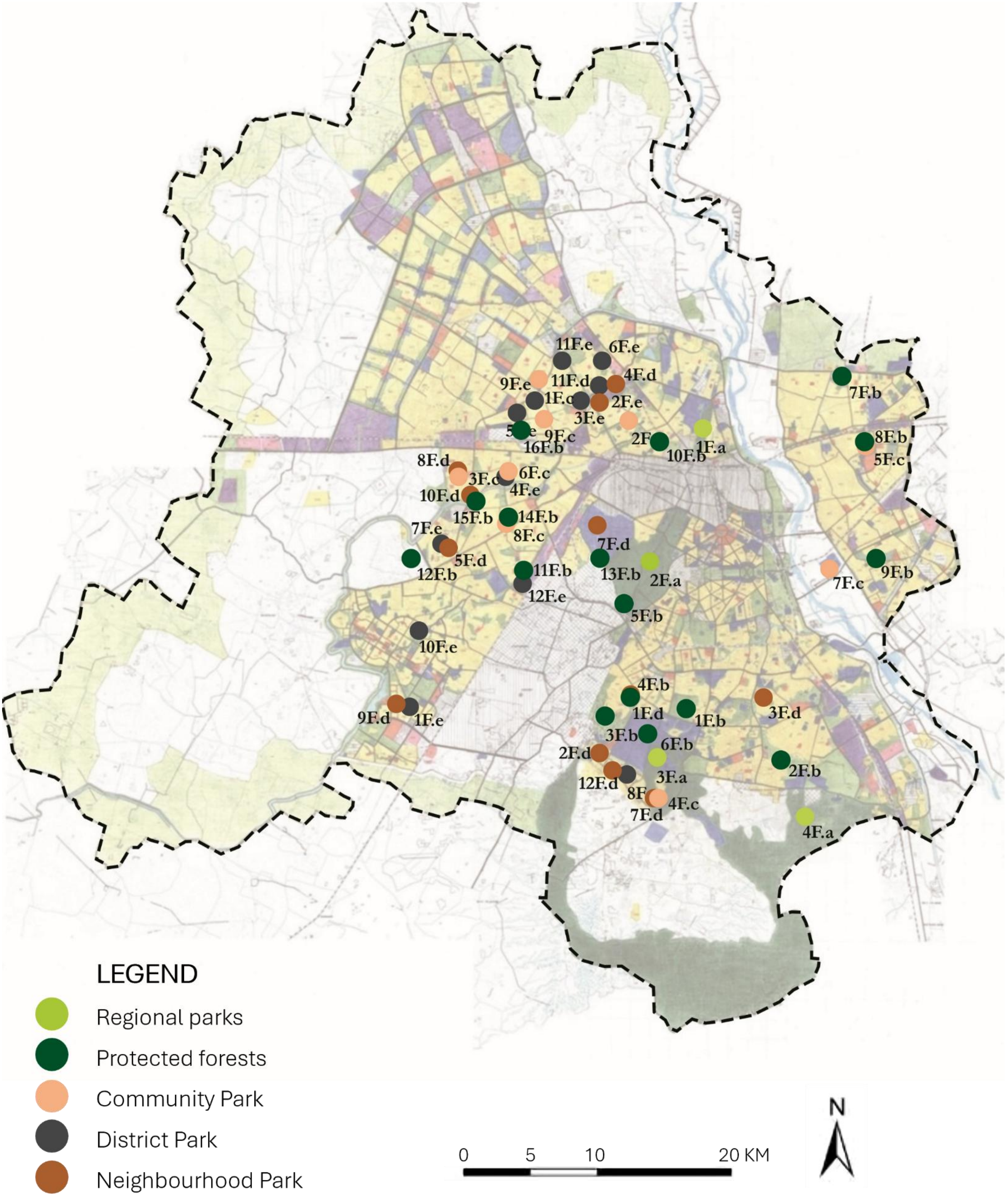


Figure 64: Master Plan of Greens (DDA)

D. District Parks

Encompassed within an area of <25 hectares, District Parks offer a wide range of recreational amenities that are not available in Community Parks or neighbourhood green spaces. By providing access to gathering places and recreational opportunities, the green space enhances users' social interaction, district parks serve as the city's green lungs, enhancing quality of life by promoting physical activity and delivering ecological advantages. The area has the following amenities: amusement park, children's traffic park, sport activity, playground, open-air food court, children's park, orchard, plant nursery, area for water harvesting archaeological park, recreational club, etc (DDA, n.d.).

E. Neighbourhood Parks

For the local population, these parks offer ‘close to home’ recreational options. They are usually 5–10 acres in size and intended to serve locals who live within walking/bicycling distance of about 800 meters. These parks feature grassed spaces with ornamental plantations, children's play areas, walking trails, gathering spots for people, rain shelters, and more. For these parks, being connected to the neighbourhood and being a part of a larger network of open space is essential. Despite being smaller than community parks, these green spaces have the potential to improve the surrounding residential area's microclimate and provide users with a tranquil respite (DDA, n.d.).

VI. 5. Climate Characteristics

Delhi is located in the Indian Subcontinent's landlocked Northern Plains. Due to its closeness to the Himalayas and the Thar Desert, it experiences both extremes of weather, which has a significant impact on its climate. According to the Köppen climate classification, the city has a humid subtropical climate influenced by the monsoon, which borders a hot semi-arid climate. The summer and winter seasons differ greatly in terms of precipitation and temperature [Figure 59 & 60].

Beginning in April and lasting through July, Delhi experiences its long and scorching summers, with temperatures reaching 45°C. In the summer, the Western side is marginally warmer than the Eastern side []. The opposite pattern occurs in the winter, when the East is significantly warmer than the West. The rainy season begins in June as humidity levels climb, combined with the warm weather. When the brief winter season begins in November, the city cools off. Since Delhi is close to the Himalayas, during the winter months, cold waves cause wind chill, which lowers the apparent temperature. Additionally, Delhi is infamous for its thick fog and haze in the winter months too.

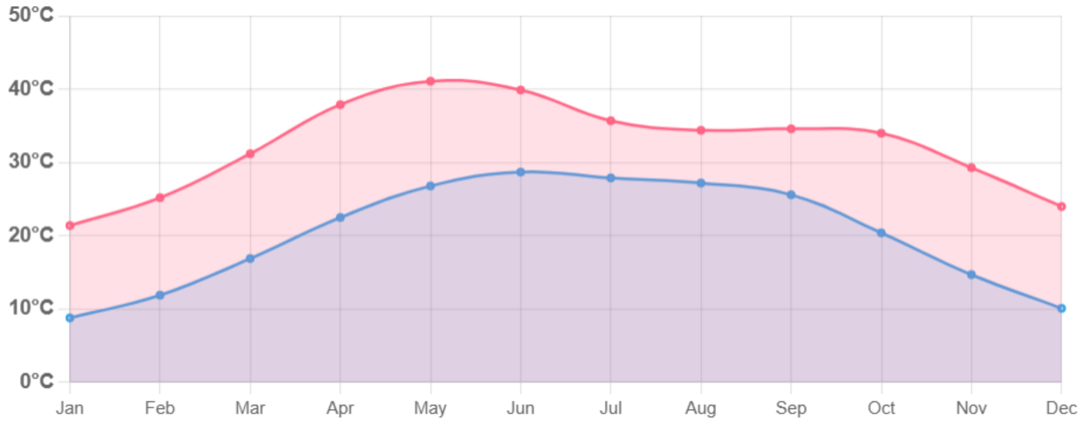


Figure 65: Average monthly minimum and maximum temperature Delhi (Weather and Climate New Delhi, *n.d.)*

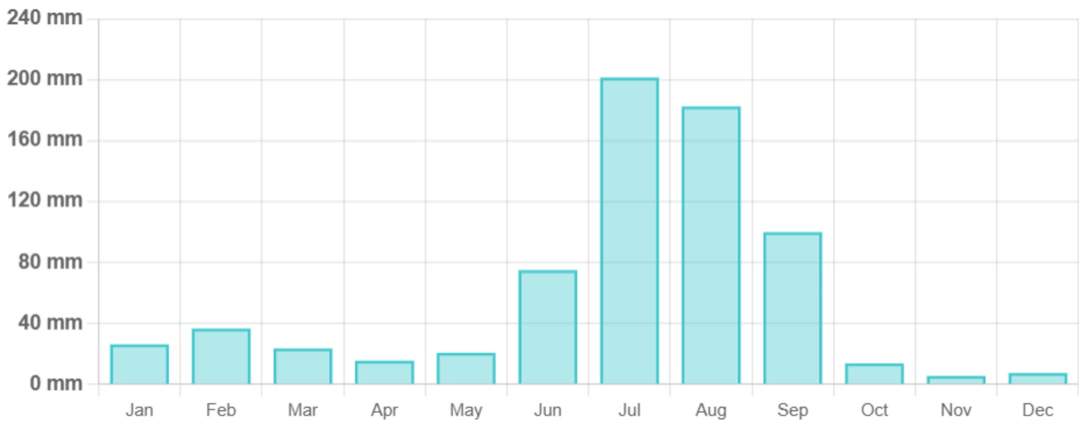


Figure 66: The mean monthly precipitation over the year in Delhi (Weather and Climate New Delhi, *n.d.)*

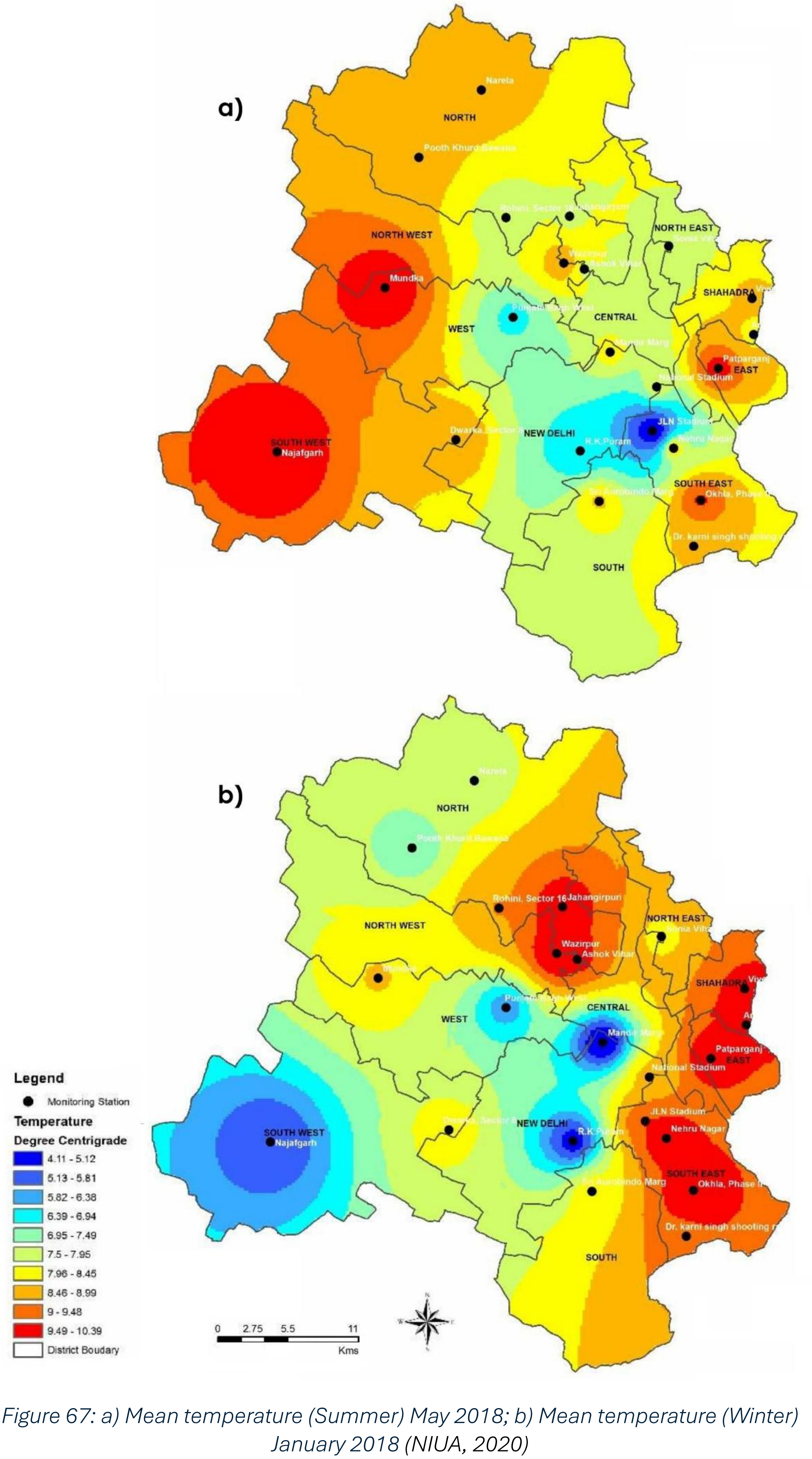


Figure 67: a) Mean temperature (Summer) May 2018; b) Mean temperature (Winter) January 2018 (NIUA, 2020)

VI. 6. Current Scenario

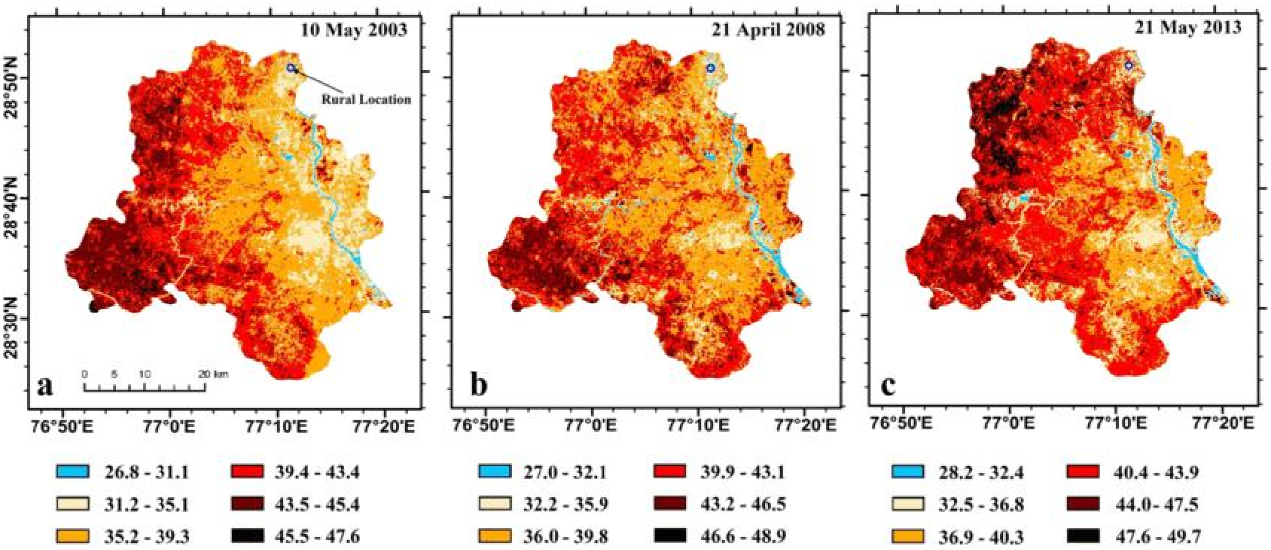


Figure 68: Land surface temperature (LST) distributions for Delhi on a 10 May 2003, b 21 April 2008 and c 21 May 2013 (Sultana & Satyanarayana, 2019)

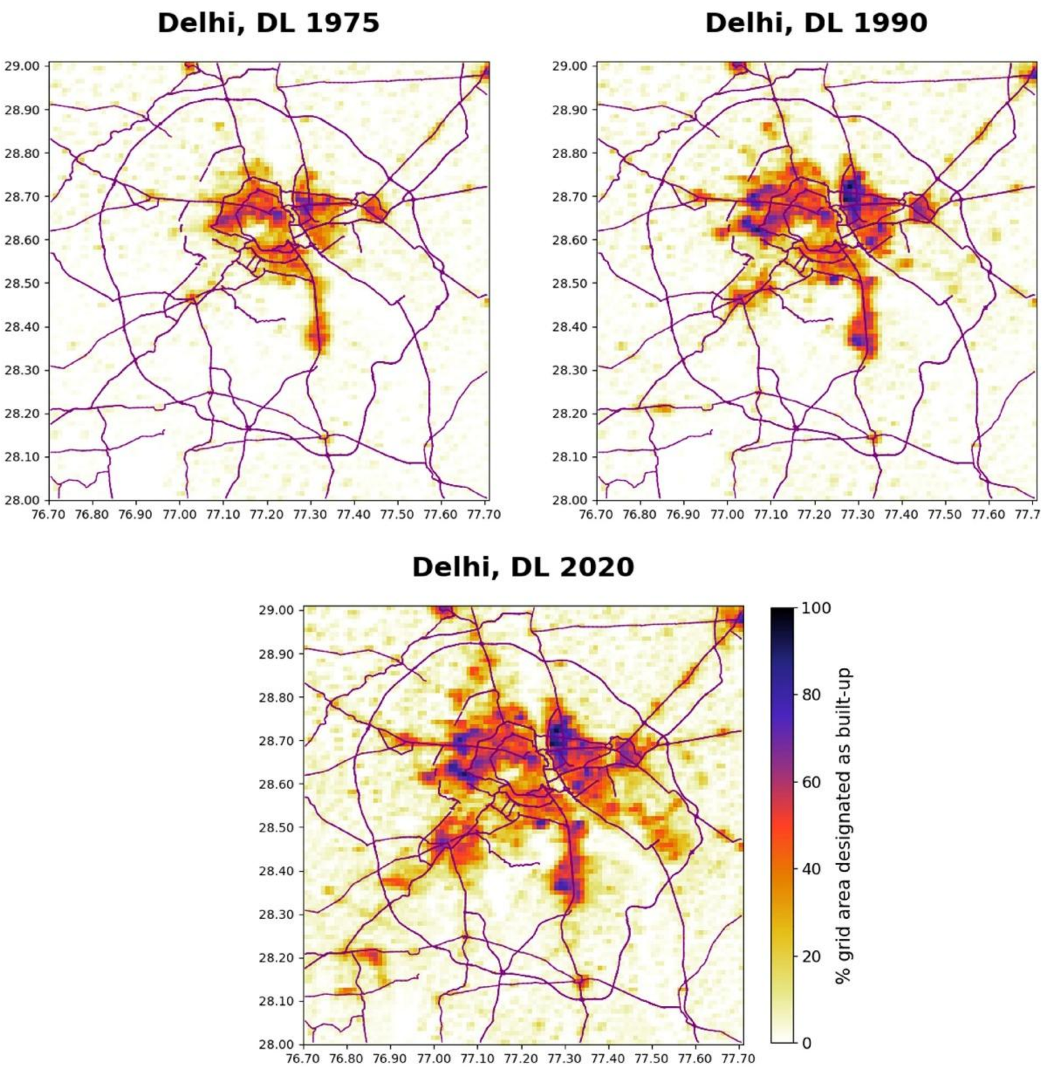


Figure 69: Change in Urban built-up Area (Guttikunda et al., 2023)

Based on the LST map [Figure 68], we see a clear trend of rising surface temperatures, which can be correlated with urban expansion and loss of green areas. Central and western parts of the city have a higher LST value, a consequence of dense urban fabric. Furthermore, there is a marked increase in built-up area observed between 1975-2020 [Figure 69], primarily in south-west and north-west directions. Many of these are caused by unplanned urbanization and contribute to the number of impervious surfaces within the city. The spatial analysis also suggests encroachment into ecologically sensitive areas, including lakes. In a study done by Panwar et al. (2025), the authors introduce the Urban Green Spaces Assessment Index (UGSAI) to evaluate the urban green space distribution across Delhi through various indicators include analysing green index, green cover, impermeable surface area and the NDVI index [Figure 70].

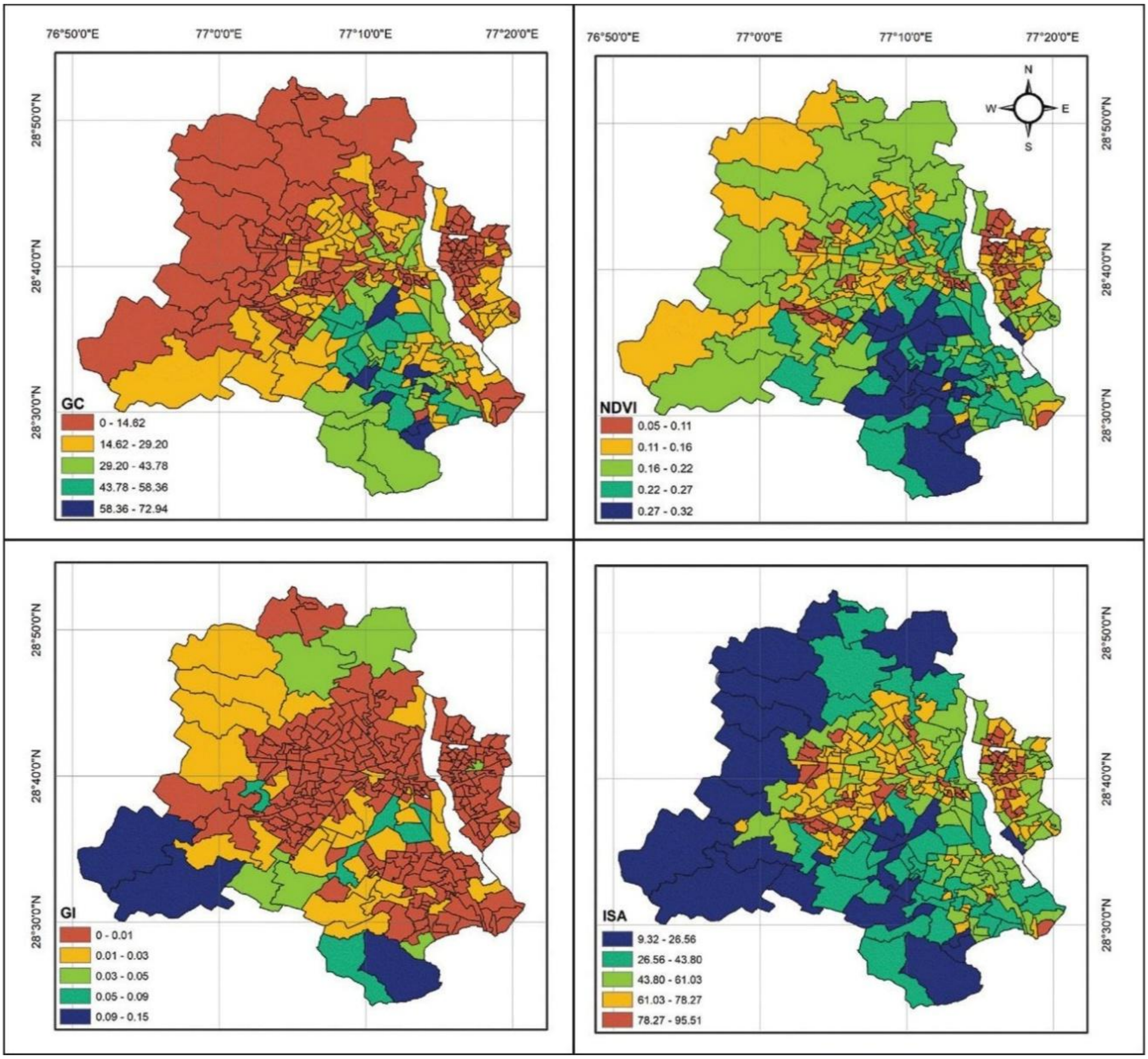


Figure 70: Spatial Comparison of Green cover (GC), NDVI, Green Index (GI), and Impermeable surface area acorss Delhi wards (Panwar et al., 2025)

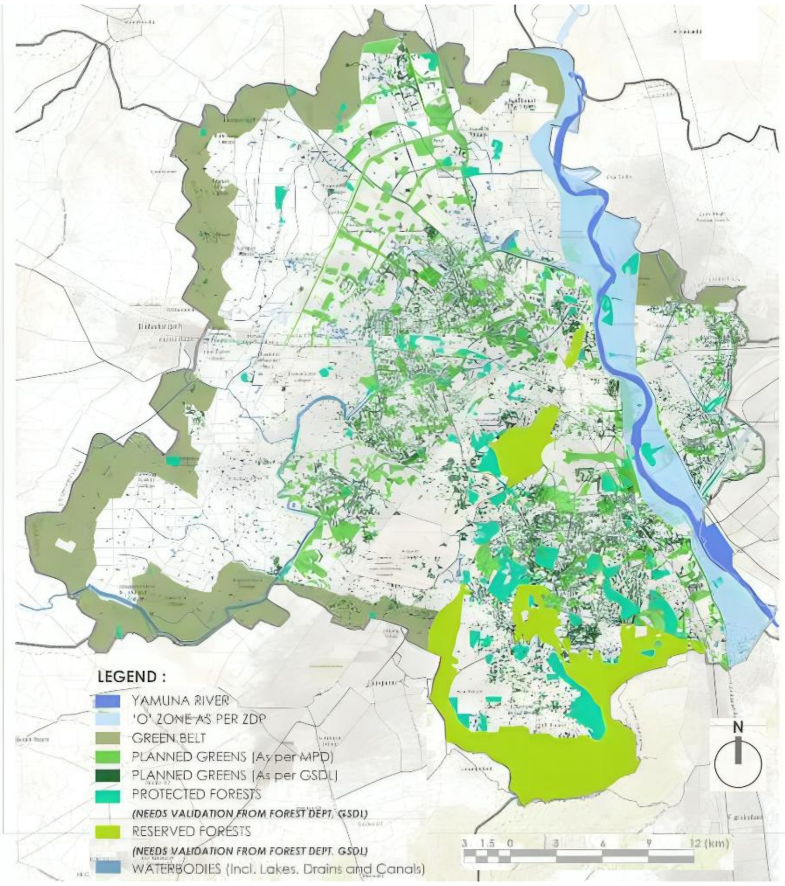


Figure 72: Spatial coverage of natural and planned green infrastructure in Delhi (NIUA, 2020)

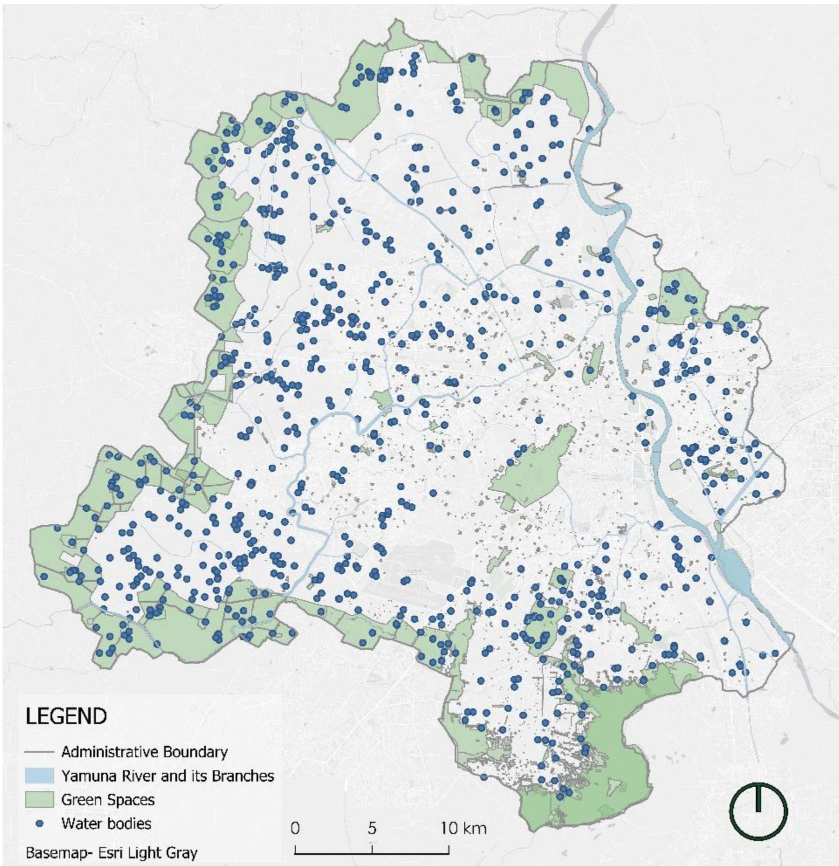


Figure 71: Map depicting green and blue infrastructure of Delhi (Author's elaboration)

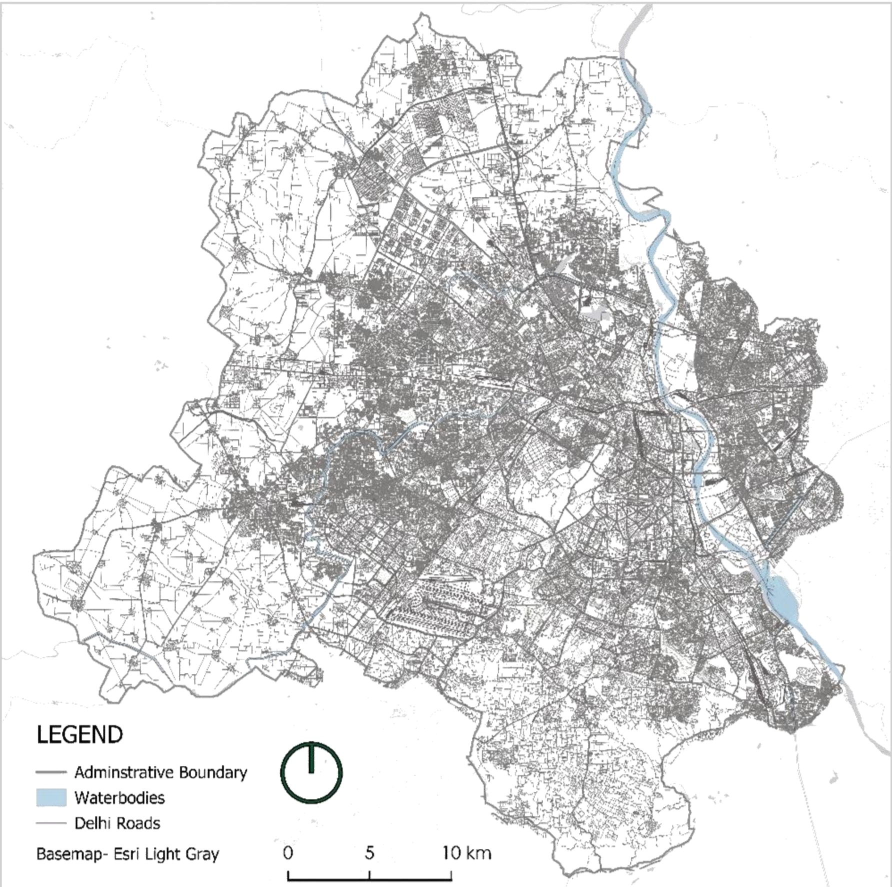


Figure 73: Map depicting road network of Delhi (Author's elaboration)

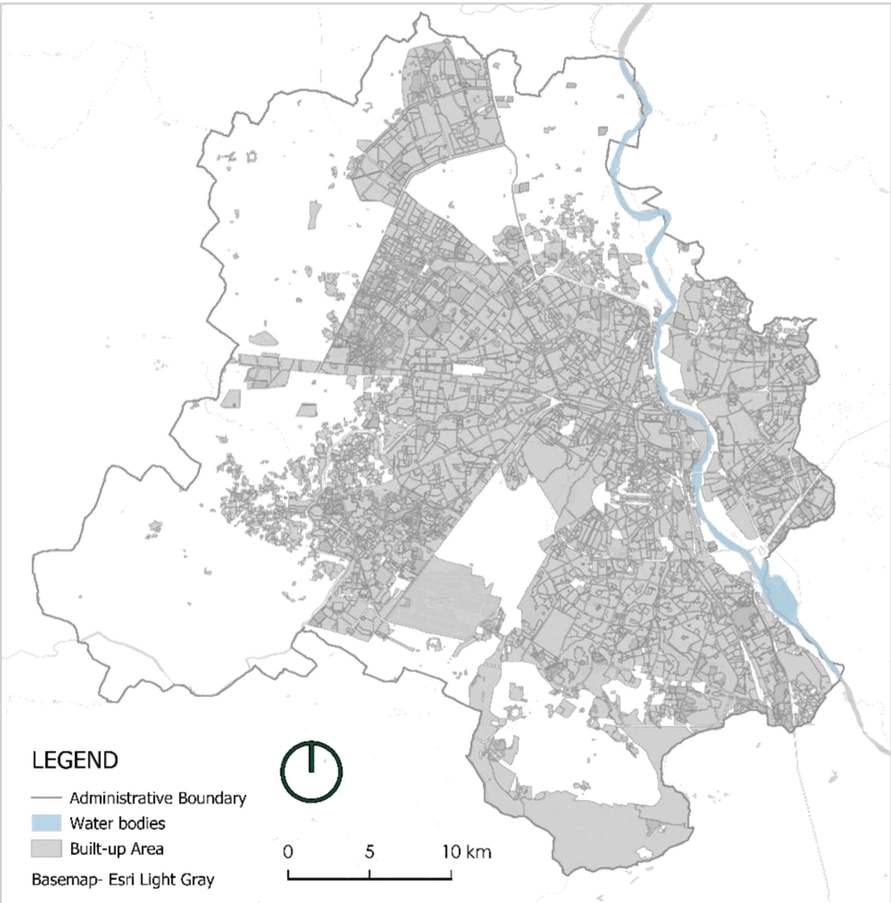


Figure 74: Map depicting built area in Delhi (Author's elaboration)

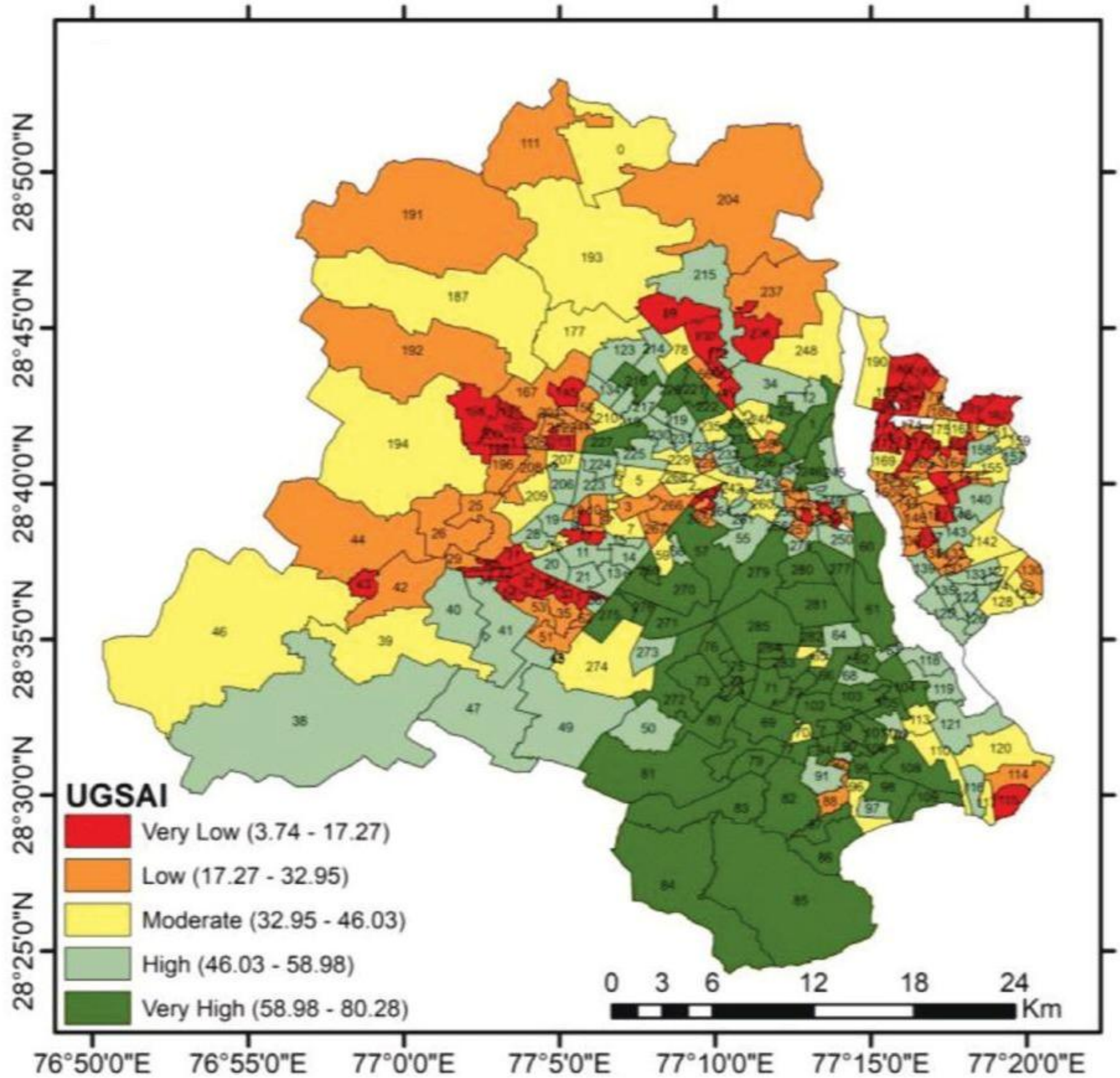


Figure 75: Urban Green Space Availability Index Distribution Across Delhi (Panwar et al., 2025)

The UGSAI assessment was conducted at the ward level by Panwar et al., (2025), integrating satellite data and land classification to produce Figure 75. The assessment shows spatial distribution disparities correlating with high density and high impermeable surface area coverage.

The UGSAI considered multiple variables to offer insights into the green space quality and quantity. Using these maps, we can prioritise high vulnerability zones for introducing GBI strategies within the city. The areas with low UGSAI scores have poor microclimate and limited access to green spaces, making these wards prime candidates for greening programs.

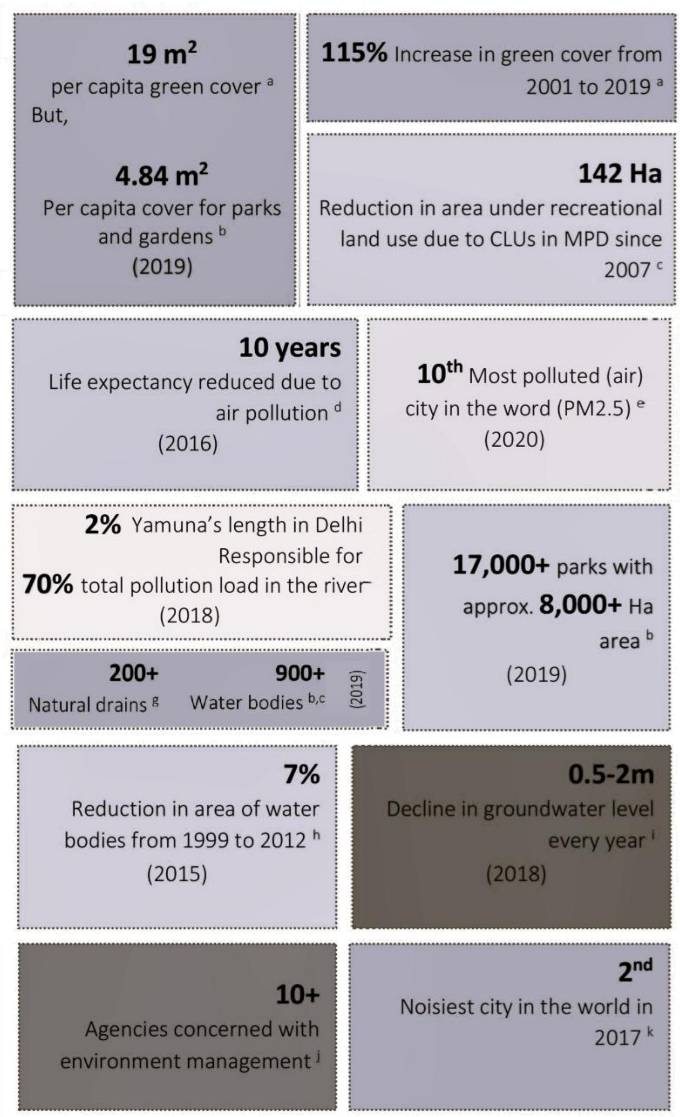


Figure 76: Key environmental statistics (NIUA, 2020)

FACTORS AFFECTING LIVEABILITY

Air pollution

Noise pollution

Green space availability

Water pollution

CRITICAL PROBLEMS

Encroachment and land use conversion

Unmanaged urban sprawl

Urban heat island

Growing population

Mismanagement within agencies

Unevenly distributed green spaces

KEY ORGANIZATIONS INVOLVED IN GBI PLANNING AND REGULATING

Delhi Development Authority (DDA) [Planning authority]

Delhi Parks and Gardens Society (DPGS) [Maintain green and recreational spaces].

Delhi Pollution Control Committee (DPCC) [Monitoring environmental quality]

Delhi Jal Board (DJB) [Water and wastewater management]

Centre for Environmental Management of Degraded Ecosystems [Collaborates with DDA on biodiversity parks]

National Mission for Clean Ganga [Yamuna rejuvenation studies]

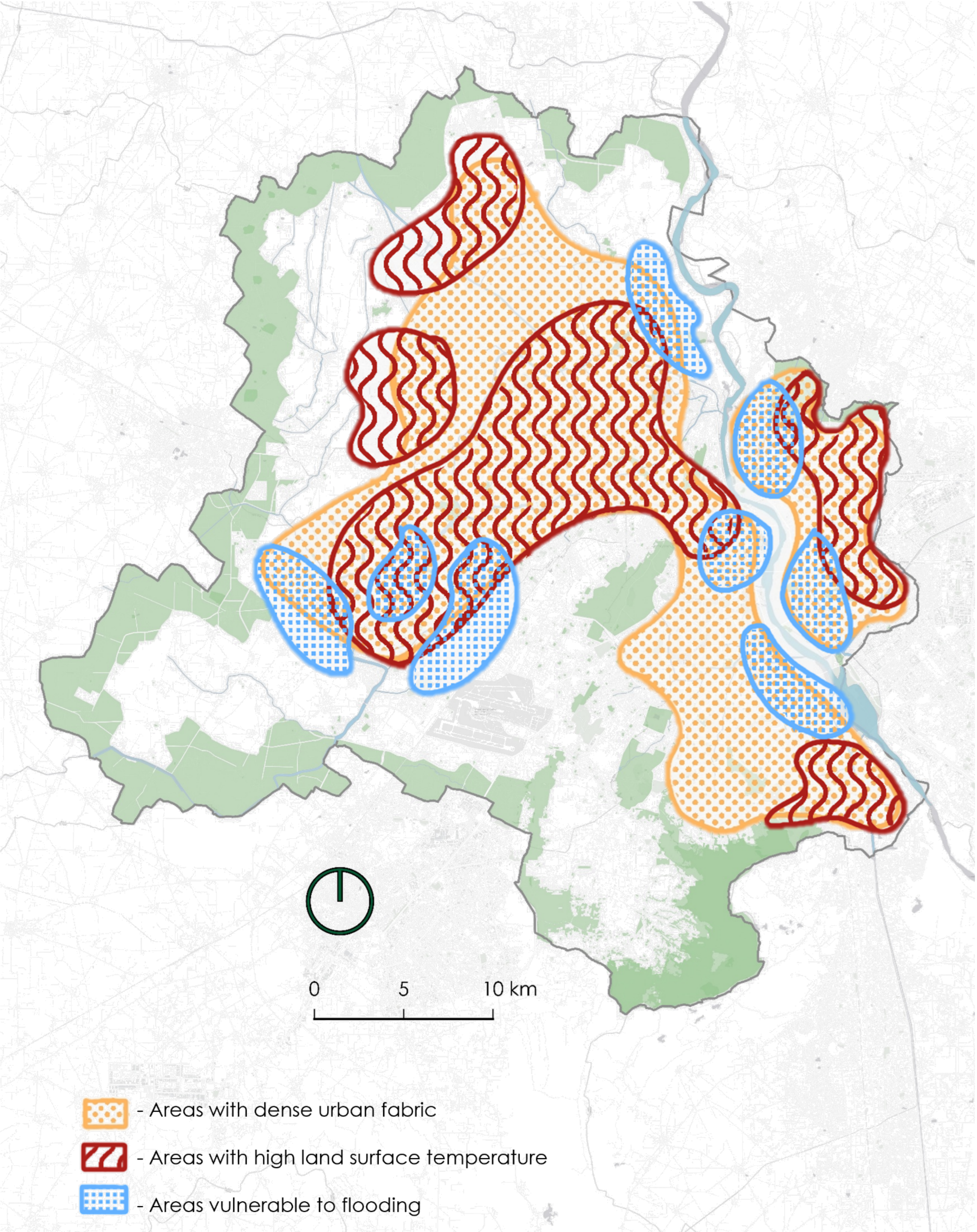


Figure 77: Map showing areas vulnerable to various risks (Author's elaboration)

VI. 7. Problem Identification and Scope

Severe air pollution, water scarcity, urban heat islands (UHI), and fast unplanned urbanisation are some of the particular environmental and urban issues that Delhi faces. It is imperative to adapt GBI tactics to Delhi's climatic, socioeconomic, and governance setting, drawing on ideas from case studies and international best practices, which this thesis attempts to propose. All of the indicators suggest that climate and environmental stress are serious issues in Delhi. The city has some of the worst air pollution in the world, with PM2.5 levels beyond WHO guidelines and extreme heat, with summer temperatures reaching 45 °C. The city's excessive groundwater extraction has caused the water table to drop by 1m, and the inadequate stormwater infrastructure and concretisation frequently result in flooding during the monsoon season.

The city's green cover has improved fast, virtually tripling over the past 20 years, from 150 sq.km in 2001 to 300 sq km in 2017. With a blend of planned and natural green spaces, it is currently one of the greenest cities in the nation. According to the Department of Forests (GNCTD) green cover covers about 20% of the land area. Despite this, Delhi's green assets are not distributed evenly, which leads to inequitable access for many, especially in the densely populated areas where the amount of green space per person is among the lowest in the nation. It creates a socio-economic issue, where there is a clear distinction between the amount of green space the wealthier neighbourhoods have vs the lack thereof that the lower-income zones possess. There is a need to address these issues without creating gentrification in these areas. Another problem is the quality of green elements, since green areas are intermingled with invasive tree species that damage the soil; these need to be replaced with indigenous varieties of greens.

According to the Delhi Parks and Gardens Society, there are around 900 bodies of water in Delhi, including lakes, ponds, and tanks. However, due to of pollution, encroachment, and the natural drying up of water bodies, the area covered by blue assets has decreased during the last ten years. One of the most important things the city needs to do is revitalise its blue assets, which the MDP 2041 recognises.

Apart from the Yamuna River, Delhi has around 50 large drains that are managed by various agencies, and due to their poor state, even the surrounding green areas have been affected by them. The Delhi Development Authority (DDA), along with other agencies, will integrate them and, by removing current contaminants and monitoring the outflow of untreated wastewater, they will eliminate all causes of pollution. A combination of natural and mechanical systems will be used. Local authorities will rigorously forbid the disposal of solid garbage at any of these locations by enforcing penalties (Rajput, 2020).

For many years, agencies in Delhi have struggled to clean drains and water bodies. Coliform and other contaminants were identified in large quantities in an IIT-Delhi study of 20 main sewer drains and five locations on the Yamuna River (Gautam et al., 2017). According to the Central Pollution Control Board (CPCB), Delhi generates 3,000 million litres of sewage per day. The Yamuna River receives more than half of this amount untreated, yet these drains are only meant to receive rainfall. DDA previously attempted to prevent rubbish dumping in Yamuna by forming a special task force, but this effort was unsuccessful (Rajput, 2020).

Delhi's urban development shows that the west, south-west, and eastern parts of the city are growing at a rapid pace. In the Union Territory of Delhi, 17% of the agricultural land has been encroached by urban growth in the periphery. The renowned Kamala Nehru Ridge area, which is regarded as Delhi's lungs, has seen a significant decline from 6.7% in 1992 to 5.5% in 2004 due to ongoing tree-cutting, construction, and quarrying (Sherbinin et al., 2007). The climate, environment, lithosphere, biosphere, hydrosphere, and land and water resources are all suffering greatly as a result of urban sprawl in India's major cities, including Delhi, this also places a tremendous strain on transportation, water, and power (Saini & Tiwari, 2020).

METHODOLOGY AND FRAMEWORK FOR GBI INTERVENTION

After a meticulous analysis of the city of Delhi, we identified the core problems within the city, mainly air pollution, UHI, flooding, and green space distribution. These problems are aggravated in certain parts of the city, which require an intervention to combat the threat to liveability. It is essential to under the context of the site and the vulnerabilities present to accurately identify which GBI strategies would be optimal. Having a structured framework for this streamlines the process of the proposal.

Step 1: Spatial and environmental analysis of the city

Step 2: Identifying key stakeholders

Step 3: Problem Diagnosis and Site Selection

Step 4: Analysing the contextual threats to the selected area

Step 5: Identifying GBI proposal on site

Step 6: Formulating an implementation and monitoring strategy

VI. 8. Proposed Green Blue Infrastructure Strategies

To address the problems stated in the previous sections, this thesis proposal includes a three-pronged approach at different fronts for GBI in the city. The proposal will include resilient, multi-functional GBI strategies aimed at improving the physiological and ecological quality within the city. The three major strategies proposed are as follows:

<u>**Strategy 1:** Metro-Linked Green Arteries</u>

As trends displayed in the previous sections, Delhi faces major urban heat island (UHI) effects, especially in dense urban areas and vast impervious roads. The LST data shows hotspots concentrated along congested transit roads and commercial hubs. While the city has an expansive system of metro infrastructure, it severely lacks quality pedestrian and cycling pathways, which discourages commuters from taking these routes.

Therefore, the GBI strategy of establishing a metro-linked green arteries network will greatly help in mitigating UHI stress and encourage walking and cycling instead. The Delhi Metro spans over 390km, with many routes elevated, which offer spatial opportunities for GBI integration. The proposal includes providing buffer zones of 20 meters along either side of the metro corridor, in a bid to reduce car dependency and support green mobility.

For these green arteries, selecting a strategic type of plantation is necessary to maximize thermal comfort, and selecting indigenous vegetation to support biodiversity. They need to have a dense canopy for shading, need to be low maintenance, and be drought tolerant. The green arteries will be conceptualized as a layered ecological and mobility corridor that will include a pedestrian tree-lined walkway, cycle tracks made with permeable materials, seating pockets with trees and water fountains, green shelters, and vertical greening or noise barriers [Figure].

For this strategy to work, there would need to be multi-agency coordination, with DDA responsible for planning and zoning of green corridors, the Delhi Metro Rail Corporation (DMRC) in charge of metro infrastructure, the Public Works Department responsible for road edge landscaping and cycling infrastructure, and the urban local bodies for monitoring safety. Among the funding mechanisms available, the strategy can be paid for by the green bonds that the MDP-2041 creates, along with the AMRUT Smart City scheme. These corridors can be phased according to priority stretches with designs adapted to the site and community needs.

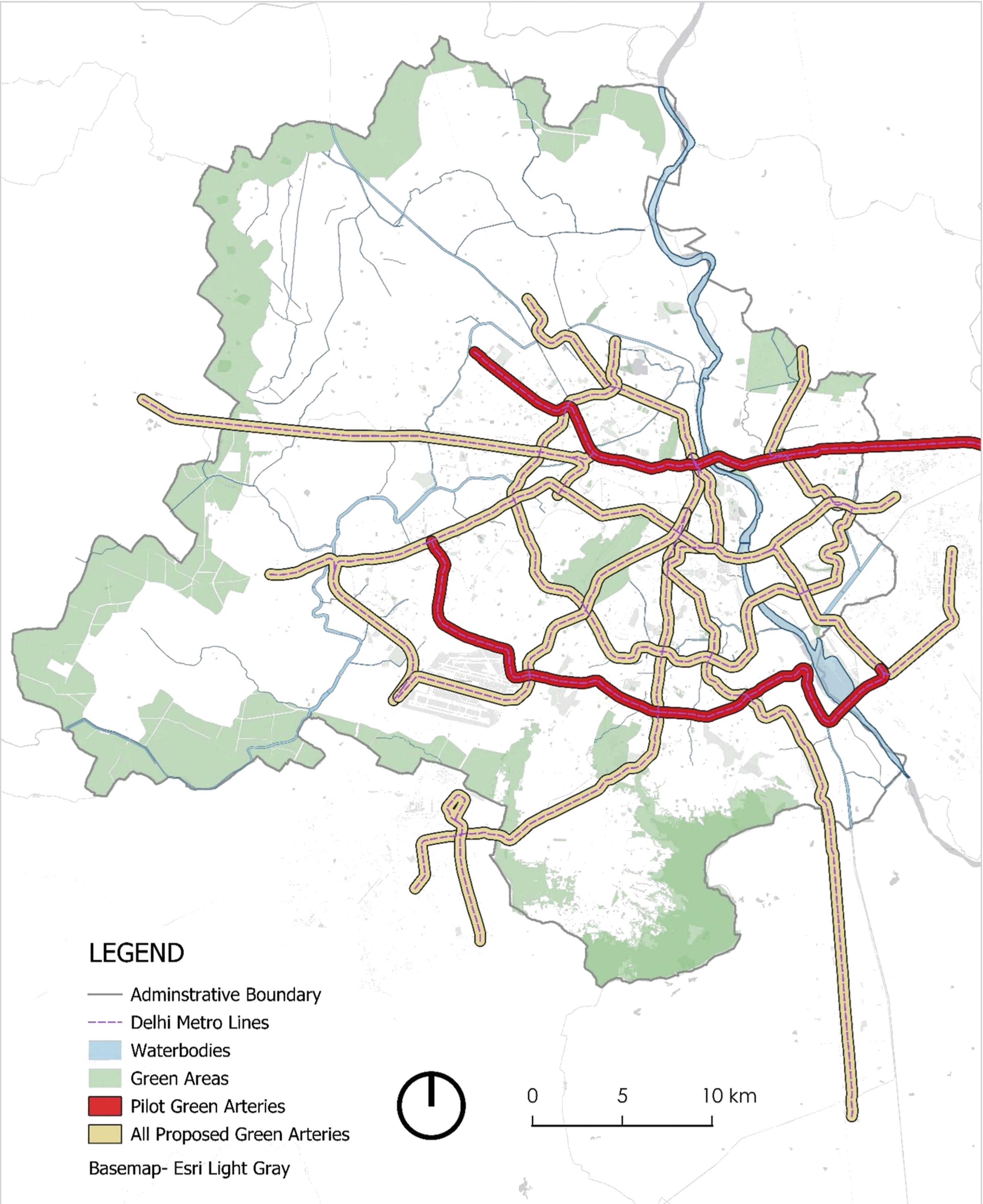


Figure 78: Metro-based Green Arteries Map, Delhi (Author's elaboration)

The corridors will serve as heat-adaptive, ecological infrastructure that will enhance the liveability of the citizens. It is an overachieving strategy, but the need of the hour is to take drastic steps towards creating more resilient infrastructure for the city. The strategy is a direct answer to the urgent need for inclusive mobility and environmental justice, especially for non-motorized transport users.

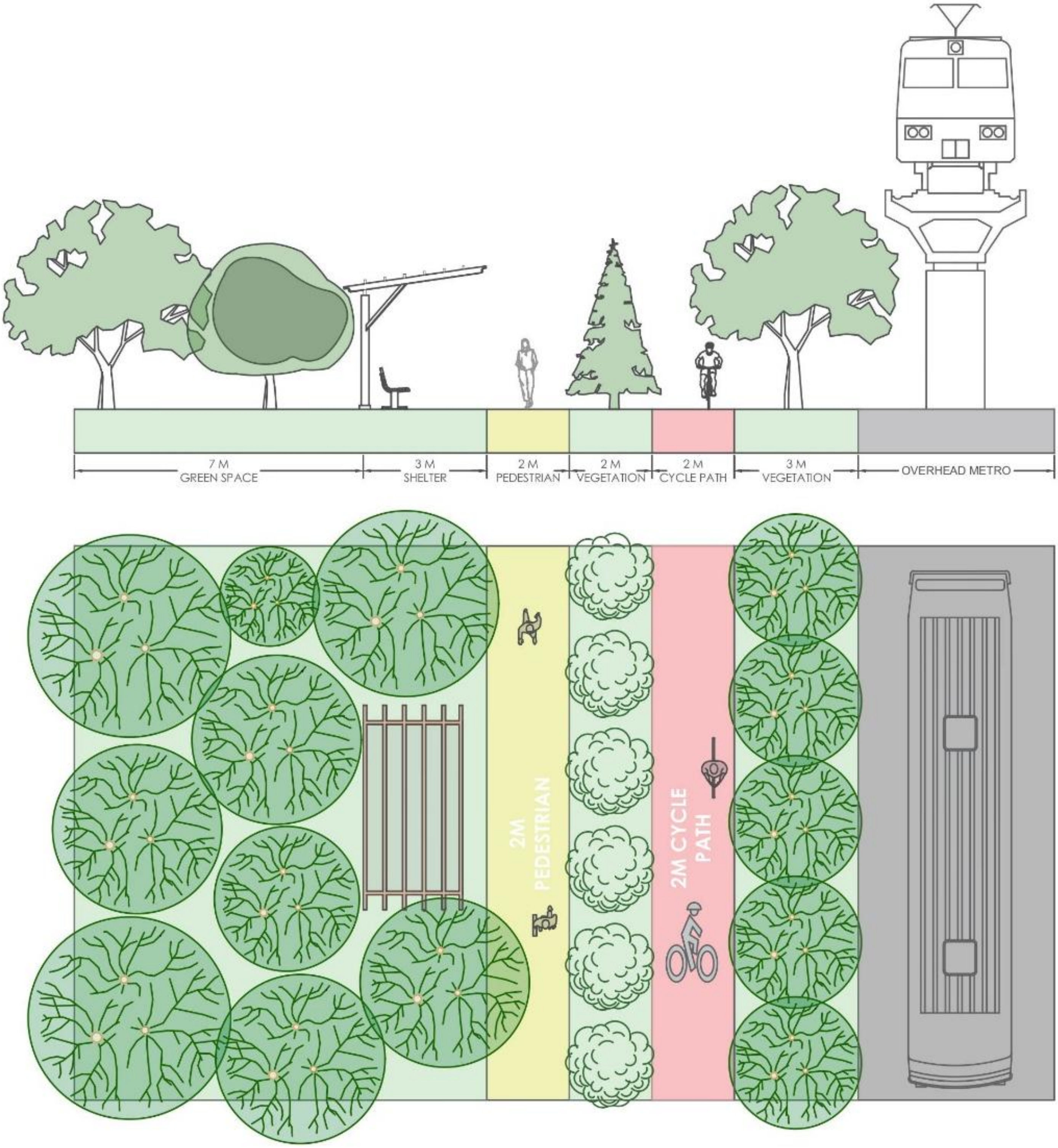


Figure 79: Green Arteries Design plan and elevation 20 meter wide (Author's elaboration)

<u>**Strategy 2:** Wetland Heritage Trail</u>

According to Delhi's wetland authority, the city is home to 1040 wetlands and water bodies, which serve as ecological lifelines of the city. Wetlands are an essential part of the ecosystem and serve as habitats for many indigenous species, and create natural flood buffers. Historically, the city's water bodies have been central to the culture of Delhi, supporting agriculture, and perhaps the most significant of those is the Yamuna River, which is considered sacred within Hinduism.

The MDP-2041 draft recognises wetlands as "essential components of green-blue infrastructure networks that improve resilience to climate change, reduce flooding, and enhance the microclimate", and thus aligning with this, the proposal is to introduce an 'Eco-heritage Wetlands trail'. This trail will include an experiential corridor that will be connected by pedestrian and cyclable interactive pathways.

The objectives of the trail will be to showcase the rich cultural history of Delhi's water-centric heritage sites and to promote interaction with nature. The proposal includes creating various points of interaction for environmental awareness, recreation, and a general zoning of activities. The trail will include six lakes:

1. Bhalswa Lake: An urban lake, which has been partially restored, is adjacent to the Bhalswa landfill. The lake offers opportunities for birdwatching, with migratory birds visiting, along with boating for recreation purposes.

2. Yamuna Biodiversity Park (Phase I and II): The parks, adjacent to each other, support wetlands and many grassland species. They cover an area of around 457 acres near the banks of the Yamuna River. The park has guided eco-walks, recreation areas, and includes a huge lotus pond, which is well-known.

3. Neela Hauz Biodiversity Park: This park features a restored lake near Aravalli, the Ridge ecosystem. The park has native vegetation trails, a constructed wetland system, along with information on the hydrology of the Yamuna.

4. Sanjay Lake: This is a man-made lake near a residential area, which was degraded partially but has since seen revival efforts. Since it is a planned lake, it includes a system of peripheral walkways, birdwatching areas, and education zones for children.

5. Purana Qila Lake: Located in Old Delhi, this water body surrounds Delhi's historic fort. Recently revived in 2018, the wetland has Mughal-era hydraulic engineering. It offers areas for recreation and boating in the lake, which curves around the old fort, showcasing it.

6. **Smriti Van Wetlands:** Sitting on an area of 34 acres, the Smriti van wetlands feature a memorial wetland forest. The area is surrounded by a large expanse of green area, aligning with the ring road edge redevelopment of the city. Facing challenges related to pollution, encroachment, and inadequate facilities, the government is in the process of addressing these issues.

The proposed north-to-south trail reflected three planning principles of ecological connectivity, public accessibility, and transport linkages. The wetlands are a part of the ecosystem of the Yamuna floodplains, the Delhi Ridge, and the historical drain systems, and their connectivity will create a blue-green corridor between them, supporting movement and people, and nature interaction. All the selected nodes are publicly owned land, and this makes them viable for community access. Additionally, each wetland node is accessible through the Delhi metro, and this encourages inclusivity and convenience across all demographics.

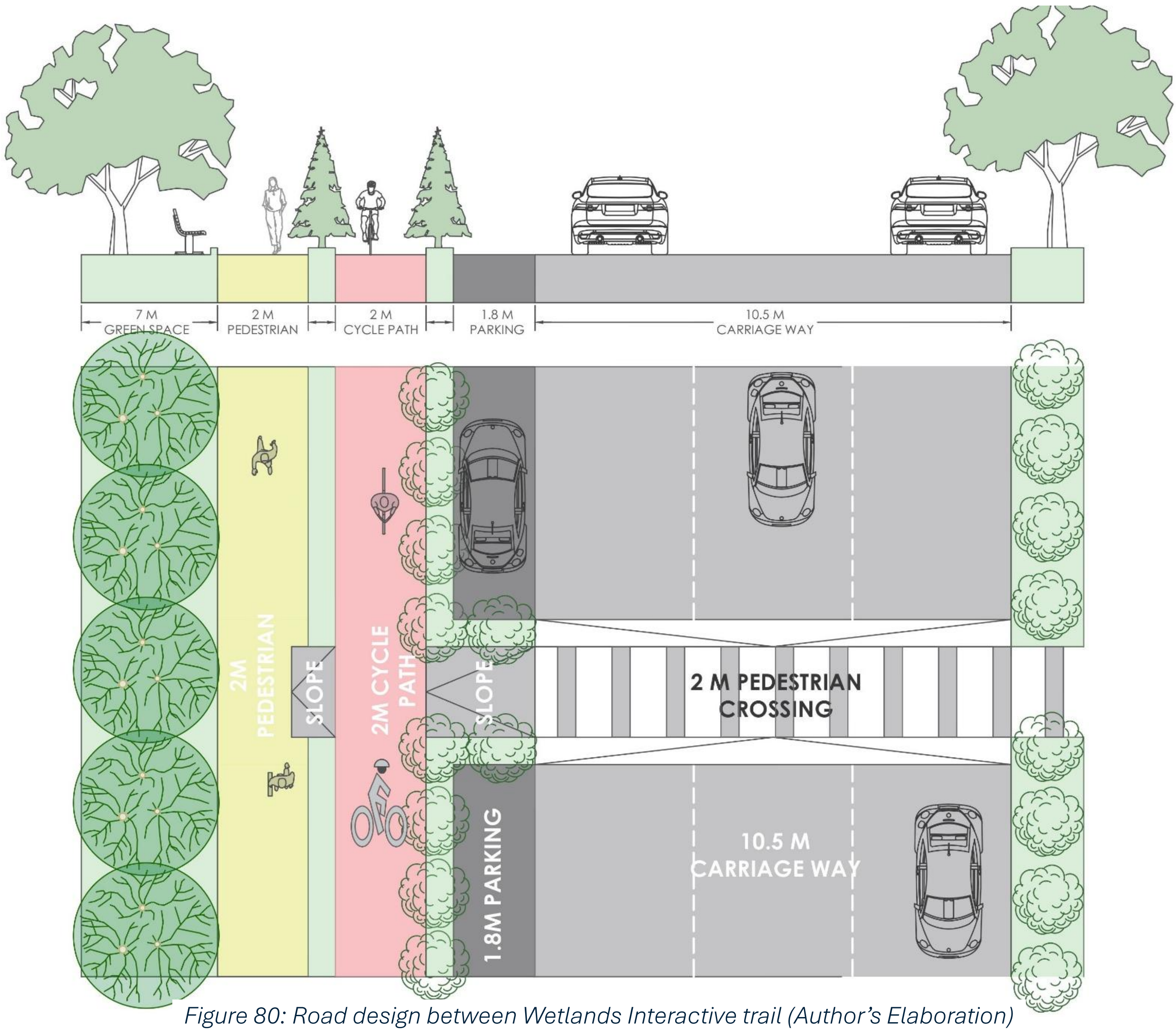


Figure 80: Road design between Wetlands Interactive trail (Author's Elaboration)

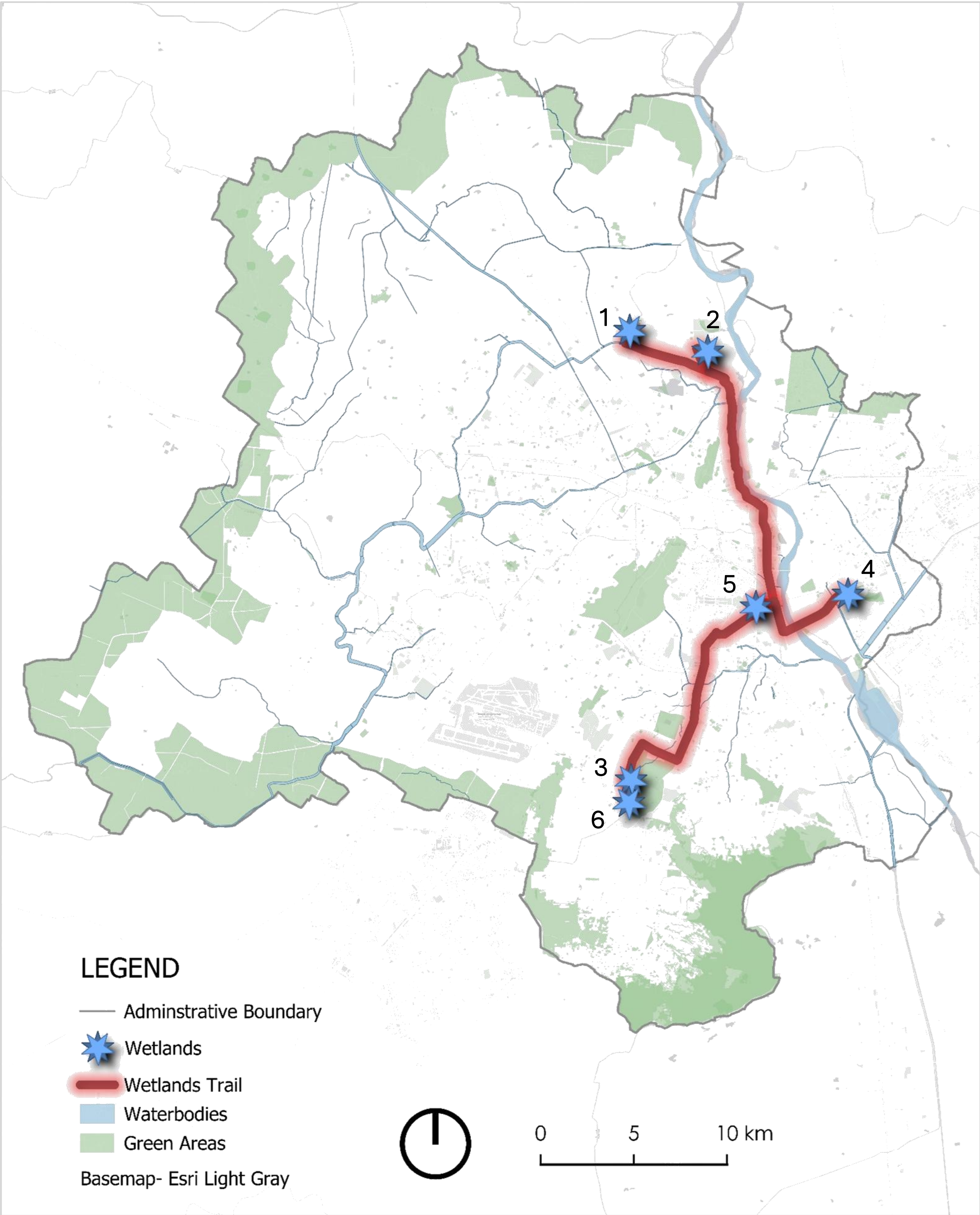


Figure 81: Wetland Trail Map Delhi (Author's elaboration)

Strategy 3: Community-Centric Green-Blue Parks

As observed from Figure 75, there is a crisis of green space equity within the dense parts of Delhi. The city has 30 m^2 of public open space and about 20 m^2 of green space per person, which is more than the WHO's recommended 9 m^2, according to Shahfahad et al. (2019). However, differences in green space availability and quality are the results of uneven distribution brought on by low- and high-density building (Mondal et al., 2021).

Aligning with the research done by Du & Zhang, (2020), stating that green space accessibility is more significant than their size, this proposal suggests converting small, underutilized, or degraded land parcels within the city into pocket parks. These green-blue parks will be designed as public recreation spaces, but also as cooling systems within the city that contribute to thermal comfort and community well-being. These will be greatly helpful in heat-vulnerable and dense parts of the city where large chunks of land are not readily accessible.

The city consists of many small patches of land between, which are vacant and used as dumping yards within the dense districts. These spaces are often used for unauthorized settlements or are encroached, especially in the areas along the riverbanks. These parks will act as social nodes, along with contributing to thermal comfort, ecological resilience, and enhancing liveability overall.

The parks will be context-specific and will include community-led planning initiatives, where the citizens within the wards will give suggestions and ideas for how they would want to utilize the space. The DDA and Urban local bodies (ULB) would be responsible for guiding in terms of what activities can be proposed, along with which design elements would be suitable for the context of the pocket parks. A tentative guideline would be published on what variety of greens are to be planted to keep the parks across the city cohesive in nature.

The funding mechanisms could be possible under the *Green India Mission (GIM)*, a part of India's National Action Plan on Climate Change, or with the Green Fund suggested in the MDP-2041 Draft. Additionally, to engage the community, school eco-hubs can be introduced, along with Youth organizations for volunteering for maintenance and upkeep.

Based on the USGAI assessment [Figure 75], one of the most suitable pilot wards for implementation of this strategy would be the Shastri Park wards (elaborated further), located in North-East Delhi, near the banks of the Yamuna River.

VI. 9. Site of intervention

<u>Shastri Park Rail Yard</u>

Towards the East of the Yamuna River, there is extreme congestion within the residential area, and little green space is accessible in the vicinity. In an attempt to increase the interaction of people with nature, proposing a point where the densely packed community can go close to the Yamuna River for recreation would be a good opportunity to create a space for the people.

As suggested in the MDP-2041 draft, the Yamuna River will have a 300m buffer along with a 75m wide buffer with cycle and walking paths, but the MDP is generalizing the areas on the banks of the Yamuna and has ignored the fact that people often use boats to visit the temple in the middle of the Yamuna River, which is religiously significant for Hinduism.

This social node could be an opportunity in the Shastri Park ward, especially due to its location opposite the Yamuna Ghat. The Shastri Park Rail Yard, as per the MDP-2041, is land officially under the governance of the transportation department, encompassing an area of 0.80 sq. km, with a huge potential for development. In the current draft, DDA does not plan on improving the area; therefore, this proposal fills that gap and calls for a GBI intervention.

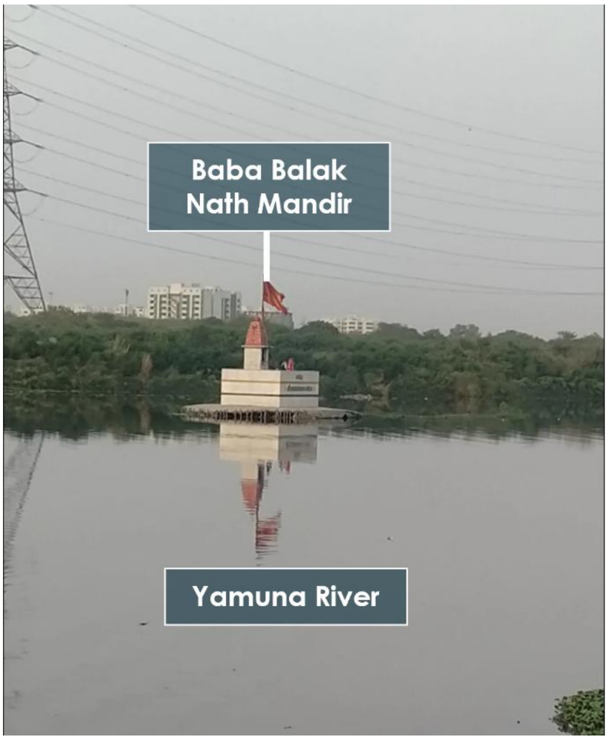


Figure 82: (left) Baba Balak Nath Mandir in the middle of the Yamuna River; (right) Shastri Park Rail Yard (Source: Google Images)

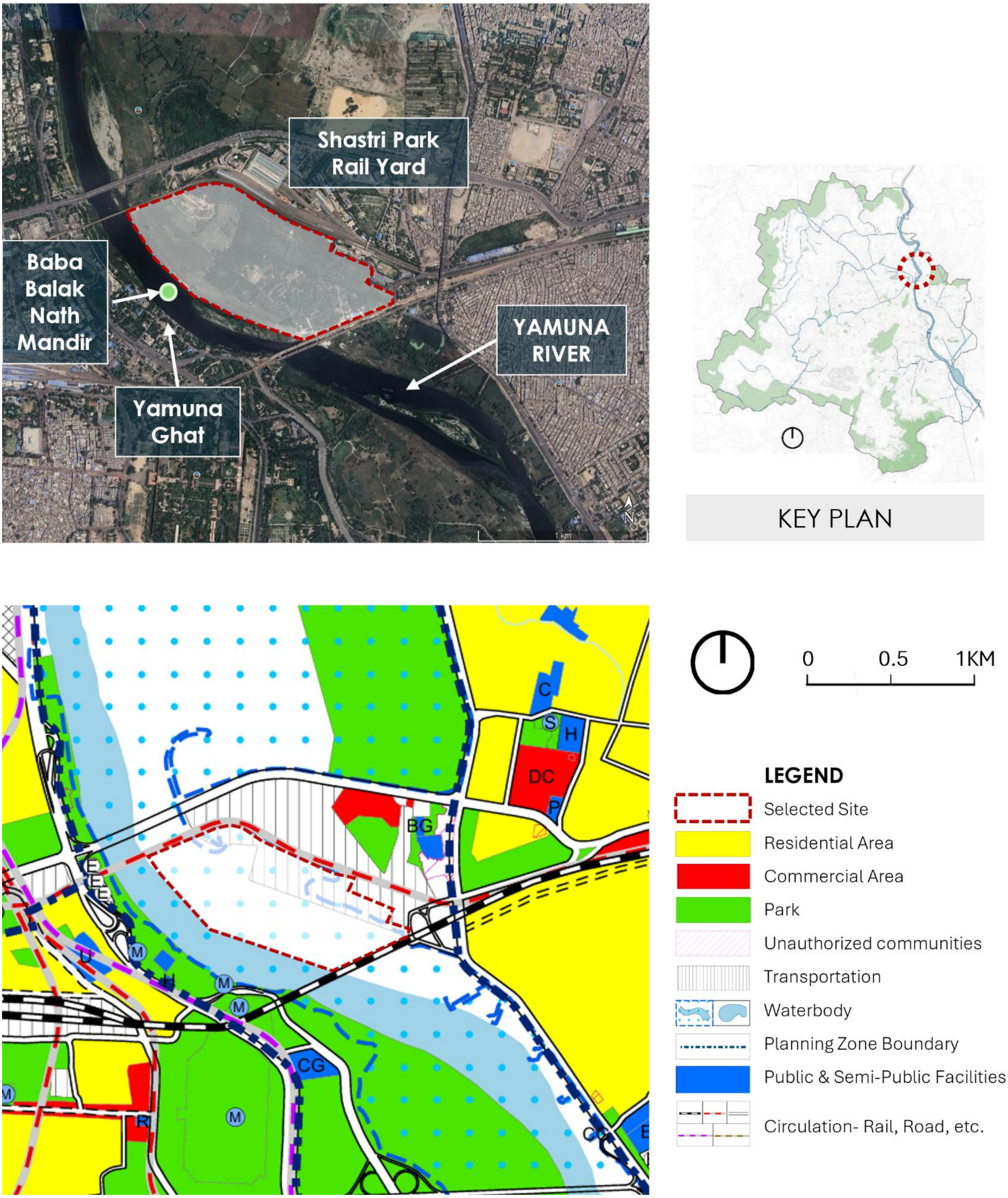


Figure 83: (Top) Selected site satellite imagery (Google Earth); (Bottom) Land use MDP-2041 Draft-2041 (Modified by author)

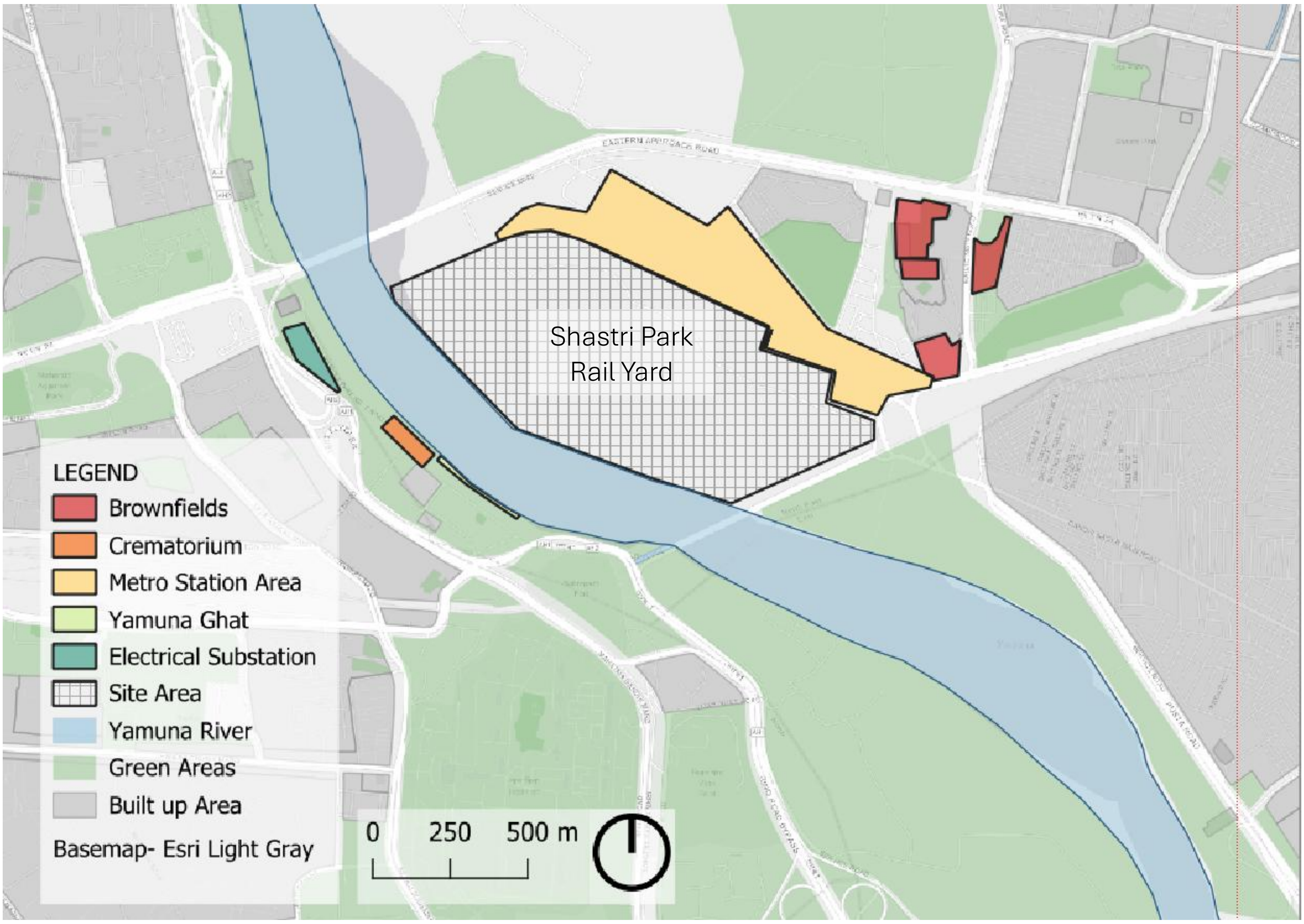


Figure 86: Site map with surrounding context (Author's elaboration)

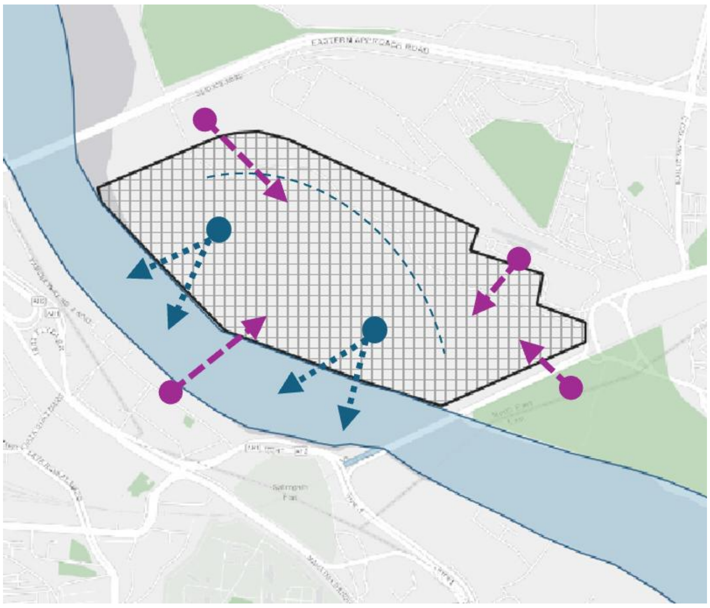


Figure 84: Improving accessibility to the site, along with reconnecting the site to the river (Author's elaboration)

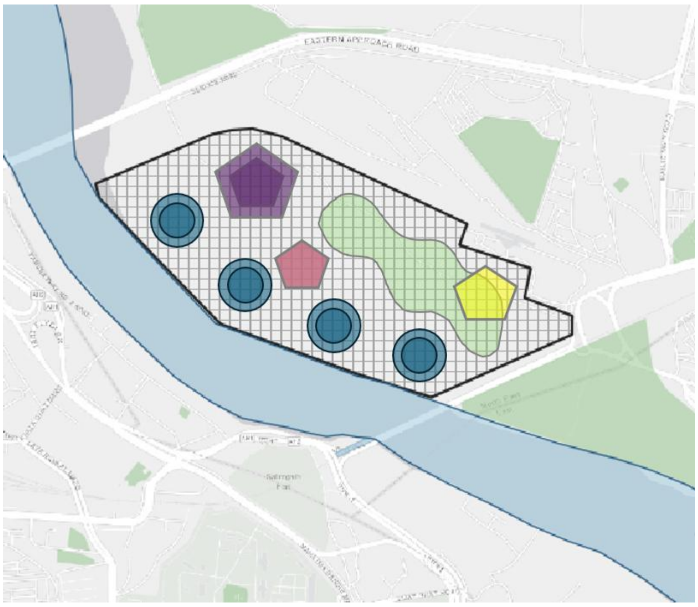


Figure 85: Introducing various flood control GBI, recreational areas, and microclimate improving GBI (Author's elaboration)

Figure 87: Community Park Zoning Plan (Author's elaboration)

LEGEND

Points of Entry

Site boundary

Permeable Pathways

Connection from Yamuna Ghat

Yamuna River

Dense plantation

A natural barrier from the Railway infrastructure of native vegetation, which will help in regulating the microclimate and air quality

Urban Farm

Community-led farm for the residents to grow crops and create a sense of stewardship and responsibility for the public areas

Children's Play Area

Recreational Children's Area with swings, slides, and climbing structures to stimulate growth and a social community

Ghat connecting Yamuna River

An extension of the Yamuna Ghat on the opposite side of the river, to create better connectivity with the river, along with access to the temple in the river.

Recreation Area

Area with amenities like an open gym, picnic areas, gazebos, an amphitheatre, along with areas to socialize, to create a strong sense of community.

Bio-retention pond

Pond located in a depression, considering the contours of the site, to act as a filtration system with plants to boost biodiversity.

Pollinator Gardens

Area with specific vegetation to promote biodiversity by facilitating plant reproduction through pollination.

Senior's Park

Area for senior citizens to offer opportunities for physical activity, social interaction, and recreation in a safe environment.

Riparian Buffer

100 meters of vegetation along the river as a natural filter and to reduce runoff.

Permeable Cycle Parking

Figure 88: Proposed Shastri Park Masterplan with variety of plantation (Author's elaboration)

Proposed Variety of Plantation

Dense Plantation

To act as a buffer from the railway infrastructure, the plan proposes indigenous vegetation variety that acts as a micro-climate regulator and supports biodiversity. Key species on site will include Neem (*Azadirachta Indica*), a fast-growing tree, excellent for air purification, and drought tolerant. Neem is also culturally significant in Hinduism and is revered as sacred, and would be apt given the site's vicinity to the temple on the Yamuna River. Peepal (*Ficus Religiosa*), another culturally important tree, offers a large canopy and contributes significantly to carbon sequestration, while Banyan (*Ficus Benghalensis*) has an expansive crown, providing ample shade, and has a robust root system. This tree is also excellent for supporting biodiversity.

Pollinator Gardens

These gardens will be curated as an essential microhabitat to attract bees, butterflies, and birds to enhance the pollination on site. These gardens will contribute to the overall ecosystem stability by improving diversity. Species such as Mahua (*Madhuca Longifolia*), a tree with nectar-rich flowers, will attract various pollinators. Jamun (*Syzygium Cumini*) will be planted for its dual role in pollinator attraction since its flowers attract bees, and its fruit serves as food for birds and bats. This is also a shade-giving tree which will help reduce the temperature on site. The Peepal (*Ficus Religiosa*) supports fig wasps, further strengthening the pollination network.

Riparian Buffer

Adjacent to the Yamuna River, the plan proposes a Riparian buffer to stabilize the riverbank and reduce erosion. This vegetation buffer will help to maintain the water quality and aquatic habitat. The main species suggested includes Arjun (*Terminalia Arjuna*), known for its extensive root system that binds the soil and improves water quality. Another species is the Shisham (*Dalbergia Sissoo*), often found along water bodies, which is ideal for erosion control. The Banyan *(Ficus Benghalensis*) has a supportive root system and contributes to preventing soil erosion and mitigating the effects of floods. They have a unique growth pattern of aerial prop roots from their branches, which allows them to spread over vast areas.

Urban Farm

To complement ecological functions, the urban farm is incorporated into the plan to serve the community. This will integrate perennial fruit-bearing species that offer food security, microclimatic relief, and recreational potential. The suggested plantations include Mango (*Mangifera Indica*), prized for its fruit yield and shade-providing canopy, which also produces nectar-rich flowers that support the insect populations. Jackfruit (*Artocarpus Heterophyllus*), known for its large, nutritious fruit, will support insect and small mammal populations. Tamarind (*Tamarindus Indica*), valued for its fruit and drought tolerance, adds resilience in the fluctuating climatic conditions. These species will be planted in accessible, shaded areas to encourage community stewardship and informal gathering spaces, integrating ecological and social infrastructure.

Figure 89: Ecological and social spaces on site (K. Jain, 2022) (Modified by author)

VI. 10. Stakeholder Participation

Within the three strategies suggested, it is vital for citizens, along with the responsible government bodies, to be apart from the inception of the planning stage to ensure all voices are heard. As emphasized in the MDP-2041 draft, citizen participation is critical for maintaining and proposing GBI. Citizen and stakeholder groups like youth organizations and NGOs are encouraged to be actively involved in the process. Additionally, the plan encourages facilitating awareness, training, and sharing knowledge to improve the effort of ecological betterment. The plan also encourages inducing a sense of shared ownership over public GBI and frames GBI as urban commons, which are resources that should be managed by citizens and public authorities together.

To counter the effects of gentrification, researchers (Bressane et al., 2024), suggest deliberate, inclusive, and equity-focused planning that involves communities and adapts to the local context. Research suggests developing a policy framework that incentivizes the inclusion of diverse demographic groups and promotes green infrastructure that supports equitable development. Additionally, researchers suggest implementing monitoring of the social impact of GBI projects to detect and mitigate displacement of residents and developing methods of monitoring quantitative metrics to assess the effectiveness of GBI in reducing green gentrification (Bressane et al., 2024).

V. CONCLUSION

VI. CONCLUSION

VI. 1. Summary of Findings

<u>Theoretical Background</u>

An analysis of the foundational concepts of green-blue infrastructure acts as an integral answer to the ongoing environmental crises around the world. Through the reviewed literature, it is apparent that GBI has evolved from being viewed as a peripheral beautification to a form of critical infrastructure that contributes greatly to climate regulation, urban cooling, and flood mitigation. GBI systems have proven to be multifunctional, climate-resilient systems with various proven benefits.

Research demonstrated that GBI initiatives enhance urban liveability by mitigating UHI effects, improving air quality, increasing access to nature, supporting active lifestyles, and fostering social interaction. Additionally, research shows successful GBI systems are those that work as an interconnected network, and fragmented greening efforts fall short in delivering city-wide environmental impacts. It stresses why a typology-based approach is advocated throughout the literature, which recognises that each site requires tailored GBI interventions. This approach balances the spatial and ecological context with the social aspects. Many reviewed theories stress the importance of GBI delivering not just environmental benefits, but also social equity. Amenities like public open space, tree cover, and microclimate comfort must be equitably distributed. Studies show that high-density settlements with often low-income neighbourhoods are often deprived of these amenities.

The policy framework reviews international strategies that support GBI integration, highlighting key policies and funding programs as well as the alignment of GBI with the UN's Sustainable Development Goals. Additionally, research consistently reinforces the value of participatory design, community ownership, and citizen maintenance. Co-creation and management of public spaces by residents have been more resilient, inclusive, and deeply rooted in the social urban fabric. In a nutshell, the theories ground the understanding that GBI is both a climate-responsive ecological system and a socially inclusive strategy that can significantly impact the liveability of the residents.

Analysing GBI strategies and initiatives

Analysing 15 initiatives and strategies adopted worldwide, chosen for their geographical, social, and environmental diversity, illustrates that GBI practices have demonstrated measurable improvements in addressing climate-related issues. These case studies are analysed in four stages: Background of the problem, key initiative or strategy, outcomes, and limitations. The analysis aimed to extract best approaches that enhanced liveability amongst residents. The analysis included a systems perspective used to explore the three main issues related to GBI, which are conditions under which GBI is appreciated most, distribution and accessibility equality, and securing the long-term continuation of benefits flowing from GBI.

Within the analysed GBI interventions, many have proven effective in regulating the microclimate, controlling flood risks, and improving the physiological and ecological environment. A critical observation from the empirical cases showcases the context dependency of the successful GBI initiatives. Tailoring projects to the site's ecological conditions and the local socio-economic needs was greatly successful in delivering community benefits.

Furthermore, the empirical experiences have confirmed that a participatory approach towards planning GBI strategies improves the acceptance and maintenance of the infrastructure. This reaffirmed the role of citizens as custodians and not just beneficiaries. One of the most common challenges across most cases has been a case of fragmentation in governance and a lack of clear inter-agency collaboration. This caused multiple delays, incomplete implementation, and underperformance.

Overall, the case studies consistently reaffirm that GBI implementation has improved liveability metrics with increased walkability, microclimate comfort, health benefits, and aesthetic enhancement. It also confirms the need for mainstreaming GBI into urban development agendas and plans.

Applying theoretical and empirical knowledge into practice

This thesis centres around the concept of green and blue Infrastructure integration to improve liveability and enhance quality of life. Remarkably, this was confirmed after a theoretical approach to understanding the concept and analysing the best-case scenarios around the world and extracting best approaches. The empirical experiences helped establish a methodology for GBI intervention in a streamlined way. This was then demonstrated within the context of Delhi, India.

After a study of India's multi-tier governance structure and major urban development missions aimed at sustainable urban growth, a clear scenario is outlined. Delhi's vulnerabilities are studied through a spatial analysis of land surface temperature, urban expansion, and green space distribution disparities. The city is susceptible to the effects of urbanisation and climate change, thus providing an opportunity to apply the theoretical knowledge.

After analysing the importance of GBI within the new master plan for the city (MDP-2014 draft), evaluating the gaps within the plan, and finding vulnerable areas within the city, this thesis proposed three strategies at different scales. Subsequently, the proposal also included stakeholder engagement strategies for equitable and resilient planning. In conclusion, the Delhi case study green blue infrastructure strategy demonstrated that integrating GBI in city planning agendas might help improve the physiological and ecological environment and positively impact the liveability of the citizens.

VI. 2. Optimal Policy Recommendation

Considering the MDP-2041 Draft and its aspirations for the city to include green-blue infrastructure actively at all levels is remarkable, but the plan lacks quantified targets within the document. It specifies goals such as increasing GBI, but does not specify how much green percentage it aims to achieve. The city has a history of environmental plans that remain unimplemented due to the overlapping competencies of the governing bodies and a lack of regulation.

From the empirical experiences and theoretical knowledge, the optimal policy recommendation must be multi-layered, embedded at various scales within the city. National policies and large-scale, centrally funded plans need to be mobilized for a lasting impact. Additionally, at both the city and local levels, governing bodies incorporating GBI provisions into their development guidelines while offering incentives and tax rebates to encourage compliance would help greatly, along with providing awareness campaigns for these benefits. Incentivizing using permeable pavers, green roofs, green walls, and offering a tax rebate on installing a certain percentage of the area with these elements for local bodies would also encourage their use. Policies that promote stakeholder engagement and increase awareness would support the community-centric GBI parks to mobilize the citizens towards a greener and more liveable future.

Problem statements that form the basis for this thesis have been comprehensively answered regarding GBI and its role in enhancing liveability across social, ecological, and economic dimensions. The thesis validates the significance multi-scale, context-sensitive strategies supported by inclusive stakeholder engagement and adaptive governance.

VI. 3. Critical Questions

There are several critical challenges that arise regarding the adoption of GBI in India, mainly structural and contextual. At the governance level, the overlapping departments at various levels create friction and substantially impacts the adoption of a lot of initiatives. Financially, the sustainability of GBI depends on mechanisms that include the private sector too, and projects like the Sabarmati riverfront development serve as a stark reminder of the urgent need for long-term investment plans and financial incentives.

Socially, the design of GBI needs to take questions of equity and access into consideration and ensure that marginalized communities are not excluded from green benefits due to gentrification. Furthermore, a lack of clear targets in planning documents like the Master Plan for Delhi-2041 risks rendering GBI strategies aspirational rather than actionable. Citizen involvement also remains murky, inviting an inquiry into how inclusive stakeholder engagement models can foster long-term stewardship. In conclusion, understanding GBI as a fundamental approach to improving liveability and sustainable urban growth, rather than just an add-on on is essential, and integrating it with larger development agendas like NAPCC, AMRUT, and the Smart Cities mission is necessary.

VI. 4. Personal reflections

Delhi is one of the most pivotal cities in the nation and has witnessed multiple empires rise and fall around it. The cultural and political significance of the city often makes it the face of the nation. It is a city personally very close to my heart, and I have seen it deteriorate over time, along with witnessing the citizens struggle to come to terms with living in those conditions.

Delhi has grappled with the problem of overcrowding, pollution, urban heat, flooding, and severe storms. However, the majority of the proposed grey infrastructures under the banner of development have been detrimental and are worsening these issues. The city has a complicated relationship with the seat of political power, making it tough for many development plans to go through, but it is the need of the hour to use nature-based solutions like green and blue infrastructure in addressing the liveability crisis within the city.

I believe that by integrating effective green and blue infrastructure strategies, Delhi can set standards for being the first city in India to achieve a big environmental turn in physiological and ecological metrics, and can be an inspiration for other cities in India and globally.

VI. 5. Replicability and Future Avenues

Future applications of the thesis could include the integration of GBI into the city's development as a means of enhancing liveability. The entire development process might be carried out in phases. The methodology presented in this thesis can be used to evaluate different urban areas and their problems, which can aid in determining the best GBI strategies that impact the liveability of the residents. The future direction should focus on making stronger institutional capacity by embedding GBI into mainstream urban plans and policies. To support this, governments and local authorities both need to ensure equitable access to GBI.

In order to create a cohesive network of places with an impact on the entire city, the thesis also recommends connecting different green and blue spaces. Furthermore, leveraging GBI to help enhance liveability by addressing urban heat, physiological health, biodiversity loss, etc, can help in attracting better private-public partnerships and encourage investments. By establishing a balance between the city's inhabitants and the environment, these approaches will transform cities into greener, sustainable, and liveable spaces.

VI. 6. Limitations of the thesis

This thesis is limited by access to certain scientific articles, books, and sources, owing to the fact that some resources were request-based articles, due to which it was restricted to compile all scientific work regarding green and blue infrastructure. Another limitation is the availability of some time-based proofs for the case studies, for which some liveability indicators could not be measured due to a lack of research on the topic or not enough follow-up on it.

The dataset used for the maps relies on the websites Geospatial Delhi Limited, which is the official website of the government, and the Open City urban data portal, which is an open-source program by the Oorvani Foundation. The data obtained from these sources has some minor discrepancies between the dataset and the real state of the green space and the built-up area.

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LLM used: ChatGPT4
Prompts used:

1. Format the following into a more refined sentence without changing the content
2. Summarise the following points without changing the content.
3. Check the text for grammatical errors